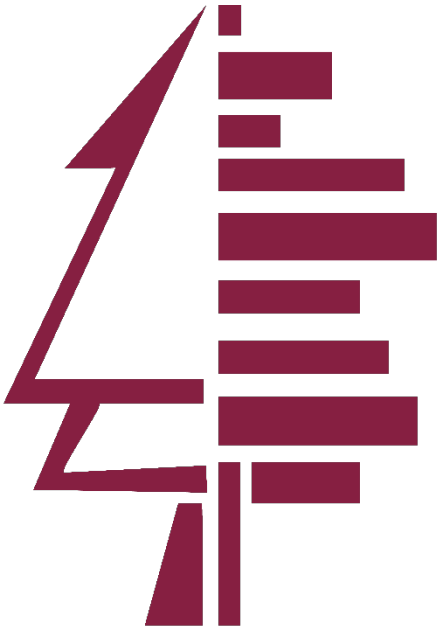

SOMENS

Blacksburg, VA 2021

Southern Mensurationists Meeting

September 19 – 21

Virginia Tech Inn and Skelton Conference Center

Contents

Welcome to SOMENS

The Southern Mensurationists group (SOMENS) is an informal collection of individuals who apply quantitative methods to better manage forests. While our focus is planted southern pine, we are broadly interested in the theory and application of statistics, data science, and computing as they relate to forestry.

SOMENS meets annually to discuss recent advancements in the science of quantitative forest management. The meeting is open to all with a primary goal of exchanging ideas and fostering collaboration. SOMENS is a great venue for students to meet and present research ideas to leaders in the field.

Organizing Committee

Corey Green	Assistant Professor	Virginia Tech
Nate Osborne	Biometrics Project Leader	Rayonier
Bronson Bullock	Professor	University of Georgia

COVID-19 Information

Masks

In accordance with Virginia Tech policy, masks must be worn at all times during the meeting in indoor public spaces except when dining. Extra masks will be available.

Vaccinations

In accordance with Virginia Tech policy, all students and employees of Virginia Tech have been required to be vaccinated. Additionally, all speakers at SOMENS are required to be vaccinated.

Dining and Social

Out of an abundance of caution, outdoor dining will be available on the Great Lawn for all hosted meals (lunch on Monday and Tuesday and dinner Monday evening). Additionally, the social will be held outdoors on the Great Lawn.

Additional Information

We want this to be a safe, successful event so please take the Covid guidelines seriously. For more information regarding Virginia Tech's Covid policies, please visit https://ready.vt.edu/.

Sponsors and Participating Organizations

The SOMENS annual meeting is funded primarily with registration dues. Support generously furnished by Rayonier was used to help offset the costs for free student attendance. Additional funding support was provided by a grant from Virginia Tech. Richard Zabel and Melinda Olson with the Western Forestry Conservation Association managed conference registration, announcements and the meeting webpage. Special thanks go out to Dr. Sheng-I Yang for designing the logo this year.

Agenda

Sunday, September 19th

12:00 pm– 7:00 pm	**Check-in at Virginia Tech Inn**

Monday, September 20th

8:00 am – 8:15 am	**Coffee and pastries**	
8:15 am – 8:30 am	Corey Green *Virginia Tech*	Introduction and welcome
Session 1. Growth. Moderator: Bronson Bullock		
8:30 am – 8:50 am	Quang Cao *Louisiana State University*	Deriving a Tree-Level Growth Model from Any Existing Stand-Level Growth Model
8:50 am – 9:10 am	Anil Koirala *University of Georgia*	Simultaneous prediction and projection basal area equations for mixed southern hardwood stands incorporating uncertainty estimators
9:10 am – 9:40 am	Laura Ramírez Quintero *University of Georgia*	Modeling Slash Pine mortality rates (relative to height growth) including response to silvicultural treatments
9:40 am – 10:00 am	Bilawal Cheema *Stephen F. Austin*	Model-based growth comparisons between loblolly and slash pine in east Texas
10:00 am – 10:30 am	**Break**	
Session 2a. Forest Resource Assessment. Moderator: Sheng-I Yang		
10:30am – 10:50 am	Holly Munro *University of Georgia*	Reconstructing loblolly pine plantations for the rapid assessment of tornado damage
10:50 am – 11:10 am	Hector Restrepo *AFM*	Remotely sensed forest inventory powered by deep learning inform timberland investment decisions in the Southeastern U.S.
11:10 am – 11:30 am	Matthew Sumnall *Virginia Tech*	Effect of unmanned aerial vehicle laser scanning pulse density on accuracy in quantifying forest structure.
11:30 am – 11:50 am	Angel Adhikari *University of Georgia*	A Comparison of Modeling Methods for Predicting Forest Attributes Using LiDAR Metrics
12:00 pm – 1:00 pm	**Lunch**	
Session 2b. Forest Resource Assessment. Moderator: Shawn Yang		
1:00 pm – 1:20 pm	Spencer Peay *University of Georgia*	Estimating leaf area in loblolly pine plantations using Sentinel-2 data
1:20 pm – 1:40 pm	Garret Dettman *Virginia Tech*	The use of small area estimation (SAE) applications in forest inventory
1:40 pm – 2:00 pm	Qianqian Cao *Virginia Tech*	Improving FIA volume estimates for counties in the Southeast with area-level SAE
2:00 pm – 2:20 pm	Tom Lynch *Retired, OKSU*	The variance of quadratic mean dbh and the stand density index estimated from sample plots or points
2:20 pm – 3:00 pm	**Break**	

