SOMENS

SOUTHERN MENSURATIONISTS CONFERENCE

SEPTEMBER 15-17, 2019

HILTON GARDEN INN ASHEVILLE DOWNTOWN

ASHEVILLE, NC

SOMENS 2019

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The electronic version of this booklet can be found at:
https://westernforestry.org

The open LaTeX template, AMCOS_booklet, used to generate this booklet is available at
`https://github.com/maximelucas/AMCOS_booklet`

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About

The Southern mensurationists group (SOMENS) was reestablished in 1999. We are an informal group of forest biometricians, mensurationists, statisticians, mathematicians, modelers, computational foresters and other practitioners whose professional interests include quantitative management, plantation management, computational forestry, inventory issues, modeling, data and the related subjects of computers, algorithms, spatial science, harvest scheduling and technology.[1]

SOMENS Annual Meeting

The Southern mensurationists meet annually to discuss current developments and applications related to the topics given above. The meeting is designed to elicit the exchange of ideas and collaboration. The meeting is open to all, and student attendance is especially encouraged to help them grow into the profession.

Organizing Committee

Nate Osborne	Biometrics project leader	Rayonier
Brittany Eidson	Executive assistant	Rayonier
Stephanie Patton	Research biometrician	Rayonier
Bronson Bullock	Professor	University of Georgia
Cristian Montes	Associate professor	University of Georgia

[1] Most of the information in this section comes directly from: `http://mensurationists.com`.

Timetable

† Indicates the moderator for a given session

Sunday, September 15th

4:00–6:00	**Registration at Hilton Garden Inn lobby**

Monday, September 16th

8:00–8:15	**Coffee and pastries**	
8:15–8:30	**Introductions and welcome - † N. Osborne**	
	Growth modeling - † C. Green	
8:30–8:50	**Quang Cao** Louisiana State University	Estimating parameters of the weibull function to characterize diameter distributions
8:50–9:10	**Anil Koirala** University of Georgia	Growth and yield models for hardwood and natural pines in the US South from 1920 to 2018
9:10–9:30	**Mauricio Zapata** University of Georgia	Modeling basal area growth after thinning – an alternative approach
9:30–10:00	**Coffee Break**	
	Industrial application of biometrics - † C. Montes	
10:00–10:20	**Donald Gagliasso** MB&G	Caveat emptor – How a forest analyst can help make informed decisions
10:20–10:40	**Zack Parisa** SilviaTerra	It's time for standards in forest inventory
10:40–11:00	**Nate Herring** American Forest Management	Integration of inventory, growth and yield, data management, and harvest planning in the Southeast US

11:00–11:20	**Henry Rodman** SilviaTerra	Applications of a sampling simulator
11:20–11:40	**Corey Green** Virginia Tech	Small area estimation in support of operational loblolly pine forest inventory
11:40–12:00	**Jim McCarter** Rayonier	An industrial remote sensed inventory system - gaps and needs
12:00–1:00	**Lunch at the Pillar Room**	
	Taper, weight and wood science - † S. Patton	
1:00–1:20	**Dan Boczniewicz** University of Canterbury	Modeling stem properties for eucalyptus in New Zealand
1:20–1:40	**Sheng-I Yang** Virginia Tech	Robustness of taper equations with alternative definitions of validation data
1:40–2:00	**Phil Radtke** Virginia Tech	A stem volume-ratio, biomass conversion & expansion factor approach to generating national-scale inventory estimates
2:00–2:20	**Bronson Bullock** University of Georgia	Modeling taper of longleaf pine
2:20–2:40	**Mark Porter** University of Georgia	Estimating height from multiple diameters
2:40–3:10	**Coffee Break**	
	Growth modeling - † C. Clark	
3:10–3:30	**Dahai Zhao** University of Georgia	Long-term dynamics of loblolly pine crown structures
3:30–3:50	**Sergio Orrego** Universidad Nacional de Colombia	Modeling height growth for teak plantations in Colombia
3:50–4:10	**Mingliang Wang** University of Georgia	Stand survival projection as a function of age versus dominant height
4:10–5:45	**Poster session in hotel lobby**	
6:00–8:00	**Banquet at Pack Tavern's Century Room**	

Tuesday, September 17th

8:00–8:10	**Recap from Monday - Holly Munro**	
	Theoretical and philosophical topics - † B. Bullock	
8:10–8:30	**Mike Strub** Independent researcher	A comparison of error distributions for estimation of stand survival
8:30–8:50	**Harold Burkhart** Virginia Tech	Thoughts on regression model selection
8:50–9:10	**Frank Roesch** US Forest Service	The sample design: a model or a rule (that will be broken)
9:10–9:30	**Chris Cieszewski** University of Georgia	Linear feature in primeval forest as indications of anthropogenic heritage
9:30–9:50	**Coffee Break**	
	Ecophysiological applications - † J. McCarter	
9:50–10:10	**Juan Quiroga** Arauco Holding	Development of ecophysiological tools for managing Arauco plantations
10:10–10:30	**Túlio Queiroz** São Paulo State University	Temperature thresholds for growing eucalyptus in South America
10:30–10:50	**Holly Munro** University of Georgia	Temperature-based model for predicting pine beetle numbers
10:50–11:10	**Stephen Kinane** University of Georgia	Modeling dominant height as a function of leaf area
11:10–11:30	**Ricardo Neto** Federal University of Viçosa	Estimation of Eucalyptus stands productivity using efficient Artificial Neural Network
11:30–12:00	**Tom Lynch** Oklahoma State University	Two- and three-stage least squares for biomass estimation
12:00–1:00	**Lunch at the Pillar Room**	
1:00–1:30	**Speaker awards ceremony - † S. Patton**	
1:30–1:45	**The Mike Strub Challenge - † M. Strub**	
1:45–2:00	**Final remarks - † N. Osborne**	
2:00–3:00	**Business meeting - † B. Bullock**	