Session 3. Silviculture and Management. Moderator: Nate Osborne		
3:00 pm – 3:20 pm	Harold Burkhart *Virginia Tech*	Comparison of Productivity of Two Generations of Loblolly Pine Plantations on Site-prepared Lands
3:20 pm – 3:40 pm	*Benjamin Protzman* *University of Georgia*	Value optimization in loblolly pine plantings across a range of densities, ages, and stumpage prices
3:40 pm – 4:00 pm	John Young *University of Georgia*	Evaluating loblolly pine (Pinus taeda) volume responses to mid-rotation competing vegetation control using Generalized Additive Modeling
4:00 pm – 4:20 pm	Dehai Zhao *University of Georgia*	Long-term response of aboveground net primary production (ANPP) of loblolly pine plantations to repeated fertilization and complete vegetation control: multilevel nonlinear mixed effects modeling analysis
4:20 pm – 4:40 pm	Bronson Bullock *University of Georgia*	A flexible Weibull-based basal area modifier for mid-rotation loblolly pine silvicultural treatments
5:30 pm – 8:30 pm	**Reception**	
6:00 pm – 8:00 pm	**Dinner on the VT Inn Great Lawn**	

Tuesday, September 21st

8:00 am – 9:00 am	**Coffee and pastries**	
Session 1. Special Topic		
9:00 am – 9:20 am	Sheng-I Yang *University of Tennessee*	Digital learning in forest biometrics education
Session 1. Incorporation of Environmental Data. Moderator: Phil Radtke		
9:20 am – 9:40 am	Cristian Montes *University of Georgia*	Modeling stand mortality in loblolly pine using environmental variables
9:40 am – 10:00 am	Stephen Kinane *TIR LLC*	Influence of Environmental Variables on Leaf Area Index in Loblolly Pine Plantations
10:00 am – 10:20 am	Shaoyang Yang *Virginia Tech*	Spatiotemporal distribution patterns of loblolly pine productivity in the Southeastern United States. An attempted study using FIA data
10:20 am – 10:50 am	**Break**	
Session 2. Allometry. Moderator: Garret Dettman		
10:50 am – 11:10 am	Bini Dahal *NCSU*	Aboveground biomass equations for black willow (*Salix nigra* marsh.) And eastern cottonwood (*Populus deltoides* Bartr. Ex Marsh.)
11:10 am – 11:30 am	Thomas Harris *Yale*	Stem taper, volume, and green weight equations for defective stems in longleaf pine plantations
11:30 am – 1:00 pm	**Lunch**	
1:00 pm – 1:10 pm	**Graduate speaker award presented by Harold Burkhart**	
1:10 pm – 1:20 pm	**Lifetime achievement award presented by Harold Burkhart**	
1:20 pm – 1:30 pm	**Closing remarks – Corey Green**	
1:30 pm – 2:30 pm	**Business Meeting – Corey Green, Nate Osborne, Bronson Bullock**	

Abstracts

Title: Deriving a Tree-Level Growth Model from Any Existing Stand-Level Growth Model
Speaker: Quang Cao
Affiliation: Professor, Louisiana State University

In this study, a new method was developed to derive a tree survival and diameter growth model from any existing stand-level model, without the need for individual-tree growth data. Predictions from the derived tree model are constrained to match number of trees and basal area per ha as outputted by the stand model. The tree models derived from three different stand models were evaluated against a tree model, in both unadjusted and disaggregated forms.

For the same stand-level model, the derived tree model outperformed its counterpart, the disaggregated tree model. This is significant because the coefficients of the unadjusted and disaggregated tree models had to be estimated from tree-level growth data, whereas the derived tree model required no tree growth data at all. The methodology presented in this study should be applicable when there is no ingrowth or recruitment.

Title: Simultaneous prediction and projection basal area equations for mixed southern hardwood stands incorporating uncertainty estimators

Speaker: Anil Koirala
Affiliation: Ph.D candidate, University of Georgia

Naturally regenerated hardwood forests are extremely important to preserve regional biodiversity as well as to support regional timber supplies. Decision support tools, such as growth and yield models, are needed to better manage these forests. However, comprehensive growth and yield models for hardwoods in the southern US are still scarce. Predicting growth and yield of hardwoods is difficult because of the multi-species and typically uneven-age structure of the stands, leading to growth rates that differ widely between individuals. Basal area is an important measure of forest stand development in forest management. To estimate the basal area of a stand at a certain age, a prediction model with different stand-level variables is required. However, to estimate future basal area, a projection model based on the current basal area combined with the associated stand-level variables is needed. Generally, information from the prediction model is used to fit the projection model and parameter estimates can be obtained either one at a time or simultaneously for prediction and projection. The main aim of this study is to fit simultaneous prediction and projection equations of basal area growth using traditional basal area models and compare it with advanced data assimilation techniques that incorporate uncertainty estimators. The differences in the estimated coefficients and the goodness-of-fit statistics between these two techniques will be evaluated.

Title: Modeling Slash Pine mortality rates (relative to height growth) including response to silvicultural treatments
Speaker: Laura Ramírez Quintero
Affiliation: Ph.D. student, University of Georgia

Mortality is an essential variable in any growth and yield system constructed with the aim of predicting and projecting growth in commercial forest plantations. Nevertheless, this variable is also acknowledged in the literature as one of the most difficult variables to model due to its stochastic nature. Modeling mortality rates using a state space approach has shown to improve the overall fit of mortality models when this rate is modeled as relative to height growth instead of relative to time. Using a long-term data set of Slash Pine, a mortality model of this nature was constructed to evaluate the hypothesis that a mortality model driven by dominant height increments captures treatment effects better than a mortality model driven by time increments. Given that silvicultural treatments are reflected in dominant height, it was expected that after including height increments, no additional factors were necessary to include the treatment effect into the mortality model. Our results show that including height growth into the mortality model reduces the overall error compared to a traditional model even when the latest includes an explicit treatment effect. Nonetheless, the model can be further improved if treatments effects are explicitly included in addition to including the height increment.

Title: Model-based growth comparisons between loblolly and slash pine in east Texas
Speaker: Bilawel Cheema
Affiliation: Ph.D. student, Stephen F. Austin University

Growth differences between loblolly and slash pine is of great interesting to foresters. This study used modeling methods to investigate their growth differences in east Texas. Datasets collected from loblolly and slash pine plots installed in extensively managed plantations in east Texas were used. Species growth differences were determined by comparing their height-age, diameter-age, and height-diameter models. Slash and loblolly pine had significantly different parameter estimates for the Chapman and Richard function-based height- and diameter-age models. Slash pine grew faster than loblolly pine, and the superiority in height increasing while that in diameter growth decreased slightly with age. Slash and loblolly pine differed also in all parameter estimates of the exponential function-based height-diameter model. Loblolly pine was taller than slash for small size (DBH ≤18 cm) trees but thereafter slash pine outperformed loblolly. While these results may encourage planting slash pine in the region, more studies are needed before definitive conclusions can be made.

Title: Reconstructing loblolly pine plantations for the rapid assessment of tornado damage
Speaker: Holly L. Munro
Affiliation: Postdoctoral fellow, University of Georgia

Wind disturbances (e.g., hurricanes and tornadoes) have significant economic impacts on forest ecosystems with annual losses in the United States exceeding 1.5 million hectares. Tornadoes are convective wind events that influence forest function, economic valuation, regeneration, carbon cycling, soil respiration, and increase the risk for other stressors such as wildfire and insect outbreaks. Rapidly assessing damage is essential for making timely management decisions aimed at minimizing timber losses and reducing the risk of additional tree mortality due to other disturbance agents (e.g., wildfire, insects, and pathogens). The objective of this study therefore is to develop standardized protocols for the rapid assessment of tornado damage in forest stands to help guide land managers and research efforts. We present on the first step in this study, which was to reconstruct loblolly pine (*Pinus taeda*) plantations (pre-storm) and subsequently estimate losses (post-storm) to serve as baseline estimates of wind damage. Reconstruction methods included establishing six sites with six 10m radius plots (36 plots total) along the path of a catastrophic tornado that occurred in April 2021 in Shallotte, North Carolina. At each site, two plots were established directly in the tornado track, two at the track edge, and two were in adjacent undisturbed forest. Diameter at breast height (DBH) and total height were measured for each tree within the plots. In addition, tree health status, proportion standing, and spatial classes were assessed to assist with damage characterization. Plot summaries were used to estimate pre- and post-storm stand basal area and volume. Future work will include developing standardized protocols for ground and remote sensing surveys using change detection techniques (pre- and post-storm estimations). Results from this study will greatly assist with rapid and accurate assessment of post-storm forest damage to guide future management practices.

Title: Remotely sensed forest inventory powered by deep learning inform timberland investment decisions in the Southeastern U.S.

Speaker: Héctor I. Restrepo
Affiliation: Senior Forest Biometrician and Finance Specialist, American Forest Management

Recent advances in remote sensing and artificial intelligence have expanded the scope of local forest measurements to a much broader regional scale. The Copernicus Sentinel program has significantly contributed to the science and practice of remote sensing for forestry applications by making accessible high-frequent, high-resolution, wide-swath, multi-spectral satellite imagery for the globe. Advances in computer science with stand-alone packages like TensorFlow and Keras have democratized the use of highly complex artificial intelligence algorithms like deep learning (DL). Plots measured in non-industrial private forests (NIPFs) were used to train, validate and test a generally applicable model in the Southeastern U.S.; whereas client proprietary data have been used to tailored DL models to the same client-specific needs. Forest inventory variables such as pine and hardwood basal area, stand density and volume, and pine volume broken down by commercial timber product classes were used as output variables. The spectral reflectance from different Sentinel 2 image wavelengths and some vegetation indices were the input variables in the DL model. The Resulting DL models are unbiased with precision in the range of 60-85 % correlation (40 - 75% R^2) depending on the data and output variable. We have deployed DL models to a large regional footprint as the client needs to inform timberland acquisition, appraisal, and real estate projects across the Southeastern U.S. However, as occurs with all systems, a permanent refinement is required in order to update and improve estimations.

Title: Effect of unmanned aerial vehicle laser scanning pulse density on accuracy in quantifying forest structure.