List of Abstracts - Talks

Modelling stem properties for eucalyptus in New Zealand's dryland environments

Daniel Boczniewicz, Justin Morgenroth & Euan Mason

University of Canterbury, Christchurch, New Zealand

Eucalyptus globoidea is an important alternative species in New Zealand, where the plantation forestry sector is dominated (~90%) by a single species, *Pinus radiata*. The heartwood of *E. globoidea* is naturally durable and does not require toxic preservatives (e.g. copper chrome arsenic) for in-ground uses, like *Pinus radiata* does. Despite this benefit, the species has not been widely studied previously and little is known about its structure or heartwood development. The aims of this study are to model the taper and volume of *E. globoidea* stem and heartwood. This knowledge will provide crucial data to forest managers and increase confidence for land owners who want to explore new wood markets and diversify the species they grow in their production forests. The study was conducted using data collected from two different sites in New Zealand, one in the North Island, and one in the South Island. Data collected included: the height of the tree, the diameters measured with the proper step length on the laying log, the area of the heartwood in the diameter measurement points. Models were developed to estimate stem volume and taper, as well as, heartwood volume and taper based on tree height and diameter at breast height. The taper and volume equations for stem and heartwood volume and taper for *Eucalyptus globoidea* will be presented. Implications of the taper and volume equations will be discussed, in the context of who will use them, how they will be used, and how these models will help diversify the species choices and wood product markets in New Zealand's plantation forestry sector.

Thoughts on regression model selection

Harold Burkhart

Virginia Tech, Blacksburg, Virginia

Model specification is the most important aspect of regression analysis. Typically there are a number of competing models, with relatively small differences among the alternatives. Fit statistics and regression diagnostics are applied for choosing among competing models, but in many cases comparisons include different forms of the dependent variable and both linear and nonlinear models, making interpretation of differences difficult. Due to the inherent interaction of data, model, and fitting algorithm with nonlinear models, the selection of the "best" model becomes especially difficult. Some specific forestry examples will be given, questions will be posed, and discussion will be encouraged.

Estimating parameters of the weibull function to characterize diameter distributions

Quang Cao

Louisiana State University, Baton Rouge, Louisiana

Different methods for estimating parameters of the Weibull function to model diameter distributions will be discussed and evaluated. These methods include maximum likelihood, least squares, and other variations. Tree diameters were measured to the 0.1-inch accuracy, and were also grouped into 2-cm and 4-cm classes.

Linear feature in primeval forest as indications of anthropogenic heritage

Chris Cieszewski

University of Georgia, Athens, Georgia

The Polish Bilaowieza Forest, home of the European Bison, is considered to be the last primeval forest in Europe. Its strict reservation area is considered untouched by human hand and is a major tourist destination and a favored ecologists' study object alike. However, both anthropological studies and experienced forester field excursions to this area can revile some linear feature suggesting human activities forming parts of the Bialowieza Forest ecosystems. We explore some examples of such field observations suggesting that there are some rows of planted pines in the predominantly hardwood dominated Bialowieza Forest, which are unlikely originated from natural regeneration.

Modeling basal area growth after thinning – evaluating an alternative approach

Mauricio Zapata Cuartas, Bronson Bullock & Cristian Montes

University of Georgia, Athens, Georgia

Growth and yield of important stand characteristics after thinning have been projected using empirical models which invariably express the yield as a function of an assigned non-thinned yield-baseline and a modifier-submodel as an adjusting term. At the same time, the modifier includes thinning intensity, site index, or any other stand conditions at thinning age in order to develop suitable projections. We propose a new projection basal area method which does not depend on the non-thinned counterpart nor use modifiers. Our model assumes that the basal area growth is explained by the aggregate basal area growth of each set of trees belonging from the diameter quantile defined before thinning, and that the growth in every quantile is a function of the thinning intensity, and the stand dominant height. Therefore, different projected growth patterns are expected for each quantile and the growth is driven by the remaining diameter distribution after thinning and stand characteristics. We fit our model using 22 loblolly pine thinned permanent plots from the Plantation Management Research Cooperative (PMRC)'s Mid Rotation Treatment Study (MRT). For validation, we use a data set of 20 first-thinned remeasured permanent plots belonging to the PMRC. We use the bias and Mean Square Error (MSE) as a performance measurement. Comparisons with three other basal area projection models already reported in the literature were made. More accurate yield and constant bias-variance on projections were obtained with the new theoretical model. Systematic sub-estimation was obtained with the models that use modifiers and particularly in these models the physiographic region has an effect on the bias prediction due in part to the change in basal area yield-baseline model. Our findings suggest that for loblolly pine, specific residual stand diameter distribution descriptors are good predictors of basal growth after thinning and no dependence of the non-thinned counterpart is required. The proposed method can be expanded including mortality, dominant height, and volume using simultaneous fitting.

Caveat emptor. How a Forest Analyst can help make informed decisions

Donald Gagliasso

Mason, Bruce & Girard, Portland, Oregon

Each year hundreds of thousands of forested acres are transacted across North America. The task of analyzing this data for your employer, or client, can seem daunting, but also provides a forest analyst with an exciting opportunity to engage in a due diligence project. Using principles that are introduced in your education and developed as a professional forest analyst, we provide information to a purchaser so that they can form a competitive bid on a property of interest. Current practices that a forest analyst conducts to assist in this process include an analysis and summary of a seller's inventory, designing, implementing and analyzing a verification inventory, and conducting a growth and yield analysis to provide long term yields into a harvest schedule model. A successful forest analyst has the knowledge and ability to complete these processes and can adapt with new technology and methods to provide their employer, or client, with the information they require for a successful land transaction.

Small area estimation in support of operational loblolly pine (*Pinus taeda* L.) forest inventory

Corey Green

Virginia Tech, Blacksburg, Virginia

Small area estimation (SAE) methods were investigated for their potential to improve the precision of total planted volume estimates in loblolly pine (*Pinus taeda* L.) plantations established from 1976-2010 in the Virginia Piedmont. Area-level SAE models that used Lidar height percentiles and stand thinning status as auxiliary information were found to improve estimate precision in all cases. Models that utilized both forms of auxiliary information provided larger gains in precision. Additionally, unit-level SAE models were investigated. Using only Lidar derived height percentiles, unit-level models offered additional gains in precision compared with all area-level models. Despite their gains in precision, unit-level models are difficult to apply in practice due to the need for accurate, spatially defined sample units and the inability to incorporate area-level covariates. Following the demonstrated improvements with both SAE approaches, the effects on the total volume estimates from reduced point cloud densities and lower DEM resolutions were investigated. Using 10- and 30-meter DEMs in conjunction with three levels of thinned point clouds (1%, 10%, and 50%), similar total volume estimates and precision were obtained compared with the full point cloud and the associated 1-meter DEM. The overall conclusion from this work is that SAE methods can offer increased stand-level estimate precision across a range of spatial resolutions for the auxiliary information evaluated.