Speaker: Matthew J. Sumnall
Affiliation: Postdoctoral fellow, Virginia Tech

Airborne laser scanning (ALS) is increasingly used to estimate various forest characteristics and spatial components. Technological improvements in unmanned aerial vehicles (UAVs) and for drone laser scanning (DLS) sensors have permitted the acquisition of high pulse density datasets. There is the assumption that higher pulse densities will yield higher accuracies in estimates. In this study we investigated the relationship between pulse density (0.25 to 300 pulses m^{-2}) and the ability to delineate individual tree crowns (ITCs), and estimate ITC height and crown horizontal diameter, in addition to plot-level leaf area index (LAI). The current study took place in an experimentally varied loblolly pine (*Pinus taeda* L.) forest, which included three stem densities: (i) 618; (ii) 1236; and (iii) 1853 trees per hectare (TPH). ITCs were classified directly from the DLS point cloud for each of the pulse densities. The correct delineation of ITCs relative to field tree coordinates was relatively consistent (±5%) for pulse densities of 5 to 300 pulses m^{-2}. ITC delineation accuracy decreased with lower pulse densities. Planting stem density did impact ITC delineation accuracy where, for higher pulse densities, plots with 618 TPH correctly classified ~88% of ITCs, and plots with the 1853 TPH correctly classified ~50% of ITCs. Estimates of tree height was largely invariant to changes in tree density. Root mean square error (RMSE) for tree height varied from 0.5 to 2.5 m at pulse densities of 300 to 0.25 pulses m^{-2}, respectively. Estimates of crown horizontal diameter varied with regard to both pulse and stem density. Estimate RMSE varied from 1.2 to 4.2 m at pulse densities of 300 to 0.25 pulses m^{-2}, respectively. RMSE could vary between stem densities from ±0.6 to 1.2 m as pulse density decreased. Anova and least square means analysis indicated there was significant difference in ITC delineation accuracy, and the estimates of tree height and crown horizontal diameter amongst the DLS pulse densities used. The accuracy of predicted LAI was largely invariant to changes in pulse density, when pulse density was above 0.5 pulses m^{-2}. Anova and least square means indicated there was little or no difference in estimates of LAI at these pulse densities. Our results suggest that low-density DLS data may be capable of estimating plot-level forest metrics reliably in some situations, however once the analysis scale reduces to the individual tree level, the influence of pulse density is more severe. The results here provide guidance to forest managers who must balance metric estimation accuracy and price when planning new ALS or DLS acquisitions

Title: Effect of unmanned aerial vehicle laser scanning pulse density on accuracy in quantifying forest structure.

Speaker: Angel Adhikari
Affiliation: Ph.D. student, University of Georgia

Forest can be characterized by various attributes related to spatiotemporal properties of forest stands such as height, basal area, stem density, volume of standing and lying trees etc. Collection of such data is often time consuming, expensive and limited to conventional methods of forest inventory. Remote sensing methods have opened new horizons for spatiotemporal data collection from local to large landscape scales and which is more cost effective and less time consuming.

Recent developments in active remote sensing specifically the three-dimensional data obtained from light detection and ranging (LiDAR) technique, have shown great potential for precise characterization of the forest. With the technological advancement and declining acquisition cost, many organizations, especially the forest industry is increasingly utilizing LiDAR for forest inventory assessments. However, the major problem when utilizing metrics derived from LiDAR data for predicting forest attributes is that they are highly correlated with each other, resulting in multicollinearity issues when developing multivariate linear regression models. To avoid this, some researchers have opted for utilizing alternative modelling approaches such as decision trees (e.g. random forest), and as other statistical modeling approaches emerge for their application into other fields, there is a need to evaluate and compare their performance and potential adoption for lidar data modeling. Therefore, we compared several approaches and assessed the capability of these methods for forest attributes prediction using LiDAR metrics as the explanatory variables and ground measurement data as the response variable.

For this study, we used data from Eucalyptus globulus plantations growing in the southwestern Biobio in Chile. As ground measurements, we used inventory data from 92 circular plots of 400 m2, and as the explanatory variables we generated metrics from airborne LiDAR data collected over the inventory plots with an average density of 49 points per m2. Predictive models were developed to estimate four forest attributes: stem volume, basal area, dominant height, and number of trees. For each forest attribute, we generated models with different methods and compared their performance. The selected modelling methods include Least Square Regression, LASSO regression, Random Forest, and Generalized Additive Model. For testing the performance of each modelling method, k-fold cross-validation method was applied.

Title: Estimating leaf area in loblolly pine plantations using Sentinel-2 data
Speaker: W. Spencer Peay
Affiliation: PMRC research coordinator and Ph.D student, University of Georgia

The relationship between leaf area index (LAI) and stand productivity in loblolly pine (*Pinus taeda* L.) plantations is well-established. Several studies have shown a positive correlation between light interception (calculated using LAI estimates) and forest biomass productivity. Despite its noted importance, LAI can be difficult to estimate and is often estimated indirectly using vegetation indices derived from remotely sensed imagery. These models link satellite derived indices with ground-measured values of LAI and are based on the linear relationship between these two stochastic variables. While this technique is effective, several of the published models found in the literature fail to account for the error present in remotely sensed data. When unaccounted for, these errors in the independent variable result in inconsistent parameters, subsequently resulting in biased estimates of LAI.

A previous study successfully accounted for the observation error associated with estimating vegetation indices using Landsat 5 and 7 imagery by implementing a Kalman Filter process model, albeit at a high model complexity cost. This work proposes a similar approach that relies on multivariate time series estimation for several satellite derived indices using a generalized additive model (GAM). This framework was able to separate the annual and seasonal signals to overcome a lack of observations due to climatic constraints.

Indices for this analysis were estimated using level-1C (top of atmosphere) surface reflectance values captured by the Sentinel-2 Multispectral Instrument (MSI). Moving forward, the remotely sensed data will be atmospherically corrected to level-2A (bottom of atmosphere) products. Regression parameters will then be estimated using an error-in-variable, monte-carlo type of approach, including a random walk autocorrelation error structure to allow for the incorporation of uneven observations over time. The proposed methodology will then be compared with other regression approaches published in the literature.

Title: The use of small area estimation (SAE) applications in forest inventory
Speaker: Garret Dettman
Affiliation: Ph.D. student, Virginia Tech

Small area estimation (SAE) is a growing area of research in making inferences over geographic, demographic, or temporal domains smaller than those in which a particular survey data set was originally intended to be used. We aimed to review a body of literature to summarize the application of SAE in forest inventory and management, both in terms of the depth and breadth of SAE applications in forest-inventory to-date, as well as the current state of terminology, methods, concerns, data sources, research findings, and opportunities for future study relevant to forestry and forest inventory research. SAE methodologies explored include direct, indirect, and composite domain estimates within design-based and model-based inference bases. SAE methods in forestry are often applied to extensive multi-resource inventory systems like national forest inventories to increase the precision of estimates on small domains or subsets of the overall populations of interest. To avoid instability and large variances associated with small sample sizes when working with small area domains, forest inventory data are often supplemented with information from auxiliary sources, especially from remote sensing platforms. Results from many studies show gains in precision compared to direct estimates based only on field inventory data. Gains in precision have been demonstrated in both project-level applications and national forest inventory systems. Potential gains are possible over varying geographic and temporal scales, with the degree of success in reducing variance also depending on types of auxiliary information and methodological alternatives, leaving considerable opportunity for future research and growth in SAE applications for forest inventory.

Title: Improving FIA volume estimates for counties in the Southeast with area-level SAE
Speaker: Qianqian Cao
Affiliation: Postdoctoral fellow, Virginia Tech

Many National Forest Inventory (NFI) stakeholders would benefit from an ability to obtain accurate estimates at finer geographic scales than is currently possible using NFI sample data, while doing so in a cost-effective manner. In the past decade small area estimation (SAE) techniques have been shown to increase precision in forest inventory estimates by combining field observations and remote-sensing. This research sought to demonstrate the potential for improving the precision of forest inventory standing wood estimates for counties in U.S. states of North Carolina, Tennessee, and Virginia, by pairing canopy height models from digital aerial photogrammetry and field plot data from the U.S. NFI. Area-level Fay-Herriot estimators were used to avoid the need for precise (GPS) coordinates of field plots. Reductions in standard errors averaging 30% for North Carolina county estimates were observed, with 19% average reductions in standard error in both Tennessee and Virginia. Accounting for spatial autocorrelation among adjacent counties provided further gains in precision when the three states were treated as a single population of forest land; however, analyses conducted one state at a time showed that good results could be achieved without accounting for spatial autocorrelation. Apparent gains in sample sizes ranged from about 65% in Virginia to 128% in North Carolina, compared to the current number of forest inventory plots. Results should allow for determining whether acquisition of statewide digital aerial photogrammetry would be cost-effective as a means for increasing the accuracy of wood volume-related estimates in the U.S. NFI.

Title: The variance of quadratic mean dbh and the stand density index estimated from sample plots or points

Speaker: Thomas B. Lynch
Affiliation: Professor Emeritus, Oklahoma State University

The quadratic mean dbh (QMD) is frequently used to help characterize forest stands for management purposes and is often used as an important variable in forest stocking guides and growth and yield models. The QMD is computed from forest inventory statics as the dbh corresponding to mean basal area per tree and is greater than the arithmetic mean dbh when the variance among dbh's is nonzero. When typical forest inventories based on fixed-sized plots or variable-radius point samples are used, the correct way to compute the mean basal area per tree is to divide the basal area per hectare estimate by the number of trees per hectare estimate. This is a classic ratio of means estimate. The QMD is then obtained as proportional to the square root of the mean basal area per tree. Although the QMD is often computed from forest inventory statics we have rarely seen estimates of the variance of this quantity reported, and are not currently aware of published formulas for the estimation or approximation of this variance.

Because the QMD is a nonlinear function of sample means we have used the well-known "Delta Method" to derive an equation that can be used to approximate the variance of the QMD. The Delta Method is based on a Taylor series approximation of a nonlinear estimator which is a function of sample means. We also present an approximation formula for the Stand Density Index (SDI), which is a nonlinear function of the QMD and the number of trees per hectare. The SDI is also frequently used in stocking guides to assess stand density but we have rarely seen variance estimates reported for SDI estimates.

QMD and SDI are nonlinear functions of sample means when computed from a typical forest inventory so they are not design-unbiased. Taylor series methods have often been used to assess the bias in nonlinear estimators. We apply a commonly-used second order Taylor series approximation to derive equations for the approximate bias in the QMD and SDI estimates. Because both these quantities are proportional to 1/n where n is number of sample plots or points, the bias in estimates of QMD and SDI approaches zero in large samples.

The equations presented for approximation of variances and biases for QMD and SDI could also be assessed using simulation methods on mapped forest stands. We have not previously seen this type of assessment of SDI and QMD as estimated from forest inventories. We will discuss preliminary approaches to simulation of estimates of QMD, SDI and their variance and bias approximations.