Planted longleaf pine growth and yield model comparison

Thomas Harris, Bronson Bullock & Cristian Montes

University of Georgia, Athens, Georgia

Longleaf pine is an alternative where low site productivity precludes the establishment of loblolly or slash pine or when the landowner objectives favor pine straw raking in the SE US. However, it is hypothesized that existing models for longleaf pine do not adequately differentiate between the different stand characteristics where longleaf pine is currently planted in Georgia and elsewhere. There is a need to model growth of longleaf pine plantations that have been established on old-field and cut-over sites. The objective of this research is to estimate new equations to predict individual tree taper, green weight, and volume for longleaf pine in Georgia and the SE US. This research will emphasize individual tree data collected using destructive sampling. Selection of 20 sample sites across Georgia was restricted to areas of longleaf pine planted on old-field and cut-over land that have not been thinned. Individual tree data has been collected from felled longleaf pine trees; destructively sampled measurements of outside bark diameter and weight along the length of each stem. The data compiled from all the felled stems will be used to generate individual tree models specific to these sites. The new models will be tested against other available models. These new equations will be useful for many recently established longleaf pine stands in GA and the SE US.

Integration of inventory, growth and yield, data management, and harvest planning in the Southeast US: Methods, Models, and Applications

Nate Herring

American Forest Management Inc., Charlotte, North Carolina

American Forest Management (AFM) as a forestry consultant provides a full range of services including land management, real estate, appraisals, and technical services to hundreds of forest landowners. Mensuration and biometrics serve as the foundation of all the aspects of technical services including inventory, data management, and harvest planning, as well as supporting the remaining consulting services. To meet the technical needs of a diverse client base throughout the US Southeast which includes TIMOs, REITS, and private landowners an efficient system to integrate inventory, growth and yield, data management, and harvest planning is needed. This system must be robust enough to accommodate common southern pine plantation species as well as less common plantation species and mixed natural forests, yet retain the flexibility to utilize different inventory and growth methods and models required by AFM's client base. It was determined that the best strategy to design this system was to use already in place software such as Remsoft, and R, utilize AFM's expertise, and leverage existing relationships with clients and research cooperatives. My presentation will showcase these methods, models and applications implemented by AFM to develop this integrated system.

Modeling dominant height as a function of leaf area

Stephen Kinane & Cristian Montes

University of Georgia, Athens, Georgia

Leaf area index, the total leaf surface area per unit ground area, is an important biophysical variable in loblolly pine plantations that can be used as an indicator of the productivity of a site. Leaf area index can be estimated for a stand using freely and readily available satellite imagery to provide long term series that can be matched with in situ stand level measurements. Peak leaf area index, the highest inter-year observed leaf area index value, has been well correlated with stemwood volume increment and has been modeled as a function of various environmental variables. With this in mind, we propose a dominant height model that uses leaf area index rather than site index as the biological driver. Using local parameters to determine the steady state peak leaf area index values attained at the individual sites, we fit a leaf area index and dominant height model simultaneously. Measurement plots from the Plantation Management Research Cooperative's South Atlantic Gulf Slopes Culture Density (SAGSCD) study were used to take advantage of large remeasurement plots and 21 years of biennial measurements. Preliminary results show that leaf area index is a suitable biological driver of productivity for dominant height.

Growth and yield models for hardwood and natural pines in the US South from 1920 to 2018: A review

Anil Koirala, Cristian Montes & Bronson Bullock

University of Georgia, Athens, Georgia

Predicting growth and yield of mixed hardwood and natural pine stands is challenging because of the uneven age, different growth rates, and different management requirements of different species. Naturally regenerated hardwood forests are extremely important for conserving regional biodiversity as well as providing a sustainable supply of timber. These forest types are very typical of those owned by small and medium-sized private landowners in the southern US. The southern US supplies more than half of country's roundwood, out of which 70% is contributed from small and medium-sized private forestlands. The growth and yield studies in the US south have principally focused on monoculture pine plantation of loblolly, slash, or shortleaf pine. This is further justified by an excessive increase in the pine plantation acreage in the region. Relatively, a lower number of growth modeling studies have been carried out for hardwood and natural pine in this region. Therefore, the main aim of this paper is to review and synthesize the literature pertaining the growth and yield modeling of the, often neglected, naturally regenerated pines and hardwood forests in the US South. After two levels of screening for relevance and scope, a total of 69 publications have been considered appropriate for our analysis. This review attempts to fill the gap of knowledge in natural forest management and explores the major challenges associated with their growth and yield predictions. These findings can also be used as a baseline information for further studies involving hardwood growth and yield models. Academics as well as forest-product companies can use this review to focus more on hardwood and natural pines.

Nonlinear two-stage and three-stage least squares and full information maximum likelihood for estimation of slash pine biomass components

Thomas Lynch & Dehai Zhao

Oklahoma State University, Stillwater, Oklahoma

Measurement of carbon sequestration in forest stands requires accurate estimation of the components of above-ground individual tree biomass including stem, bark, branch and foliage biomass. Slash pine total tree and component biomass prediction equations were developed using three estimation methods often used in econometrics: nonlinear two-stage (2SLS) and three-stage (3SLS) least squares and full information maximum likelihood (FIML). Equation systems were fitted to component biomass data from 306 slash pine trees sampled in the southeastern USA. The total, wood, branch and bark biomass component prediction equations from each system fit the data very well explaining 92 percent or more of total variation in each component with performance metrics similar to previously published results from SUR on the same data. The foliage biomass prediction equations explained 79, 79 and 84 percent of the total variation with 2SLS, 3SLS and FIML respectively. For foliage biomass 2SLS, 3SLS and FIML predictions had lower average percent errors, mean absolute percent errors and percent root mean squared errors than seemingly unrelated regressions or ordinary least squares. FIML and 3SLS estimation improved predictions for the foliage biomass component. These methods permit development of systems of equations for biomass components in which dependent variables in any particular equation can be used as explanatory variables in other system equations.