Title: Comparison of Productivity of Two Generations of Loblolly Pine Plantations on Site-prepared Lands
Speaker: Harold E. Burkhart
Affiliation: Distinguished University Professor, Virginia Tech

Permanent sample plots were installed in two generations of operationally-established loblolly pine plantations across the southeastern United States. The first population, established with non-genetically improved seedlings, did not receive mid-rotation fertilizer or competition control treatments. Approximately 20 years later, using consistent measurement protocols, permanent plots were installed in operationally-established plantings with genetically improved seedlings and receiving mid-rotation fertilizer and release treatments. These two studies, both of which reflect contemporary plantation management at the time they were initiated, were analyzed to examine the impact of changing management intensity and environmental influences on productivity. Results showed that the second generation of plantings generally exhibited substantial increases in site index and in maximum stand density. Assuming a constant rotation age of 25 years, and computing mean annual increment using an empirical yield function fitted to the overall data, gave an estimated increase in volume production of 47% for the region. The estimated productivity gains differed by physiographic regions with the Piedmont showing an estimated increase of 83%, Atlantic Coastal Plain 64%, and Gulf Coastal Plain 34%.

Title: Value optimization in loblolly pine plantings across a range of densities, ages, and stumpage prices

Speaker: Benjamin Protzman
Affiliation: M.S. Student, University of Georgia

High pulpwood prices and market demand in coastal areas of the southeast United States incentivize many landowners to manage timber at shorter rotations and at higher planting densities to take advantage of competitive markets. More research is needed on how beneficial this short rotation and high planting density pulpwood production is for timberland owners. Additionally, some areas in the southeastern U.S. pay a premium for sawtimber. The objectives of this research are to: evaluate the impact of planting density on yield across a range of ages and stumpage prices and determine optimal harvest regimes.

This research will use the Plantation Management Research Cooperative (PMRC) culture/planting density study plots across the southeast United States and TimberMart South stumpage prices, to calculate yield (green tons/acre), gross revenue ($/acre), internal rates of return (IRR), net present value (NPV), and bare land value (BLV) of plots planted at various densities over a range of ages.

Preliminary analysis for one installation has indicated that lower density (300 TPA) stands generate a higher NPV than other planting densities when evaluated from ages 5 to 24. Forthcoming research will compare the variability of economic returns based on planting density and market stumpage prices across the southeast U.S. Through this research, we hope to develop a better understanding of loblolly pine planting densities on yield (tons/acre) for the economic benefit of landowners.

Title: Evaluating loblolly pine (*Pinus taeda*) volume responses to mid-rotation competing vegetation control using Generalized Additive Modeling

Speaker: John Young
Affiliation: Ph.D. Student, University of Georgia

Competing vegetation (CV) is often controlled within intensively managed loblolly pine (*Pinus taeda*) plantations. Effects on crop-tree growth are known to be positive for applications at stand establishment and can significantly impact yield at final harvest. Active mid-rotation management has become commonplace in plantation forestry as it further extends the positive effects on crop-tree growth throughout the rotation. Previous efforts to understand the efficacy of mid-rotation treatments have focused primarily on pine responses relative to individual treatment effects. Recurrent CV is often observed post-treatment, and the magnitude and duration of the CV response is likely to influence pine volume growth. An ongoing study conducted by the Plantation Management Research Cooperative (PMRC) at the University of Georgia has monitored competing vegetation growth on pine plantations across the southeast US following mid-rotation silvicultural treatments. Study installations represent unique combinations of thinning to a desired basal area in conjunction with a one-time, post-thin, application of fertilization and herbicide at a level considered operational per site. Treatment responses are measured every two years for both the over- and understory. Evaluating pine volume response relative to recurrent CV density, instead of individual treatment effects, may provide additional insight into how crop-trees respond to CV control. Generalized Additive Modeling (GAM) techniques were considered for evaluating this relationship. Models incorporating either a CV density measurement or individual treatment effect to describe pine volume response will be compared. Finally, the benefits of GAMs and future directions for this work will be discussed.

Title: Long-term response of aboveground net primary production (ANPP) of loblolly pine plantations to repeated fertilization and complete vegetation control: multilevel nonlinear mixed effects modeling analysis

Speaker: Dehai Zhao
Affiliation: Senior Research Scientist, University of Georgia

It is well known that aboveground net primary production (ANPP) reaches a peak early in stand development and then gradually declines. Intensive silvicultural treatments such as competing vegetation control, fertilization, or both have been widely used in pine plantations in the southeastern United States and shown large gains in early growth. However, their long-term effects on age-ANPP patterns remain to be investigated. In this study, a multilevel nonlinear mixed effects modeling approach is used to model loblolly pine (*Pinus taeda* L.) age-ANPP relationships in conjunction with four silvicultural treatments: Control (C) – no additional treatment following site preparation; Complete control of competing vegetation using herbicide through the life of the study (H); Fertilization (F) – annual fertilization until age 12, then fertilization every other year until growing season 28; and Complete vegetation control and fertilization (HF) - combining the H and F treatments. The large ANPP variations were explained by site- and block-level random effects. The treatment effects altered the pattern of age-ANPP relationships substantially. The magnitude of both ANPP before age 16 and maximum ANPP followed the order of HF > F > H > C. Larger age-related declines of forest ANPP were associated with both repeated fertilization associated treatments (F and HF), which revealed that soil nutrient availability might not be responsible for age-related declines in ANPP for loblolly pine in the southeastern US.