An industrial remote sensed inventory system – gaps and needs

Jim McCarter

Rayonier, Wildlight, Florida

Industrial forestry companies have high information demands for making strategic decisions on their lands and associates assets. Traditional forest inventory, increasingly combined with remote sensing technologies, provides the base information needed by companies. What combination of technologies and approaches provides an efficient, accurate, robust, and yet flexible system? This talk will review pieces that already exist, discuss new opportunities, and highlight some needs.

Temperature-based model for predicting southern pine beetle numbers

Holly Munro, Cristian Montes & Kamal Gandhi

University of Georgia, Athens, Georgia

Southern pine beetle (*Dendroctonus frontalis* Zimmerman) (SPB) is considered the most economically and ecologically important bark beetle species that kills pines in the southeastern United States (U.S.). Historically, SPB have been confined to the southeast, likely due to temperature constraints. There is concern that warming temperatures will result in further range expansion into the northeast U.S. and Canadian Provinces, which may devastate naïve pines lacking defenses against SPB. The objective of this study was to elucidate the spatial-temporal effects of temperature on SPB and how this may change under future warming temperatures. A model was built using SPB trap catch data for 2014-2017 and were paired with average monthly temperatures for each of the preceding 12 months. Past and current temperature data were obtained from DAYMET (NASA Earth Data), and future data were obtained from WorldClim. Analyses were performed using two-step regressions and AIC was used for model selection. The best model included average temperatures for February, and this model was used to map the spatio-temporal risk of SPB. Results indicate that areas were unable to support SPB populations until temperatures for February were above 7 oC. Temperatures were unlikely to support SPB populations in the northeast U.S. until early-2000s, and temperatures in all the northeast U.S. will be adequate to support SPB populations by 2050. Elucidating when and where future outbreaks will occur may allow forest managers to be proactive in managing forests and will provide critical pest management technology for maintaining healthy pine forests.

Estimation of Eucalyptus stands productivity using efficient Artificial Neural Network

Ricardo Neto, Helio Leite, Bogdan Strimbu & José Gleriani

Federal University of Viçosa, Viçosa, Brazil

The forest environment can be defined as the exterior forces and substances that affect forest development, structure and reproduction. To model the complex non-polynomial forest interrelations parametric and nonparametric representations were developed, such as Artificial Neural Network (ANN). ANNs, which seems to be more robust than statistical models to outliers and non-linear domains, face difficulties related to the choice of the training algorithm and structure or size of the network, which directly affect its efficiency and generalization capabilities. The objective of the present study is to find the most efficient ANN configuration algorithms and pruning methods to estimate the eucalyptus productivity from geomorphologic, climatic, and continuous forest inventory data. Given the same hardware resources, we evaluated the efficiency of a Multilayer Perceptron ANN as the combination of the processing time to supply a solution and the accuracy of the results. We have chosen the Multilayer Perceptron ANN because although simple, this type of ANN is a powerful tool for modelling data sets, particularly when the statistical models obtained are very low in the models normally used. We increase the efficiency of the network in two steps: one outside the ANN, thru Principal Component Analysis (PCA), which reduces the size of the input, and one inside the ANN, thru dedicated pruning methods, which reduces the number of connections and neurons. We used data from 507 Eucalyptus plantations, 3 years to 7 years old, ranging from 3 ha to 79 ha, located in Minas Gerais, Brazil, to test different network configurations (i.e., number of neurons in the hidden layers, 1 to 30), ANN back-propagation training algorithms (i.e., unimproved, Chunk, Momentum, Weight Decay, Resilient Propagation and Structural Group Contribution) and ANN pruning methods (i.e., Magnitude Based Pruning, Optimal Bran Damage, Optimal Brain Surgeon, Skeletonization and Non-contributing Units). Each ANN was trained five times to assess the impact of the initial weights on the results, which led to a factorial experiment with 9000 combinations (i.e., 2 input data x 30 # hidden neurons x 6 training algorithms x 5 pruning methods x 5 replications). We compared the ANNs performances using five metrics: processing time, bias, mean absolute error, root mean square error, and Pearson correlation coefficient. The most accurate result was supplied in in approximately 38.81 sec by an ANN using the PCA data, trained with the Structural Group Contribution algorithm with four neurons in the hidden layer and Magnitude Based Pruning method. However, an accuracy loss of less than 1% (i.e., the second most accurate results) was obtained in 1.7 sec from the same ANN configuration, except no pruning. Therefore, we found that the most efficient prediction of Eucalyptus productivity does not use all the data and or the most complex training algorithms.

Modeling height growth for teak plantations in Colombia using a reducible stochastic differential equation approach

Sergio Orrego, Cristian Montes, Héctor Restrepo, Bronson Bullock & Mauricio Zapata

Universidad Nacional de Colombia, Medellín, Colombia

Teak (*Tectona grandis* L.f.) is a highly valued tropical hardwood tree species, and new plantations are increasingly being established in tropical regions to meet a rising demand for teak timber. A stochastic differential equation, along with a Bertalanffy-Richards type height growth model, were used to model and estimate top height growth and site index of teak plantations in Colombia. Most of these plantations were established in the Caribbean region of Colombia, a region climatically suitable for teak growth by having a monsoon climate with a unimodal precipitation pattern. Data of diameter at breast height (1.3 m above ground) and mean top height (mean tree height of the 100 largest trees per hectare), periodically measured in 44 permanent sampling plots of 0.06 and 0.10 ha over a 17 year period, were used in this study.

Environmental variability and height measurement errors for teak were explicitly considered as the main uncertainty sources of mean top height growth. The asymptote and the scale time or growth rate were defined in the height growth model as local and global parameters, respectively, and performed best based on statistical performance and biological rationale, for estimating mean top height for teak. This model was better than a model estimated in which the growth rate and the asymptote were specified as local and global parameters, respectively. The selected model was employed to depict site index curves using 12 years as the base age. Results suggest that most of the uncertainty associated with the mean top height growth of teak plantations in Colombia, was largely explained by environmental variability. The best estimated model using the stochastic differential equation approach can be very useful for the prediction of height growth and the evaluation of site productivity of teak plantations in Colombia. These results can also be extended to neighbouring countries with similar biophysical characteristics to those prevailing where teak was planted in Colombia.

It's time for standards in forest inventory

Zack Parisa

SilviaTerra, San Francisco, California

Billions of dollars are transacted based on the inventory, growth, and scheduling work performed by many of the professional biometricians in our community. Homespun inventory methods, blackbox growth, and opaque harvest scheduling increase financial and environmental risk while slowing economic growth in the forest sector. What is the best practice for a particular time and place? To answer this question, we need a comprehensive method of benchmarking biometric practices. While there are no silver bullets in forest mensuration, benchmarking will allow the community-driven definition of the minimum acceptable practices to inform forest management. Benchmarking also provides a way to assess the efficacy of emerging technologies and novel practices. In this talk, I'll present a framework for how this could work and solicit feedback from the audience.

Estimating height from multiple diameters

Mark Porter, Cristian Montes, Bronson Bullock & Joseph Dahlen

University of Georgia, Athens, Georgia

Total tree height is useful for estimation of individual tree volume as well as quantifying site productivity. Total tree height estimation has traditionally used diameter at breast height as the primary predictor. With the rise of terrestrial laser scanning and terrestrial photogrammetry it is now possible to easily obtain multiple stem diameters. In this project we explore several methods of incorporating additional diameters in height prediction in comparison to a common height prediction model. Under certain conditions we found that the addition of a second upper stem diameter improves total height prediction.

Development of ecophysiological tools for the sustainable management of plantations of *Pinus radiata* and *Eucalytus globulus* in forestal Arauco

Juan José Quiroga

Bioforest S.A. - Arauco Holding, Concepción, Chile

Whole tree harvesting has increasingly been used, encouraged by energy necessities coming from the pulp industry. In Chile in particularly, the forest business has a diversified market, however, there is a big concern regarding soil nutrient depletion and a decrease in forest productivity in the long term. From 2012 until 2015, it was developed allometric models for both biomass area and soil nutrient content in *Pinus radiata* and *Eucalyptus globulus* plantations belonging to Forestal Arauco company. The main objective of this study is to evaluate the impact of whole tree harvesting operation in term of sustainable management. The following ecophysiology parameters were measured throughout this study: a) total aerial biomass by components (stem, bark, branches and foliage) during the entire forest rotation, b) nutrient content within those components and; c) Nutrient exports driven by whole tree harvesting technique. Additionally, forest yield was evaluated across a range of growth trajectories under Whole tree harvesting operations across the entire plantation area in Forestal Arauco. We sampled 482 and 153 trees located in 53 and 17 properties, respectively. Using the individual information per sample, models were generated allowing us to estimate total aerial dry biomass, and its components, as well as potential biomass for energy purposes. Using R-project software, we were able to estimate using statistical models, biomass and nutrient content per tree under any circumstances (regardless of it forest management, age or site index). Each model was validated using 120 new trees with destructive sampling in *Pinus radiata*, and 80 trees in *Eucalyptus globulus*, getting a good correlation in both cases (R2 value 0.96 to 0.98 in *Pinus radiata*, and 0.84 to 0.89 in *Eucalyptus globulus*). The mentioned models have the advantage that are easy to apply for operational inventories, enabling a quick and simple generation of a quantitative evaluation of the forest biomass and the distribution of nutrients by components within the plantations. Additionally, the company is able to evaluate in the long term, soil nutrients removal impact and biomass quantity for energy purposes in different harvesting operations, in the entire plantation area belonging to Forestal Arauco, without using lidar images or any geomatic tools.

Applications of a sampling simulator for two-stage, unequal probability sampling

Henry Rodman

SilviaTerra, Duluth, Minnesota

Two-stage sampling is useful in forest inventory because it offers improved resource efficiency over simple random sampling by reducing the number of stands that are visited. Additional sampling efficiency can be gained by using auxiliary information for selecting sampled stands, but altering selection probabilities comes at an analytical cost! Unequal probability sampling is well documented in statistical literature, but the estimators for sample variance are more complex than those for sample designs with equal probability and/or sampling with replacement and they require joint inclusion probabilities for each pair of primary sample units. I will present a simulation-based approach to obtaining estimates of joint inclusion probability and to demonstrate the efficiency of a two-stage sample with unequal probability.

The Sample Design: A Model or a Rule (that will be Broken)

Francis Roesch

US Forest Service, Asheville, North Carolina

All of the assumptions, estimators and results in design-based estimation begin with the assumption that a sample design exists and that the sample observations have been obtained with respect to that design. During the execution of most large sampling efforts violations of the design occur. Sometimes these potential violations were anticipated and some solution had already been devised and incorporated into the processing system. For instance, much work has been done to accommodate missing observations. In cases such as these, the sample frame is intact, but a value is not obtained for certain elements of the frame. More rarely discussed is the problem of the recalcitrant frame; that is the frame that does not really divide the "population" entirely and uniquely into the expected, knowable units. This problem is sure to arise when the "population" is defined in general for many variables of interest and not defined specifically for each of them, as in large forest inventory and monitoring efforts such as the USDA's forest Inventory and Analysis Program and other National Forest Inventory (NFI) systems. It also occurs when the frame is defined in the two dimensions of land area while observations on variables that are affected by time are made over a significant period of time. In these cases, our perception of the frame can hinder our ability not only to provide estimates of growth or change in particular forest attributes but also our ability to provide estimates of instantaneous values of forest attributes. A further complication can arise when estimates of growth in a forest attribute are made from observation intervals of varying lengths of time. A discussion is given about the benefits of viewing the sample design as a 'model' rather than as a 'rule' for analyses of forest monitoring data.