Title: A flexible Weibull-based basal area modifier for mid-rotation loblolly pine silvicultural treatments

Speaker: Bronson Bullock
Affiliation: Professor, University of Georgia

Mid-rotation silvicultural practices (MRSP) like thinning, fertilization, competitive vegetation control, and their combinations are common in the southeastern United States. Here we use longitudinal data in 49 experimental installations from the regional Mid-Rotation Treatment study established by the Plantation Management Research Cooperative (PMRC) at the University of Georgia across the southeast U.S. to evaluate a Weibull pdf as a treatment modifier function coupled with a dynamic basal area growth model. The new formulation results in a compatible and consistent growth and yield system and provides temporal responses to treatments.

Because of the model structure, the response to treatment changes with physiographic region, age of application, and dominant height growth as indicators of site quality. Validation tests indicated that the model has high predictive accuracy (the cross-validation variance explained was 98.6%, and the prediction root mean square distance was 1.03 m2 ha-1). Therefore, the proposed modifier and model adequately represent regional basal area growth conditions.

Title: Digital learning in forest biometrics education
Speaker: Sheng-I Yang
Affiliation: Assistant Professor, University of Tennessee

As a modern forestry professional, quantitative skills are essential to accomplish the daily tasks in forestry and natural resources. However, it has been widely reported that teaching forest biometrics and quantitative courses is challenging in forestry and natural resources programs because students are often intimidated by mathematics. How to properly motivate and guide students in the learning process is an important topic.

The pandemic accelerated the digital transformation of higher education. Although online learning offers many advantages to students (e.g., flexible schedule), many forestry courses are field-based, which are difficult to transform to online environments. Creating effective teaching strategies and adapting field-based courses for e-learning have presented new challenges for instructors. To better involve students in distance learning, technologies were incorporated into classes. In this presentation, an example will be given to demonstrate using YouTube videos and web-based apps in a forest inventory course. Although the field portion of the class was greatly reduced, the students could explore the topics and learn at their own pace which creates a diverse learning environment for various learning styles.

In addition to college students, the online tools can easily be accessed by anyone who is interested in learning forest measurements and biometrics. Following the end of the pandemic, the digital resources provide opportunities for the beyond-the-classroom learning and extension education.

Title: Modeling stand mortality in loblolly pine using environmental variables
Speaker: Cristian R. Montes
Affiliation: Associate Professor, University of Georgia

Estimation of long-term forest value depends on the ability to predict not only stand productivity, but also the number of trees that survive at a given point in time. Despite this relevance, there is an important disproportion between the number of papers estimating site productivity and the number of papers focused in estimating stand survival. It has been argued that the former is needed to calculate the later, jet the later that finally determines the forest value. There are several reasons for the disproportion with practitioners arguing that it is harder to calibrate a survival model than it is to calibrate a dominant height equation, the requirements for long term data are less restrictive for dominant height over time as compared to mortality models and model convergence for non-linear functions is better granted for the former as compared to the later.

Several models have been developed to estimate stand survival, using of time, site index, and dominant height (e.g. Zhao et al. 2007, Garcia, 2009) as the main drivers for mortality. All these functions relate either the rate of change in trees over time, or the proportion of surviving trees over time with variables that depend on stand metrics over time (endogenous variables). When site index or dominant height are included as part of a mortality or a survival model, climate and soil are assumed to be implicitly accounted.

On even aged plantations, tree survival depends on factors related to carbon depletion, pathogen infection, insect defoliation, catastrophic events and their interaction. Competition between trees in a given stand on the other side, is a way to express these ratios of carbon depletion between trees that have better access to do photosynthesis in detriment of those with lower capacity, covering just one aspect of stand mortality, that is related to the increase in stand heterogeneity over time, resulting in bigger trees and suppressed trees.

In this research, we evaluate the effect of adding biophysical variables responsible for plant stress to the relation between mortality rate and dominant height grow, in addition to the traditional effect of dominant height into stand mortality. Water deficit, excess water, and available water calculated as yearly water balance aggregators were calculated for a series of growth plots distributed over the southeast US. A model that includes these three values proved to be significantly better at explaining stand survival as compared to not including them. Our results highlight the importance of biophysical indicators in determining not only stand growth but also processes responsible for stand mortality over time, improving value estimates for commercial forest plantations.

Title: Influence of Environmental Variables on Leaf Area Index in Loblolly Pine Plantations
Speaker: Stephen Kinane
Affiliation: Inventory analyst, Timberland Investment Resources

Variation in radiation interception is a considerable source of the variability observed in forest productivity. Leaf area index is an important biophysical variable that serves as the surface in which energy is exchanged in the canopy. To adequately capture the variability in radiation interception, we proposed a model that describes leaf area index growth in loblolly pine (*Pinus taeda* L.) plantations in the southeastern United States using a delayed differential equation and periodic coefficients to enforce the seasonality of resource availability. Furthermore, productivity modifiers were incorporated to test the effect of different environmental variables on capturing additional variability observed in leaf area index time series. Monthly maximum temperature and monthly excess water were found to influence the leaf area index of stands and modifiers were included improve overall model performance.