Temperature thresholds for growing Eucalyptus in South America

Túlio Barroso Queiroz, Otávio Campoe, Cristian Montes & Mauricio Cuartas

São Paulo State University, São Paulo, Brazil

The weather variability along the year and between years is one of the keystones to understand changes in forest productivity. Endogenous plant processes are regulated by temperature, so the expected stand dynamics of a particular species is expected to respond to local weather conditions. We studied the relation between the growth and temperature for *E. urophylla* in South America. Our model describes the temperature range required for optimal growth in this genotype. Eight sites with high variability in the average annual temperature (between 10°C and 30°C) were selected. They are located in Brazil (6 sites) and Uruguay (2 sites). In each site ## 80-trees plots were measured every six months from 2012 to 2018 and the temperature was recorded every 1 hour in each site using meteorological station. The productivity was defined as increments in total biomass. Therefore, biomass equations were adjusted using a destructive sampling with trees along the observed diameter classes and using the inventory a biomass time series was computed and paired with the temperature records. The current biomass increment was transformed into relative value, so the maximum increment for each genotype was fixed to be 1. Among the tested models, the second-grade polynomial presented the best fit. This model was used in the process called Data Envelopment Analysis (DEA). The parameterization process was performed by simulating and identifying the model coefficients more adequate for the data set using optimizations routines. Finally, the optimum growth temperature can be obtained by calculating the discriminant value (16.15°C and 22.85°C). In this case the discriminant always will be positive, and the coefficients are real, then the polynomial has two real roots. We found that the minimum temperature for growth is 6.76°C and the maximum is 29.84°C. Also, monthly minimum and maximus can be derived. We believe that this determination can drive managements decisions based on expected scenarios of climate change and the thermal requirement for the genotype studied.

A comparison of error distributions for estimation of stand survival

Mike Strub

Independent researcher

Seven error distributions for prediction of whole stand survival were compared using data and the two prediction equations (whole stand and tree level) from Cao (2017). The error distributions include the continuous normal, binomial, Poisson binomial, discrete normal (based on class intervals), beta binomial, mixed binomial and mixed Poisson binomial. The error distribution with highest likelihood for the Cao (2017) data and models was the beta binomial. The tree level equation had higher likelihood than the stand level equation with the beta binomial.

Cao Quang V. 2017. Evaluation of methods for modeling individual tree survival. For. Sci. 63(4):356–361.

Stand survival projection as a function of ages versus dominant heights

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Age- and height-based Clutter-Jones survival models were compared for their fits and projection using a long-term site-preparation study data. Overall, dominant heights provided better survival projection relative to ages. We recommend height-driven survival model for use, while keeping age-based model as a benchmark free of height measurements.

Robustness of parametric and nonparametric fitting of tree-stem taper with alternative definitions for validation data

Sheng-I Yang & Harold Burkhart

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Modeling tree-stem taper, a quantitative description of tree shape by predicting tree diameter as tree height increases from tree stump to the tip, has been widely discussed in forestry literature (Burkhart and Tomé 2012). Recently, computation intensive algorithms have been proposed to estimate tree taper, but reliability of applying the methods still needs to be examined. In this study, the robustness of tree taper modeling procedures with alternative definitions for validation data was evaluated. Specifically, tree stem taper predicted by a parametric segmented polynomial regression model proposed by Max and Burkhart (1976) was compared with that predicted by a nonparametric random forests regression method (Williams 2011). Data collected from natural stands of loblolly pine were used in analyses. To evaluate the performance of the two fitting/training procedures, sample trees for validation were selected according to four different data division strategies: random selection of one-third of the trees in the dataset, selection of the smallest one-third of the trees according to diameter at breast height (DBH), selection of the middle third of the trees by DBH, and selection of the largest third of the trees by DBH. Sample sizes for fitting/training and for validation were the same for all data splitting schemes. Results indicate that tree taper can be reasonably well predicted by both procedures when small, medium-sized, or randomly-selected trees are withheld for validation. However, when large trees were withheld for validation, diameters predicted by the random forest regression method were notably less accurate than those predicted by the segmented polynomial regression model, especially for diameters close to tree top (error of more than 7 cm or 3 in. was observed). The results of this preliminary study provide information about the robustness of parametric and nonparametric fitting of tree stem taper under varying levels of interpolation/extrapolation from the fitting to the validation data.

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Long-term dynamics of loblolly pine crown structures

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Loblolly pine (*Pinus taeda* L.) is an important timber species in the southeastern US. A better understanding of loblolly pine crown relationships with growth will help improve productivity estimates and optimize management regimes. Using data from loblolly pine culture/density studies, long-term effects of planting density, cultural intensity and site quality on loblolly pine growth and crown attributes were explored. Destructive biomass sampling was also conducted and vertical distribution of foliage biomass were assessed. Lower planting density or more intensive treatment increased average crown length. Crown ratios declined over time, and the decrease rate increased with increasing initial density and cultural intensity. Foliage to branch biomass ratio decreased over time, and was not significantly affected by cultural intensity or planting density. Stem to crown biomass ratio was significantly affected by planting density but not by cultural intensity. More intensive stands or stands on more productive sites raised to a maximum foliage biomass at earlier ages, then flattened. Planting density significantly affected foliage biomass in early development stage, and this effect was no longer significant during the mid-rotation stage. However, vertical distribution of foliage biomass and foliage density was still affected by planting density and cultural intensity.

List of Posters

Simultaneous prediction and projection equation for basal area growth of unthinned loblolly pine stands

Anil Koirala, Cristian Montes & Bronson Bullock

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Until the 1950s, only about 2 million acres of pine plantation existed in the US south. This has dramatically increased more than fifteen times in just 50 years period. Loblolly pine plantation alone, now comprises more than 15 million acres of land in this region. Growth of loblolly pine varies across the planted range and is affected by local climatic and growing conditions. Basal area is an important measure of tree growth in plantation forestry. It plays a vital role in stand-level growth and yield model development process. In order 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 essential. 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 Pienaar basal area model (1986) for unthinned stands. Data for this study was obtained from 180 plots of unthinned loblolly pine stands in the Plantaiton Management Research Cooperative (PMRC) western gulf culture density study.

Production of *Picea rubens* for Southern Appalachian restoration initiatives

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The spruce–fir (*Picea rubens* and *Abies fraseri*) forests of the southern Appalachian Mountains once dominated the upper elevations of the southeastern United States. Today, however, these mountain-top communities only occur at seven locations throughout southern Virginia, western North Carolina, and eastern Tennessee (Berry and Smith, 2013). Causes for this widespread decline have been traced to stress factors such as logging, acid rain, attacks from invasive insects [e.g., balsam wooly adelgid (*Adelges piceae*)], and alteration of the environment due to climate change (White and Cogbill, 1992). Targeted initiatives have been developed, including the Southern Appalachian Spruce Restoration Initiative (SASRI), to restore and replant *Picea rubens* in ecologically appropriate locations throughout the Southern Blue Ridge ecoregion. However, procurement of *Picea rubens* for restoration has been difficult, as the success of young life stages of plants, such as tree saplings, is critical to establishment, especially in harsh environmental conditions. *Picea rubens* saplings tend to have distinct physiological and morphological differences compared to adult plants, such as increased photosynthetic capacity, carbon allocation, and unique xylem considerations (Niinemets 2002). As a result, juvenile age classes are generally considered more sensitive to environmental stress than mature trees (Greenwood et al. 2008) and difficult to produce. Therefore, a propagation and production system were developed by Southern Highlands Reserve (SHR) to increase both production and transplant success. Spruce cones were collected throughout the Southern Appalachians in early September and stored in brown paper bags until they matured and dried. Seeds were removed from the cones and germinated in a propagation flat. Following germination and root development, seedlings are transplanted into a 2" Rootmaker® 32-count tray with a bark-based substrate and grown for an additional six to nine months until roots are fully developed. Finally, seedlings are transplanted into 1gal. Rootmaker® pots utilizing bark-based substrate and top-dressed with slow release fertilizer. Plants are grown in full to part shade for an additional one to two years until 12 to 18 inches tall. Utilizing this system, success rates for both production and restoration have a 90% reported success rate. Other contributing factors include elevation, topography, and climate of the production site, mimicking conditions at final restoration sites, and thereby reducing transplant shock. Further research into production techniques and population genetics-based hardiness of *Picea rubens* would further elucidate the production and restoration process.

Optimal growth temperatures for contrasting eucalyptus clones across a climatic gradient in Brazil and Uruguay

Túlio Barroso Queiroz, Otávio Campoe, Cristian Montes, Mauricio Cuartas, Sameen Raut, Iraê Guerrini, Clayton Alvares, Claudio Silva, James Stahl, Gabriela Moreira, Marco Figura, Helton Lourenço & Ricardo Buzzo

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The ability to adapt to different ecological conditions (climate, soil and elevation), high growth rate and multiple uses (pulp, sawn timber and bioenergy) makes Eucalyptus one of the prime tree species in South America. Brazil has an average annual precipitation ranging from 700mm to 3100mm and an average annual temperature which ranges from 10°C to 30°C. In contrast to that, Uruguay frequently experiences temperatures less than 10°C. Because of high productivity of Eucalyptus in Brazil, the demand for research explaining its productivity in relation to the eco-physiological mechanisms and weather has increased. The Cooperative Program on Clonal Eucalyptus Tolerance to the Hydrous and Thermal Stresses (TECHS) that is administered by Forestry Science and Research Institute (IPEF) was established as a result of such demand. This study has the objective of identifying optimal temperatures and ranges for growing Eucalyptus in Brazil and Uruguay. Optimal growth temperature is important to understand changes in species deployment productivity and management. Growth of 3 genotypes of Eucalyptus (*E. urophylla* – A1, *E. grandis* x *E. camaldulensis* – C3 and *E. benthamii* – *J1*) were monitored in 6 Brazilian states and 2 cities in Uruguay at an interval of every 15 or 30 days since 2012 to 2018. The optimum temperature was found using the discriminat of the second-grade polynomial. Our analyses captured the thermal stress in eucaliptus cultivated in different climatic conditions. Annual and monthly temperatures optimal for growth of the eucalyptus genotypes most planted in South America were identified. The maximum growth can be achieved through a range of temperatures between 16.92°C and 23.90°C. While the J1 genotype starts his growth at 1.84°C, A1 genotype starts at 4.76°C and C3 starts at 12.53°C. This information may be used to indicate the cultivation of species for different regions. Lastly, we intend to understand tree growth and its relationship with climate in order to improve deployment productivity and management.

Application of bio-imaging techniques for accurate quantification of compression wood and wood to bark volume ratios in longleaf pines of South Georgia

Sameen Raut

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The conversion of forest land to agriculture resulted in the loss of 97 percent of longleaf pine forests in the southern U.S. Reforestation efforts in the 1950's established other southern pines across the southeast, namely loblolly and slash pine. However, recent efforts have led to the reestablishment of approximately 4 million acres of longleaf pine throughout the south on both converted agricultural fields and cutover forestlands. The application of modern silvicultural practices, combined with the lack of genetic improvement, has proven detrimental to longleaf pine stem wood and quality, with some sites having over 50% stem defect rate. Defects including sweep, forking, and ramicorn branching will result in the formation of compression wood which is undesirable for manufacturing. This study will investigate the applicability of bio-imaging techniques to quantify the amount of compression wood from longleaf pine. We are in the process of collecting cross sectional disks, extracted at multiple height levels, from 400 longleaf trees across South Georgia. Green disk surfaces will be machined using a CNC router and subsequently photographed. An RGB image will be collected for making inferences about wood and bark volume and disk shape. A second image taken using circular polarized light will fluorescence the compression wood and allow for accurate quantification of the compression wood quantity. Following imaging, wood and bark volume, specific gravity and moisture content will be determined manually with comparisons made been the two volume measurements. Analysis of Variance using linear mixed models with stand and tree sampled as random factors will be conducted to determine differences in wood and bark properties between the converted agricultural fields and cutover forestland sites.

Biophysical drivers of the loblolly pine timber production and its uncertainty in the Southeastern U.S.: a stochastic spatial 3-PG model

Héctor Restrepo, Cristian Montes & Bronson Bullock

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Prediction of forest productivity can be accomplished using either process-based or empirical growth and yield models. Despite the generality of empirical models as compared to process-based models, they lack the ability to incorporate and integrate climate, soil, and topography in a sound way. One of the most popular process-based models is the 3PG model (Physiological Principles Predicting Growth). The model has been successfully applied to estimate loblolly pine net primary productivity in the southeastern U.S. using historical past climate. However, one of the shortcomings of the model is that it relies on its deterministic approach to incorporate climatic inputs, resulting in deterministic outputs. Efforts to project forward demand the inclusion of downscaled climatic scenarios, leaving little insight for uncertainty estimates, discarding local information about climatic inputs and their correlation on any given site. The objective of this research was to evaluate a stochastic approach to productivity forecasting using climatic variables derived from a spatial Monte Carlo simulation to account for environmental variations associated with temperature, solar radiation, and soil water availability with explicit co-variance matrices. Our spatially explicit 3-PG model with stochastic components was able to give insight about loblolly pine timber production, and its biophysical risk, that can be used for decision making. Our results show larger variation in productivity in areas with low productivity and a more stable value in areas with higher productivity. Moreover, forest yield information from this process-based model may be combined with empirical forest yield models to improve timber production accuracy estimates, which should result in a reduction of the financial risk associated with forestland investments.