Title: Spatiotemporal distribution patterns of loblolly pine productivity in the Southeastern United States. An attempted study using FIA data
Speaker: Shaoyang Yang
Affiliation: Postdoctoral fellow, Virginia Tech

Loblolly pine (*Pinus taeda*) has been regarded as the second-most common species of tree in the United States. For its timber, loblolly pine is regarded as the most commercially important tree in the Southeastern United States. Furthermore, loblolly pine forest productivity has historically been a central concern in forest industry, management, silviculture, especially for loblolly pine plantations. Therefore, mapping and understanding the spatiotemporal distribution patterns of loblolly pine productivity and its impact factors at different spatial scales have become very important for forest industry, especially at the locations without previous data supports. In this study, individual tree productivities of loblolly pine at different based heights (35 ft, 45 ft, 55 ft, and 65ft) are calculated by using different levels (plot and tree levels) of FIA data from 1998 to 2020 including 11 southeastern states from East Texas to Virginia. The calculated productivities from FIA data are calibrated with field measured data of Non Intensive Management and Intensive Management Projects that were established since 1980s. Spatial interpolation (ordinary kriging, regression kriging, and bayesian interpolation) and statistical methods (classification regression tree and spatial Poisson regression) are used to generate and analyze the spatiotemporal distribution patterns of loblolly pine productivity and its impact factors. The results indicate that the productivity of loblolly pine trees calculated by using the FIA data has a high precision compared with the results calculated from the NIMP and IMP projects which reveal that the FIA data has the potential to be used as a reliable data source to calculate forest productivity. However, due to the limitations of FIA data, only the tree level productivity could be calculated but not the plot level which could also limit the implementation and analysis of the results. Moreover, the topographies (such as altitude and latitude), managements (thinning, understory vegetation control, and fertilization), disturbances (insect, weather, and fires) could also cause and affect the variations of loblolly pine productivity at different spatial scales.

Title: Aboveground biomass equations for black willow (*Salix nigra* marsh.) And eastern cottonwood (*Populus deltoides* Bartr. Ex Marsh.)

Speaker: Bini Dahal
Affiliation: Ph.D. Student, North Carolina State University

Black willow (*Salix nigra* Marsh.) and eastern cottonwood (*Populus deltoides* Bartr. Ex Marsh.) are short rotation woody crops native to Lower Mississippi Alluvial Valley (LMAV) and have the potential to provide higher biomass yield in short period of time. This study aimed at developing allometric equations to estimate individual tree, clump, and area level aboveground biomass (AGB) of these species using destructively sampled data collected through the age of 6 years. Diameter at breast height (dbh), total stem height (tht), and their transformations and combinations were the predictors of individual tree AGB. Models for clump biomass included number of stems in the clump as an additional predictor variable. Area level AGB was predicted using dominant height, stand age, and initial planting density. A logarithmic model that used the product of squared dbh and total stem height was the best fitting model (R^2 = 0.95) for the individual tree AGB estimation for black willow whereas a model that used log transformed dbh and height as separate predictors was the best fitting model for eastern cottonwood (R^2 = 0.93). For the clump level AGB, logarithmic model that used dbh and height as the separate predictor was the best fitting model for both species. At the area level, logarithmic models with stand age, dominant height, and initial planting density produced the best result.

Title: Stem taper, volume, and green weight equations for defective stems in longleaf pine plantations

Speaker: Thomas B. Harris
Affiliation: Ph.D. Student, Yale University

The ability to predict volume or green weight from forest inventory is an important tool for managing forestland. However, models fit with data from non-defective "straight" trees may not perform well on forked, crooked or other defective stems. We destructively sampled 320 trees, across 16 sample sites established for this research. On average, 36% of longleaf pine trees from our sample stands had stem defects. We fit equations to model stem taper for diameter inside bark (DIB) and, volume and green weight outside bark for defective stems for longleaf pine plantations in Georgia. Stem taper inside bark, and the implied volume inside bark, had subtle variation due to stand origin. Stands from old-field origin had double the rate of stem defects compared with cut-over sites. The volume and green weight in forked trees was about 11% higher than non-defect trees and about 15% less in crooked trees compared to non-defect trees with the same DBH and total height. These models will be useful for predicting volume and green weight of existing longleaf pine stands and newly established stands across GA and the SE US on old-field and cut-over sites.

Hotel and Conference Center

Virginia Tech Inn and Skelton Conference Center
(https://www.innatvirginiatech.com/)

Directions: From I-81: Exit 118B Blacksburg/460 West. Exit Prices Fork Rd/Downtown, Route 412 East. Right at first traffic light into hotel entrance.

Other Information

- **Talks** will be held in the Alumni Assembly Hall located in the Inn at Virginia Tech.

- **Breakfast** is on your own. Preston's Restaurant is conveniently located on site. Other local options are available in Downtown Blacksburg (~1-mile walk) and across Prices Fork (~0.5-mile walk)

- **Lunches** will be provided on the Great Lawn of the Inn around Noon on Monday and Tuesday. Please contact the conference organizer if you have a dietary restriction.

- **Coffee and snacks** will be offered in the back of the conference room periodically throughout the entire meeting. Please notify one of the organizers if supplies run out.

- **Wi-Fi** will be available during the conference. Please contact staff of the Inn if you have difficulties getting connected.

- The **conference banquet** will be held on the Great Lawn of the Inn on Monday evening. A hospitality will be held prior, during, and following dinner. Please contact the conference organizer if you have dietary restrictions.

Notes