Assessing stand characteristics of enhanced loblolly pine plantations in the Southeast

Melissa Shockey, Bronson Bullock, Cristian Montes, Michael Kane & Rafael De La Torre

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Developing a benchmark of comparison among improved genotypes of Loblolly pine (*Pinus taeda L.*) is important to quantify genetic gains as future selections aim to improve growth characteristics. A well-performing, early selection, open-pollinated loblolly pine family would be a more meaningful operational baseline of comparison for forest land managers than wild seed checklots. This study characterizes a widely planted open pollinated loblolly pine family across a range of sites and ages by describing diameter distributions and height-diameter relationships. A system of equations is presented for the selected open-pollinated loblolly pine family of interest. To complete the system of equations, a volume equation was selected from existing literature to estimate volume per hectare.

PSTapeR: an R package for tree taper modeling

Mauricio Zapata Cuartas, Bronson Bullock & Cristian Montes

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PSTapeR is an implementation of functions in R for fitting a taper equation using penalized spline linear mixed models. Contrary to the parametric approaches for taper modeling, PSTapeR uses semiparametric methods, thereby the final model is data-driven, and no dependence exists on a specific equation form. A representative training stem analysis data set is required to calibrate the model for a particular species. PSTaperR generates automatically diameter-class groups and these are included as an additive predictor variable. This strategy showed important improvements in prediction accuracy compared with other parametric equations. Further functions are provided to estimate the uncertainty around the predicted radius curve and to calculate the total and merchantable volume. In addition, tree volume confidence bounds can be calculated allowing the user to assess the volume estimation from inventory data. Approximate confidence bounds are obtained by integration on simultaneous confidence intervals for the predicted stem curve. This allows more agile computations on large inventory processing jobs. Also, exact confidence intervals based on a Normal approximation are provided but adds to execution time. A small sample data set is provided in the package with stem analysis for 147 loblolly trees that were obtained in unthinned loblolly pine plantation stands located at Whitehall Forest at the University of Georgia. We compare PSTapeR with other six alternative parametric taper equations including single, segmented, and variable-exponent equations. Our findings suggest that assuming a priori fixed forms in taper models impose an unnecessary restriction that fails to explain the tree shape form. Measurements of bias and residual variance showed that PSTapeR consistently outperforms the six alternative parametric equations. Also, we emphasize the capabilities of our method to report uncertainty.

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Useful Information

Talks will be held at the **Helens Bridge Room** at the Hilton Garden Inn Downtown Asheville (HGI). It is situated on the ground floor of the hotel.

Breakfast is on your own. There are many breakfast spots near the conference location. The organizers suggest Old Europe Pasteries, which is a 10-minute walk from the hotel at the corner of College and Broadway Street.

Lunches will be provided in the Pillar Room of HGI at noon on Monday and Tuesday. Monday will be a BBQ lunch with a Fajita bar on Tuesday. Please contact the conference organizers 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 coffee runs out.

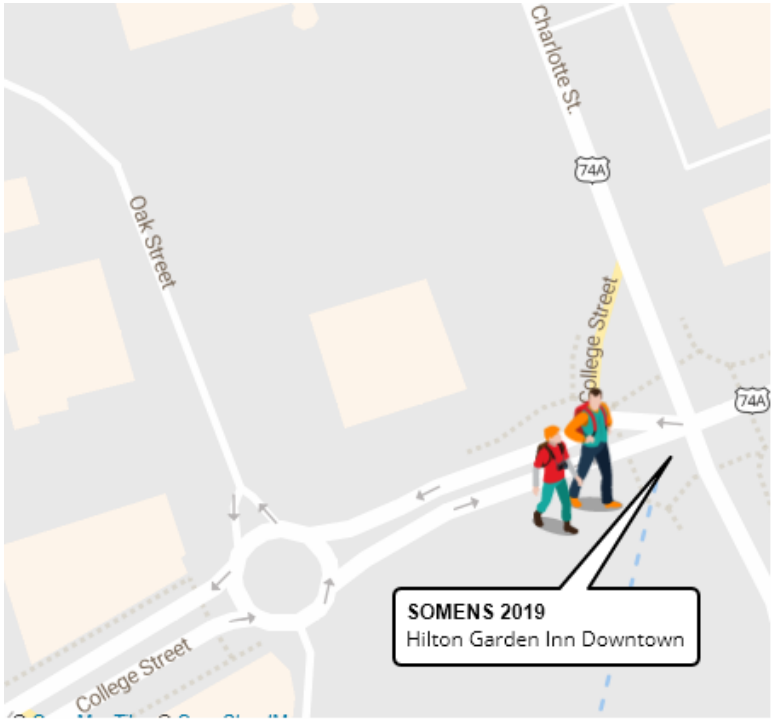
The **poster session** will be held on Monday night on the ground floor of the HGI prior to the conference banquet between 4:10 and 5:45 PM.

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

The **conference banquet** will be held at the Century Room of Pack Tavern, at 20 S Spruce St, Asheville, NC 28801.

How to get to the Hilton Garden Inn?

The Hilton Garden Inn is located at 309 College St, Asheville, NC 28801 (see map below). There is parking in a deck on site, for standard sized cars and trucks. The hotel is about a 10-minute walk from the center of Asheville, which hosts several breweries, art galleries and restaurants. The Asheville Airport (AVL) is about a 15-20 minute ride from the Hilton Garden Inn. We'll be at the hotel for the duration of the conference (or within short walking distance for dinner). Uber and Lyft are allowed at the airport and probably cheaper than a taxi.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