

Alison L. Ritz, Valerie A. Thomas, and Randolph H. Wynne  
Department of Forest Resources and Environmental Conservation

**Goal:** To develop a model that accurately calculates the canopy height of actively managed loblolly pine plantations from NAIP photogrammetric point clouds.

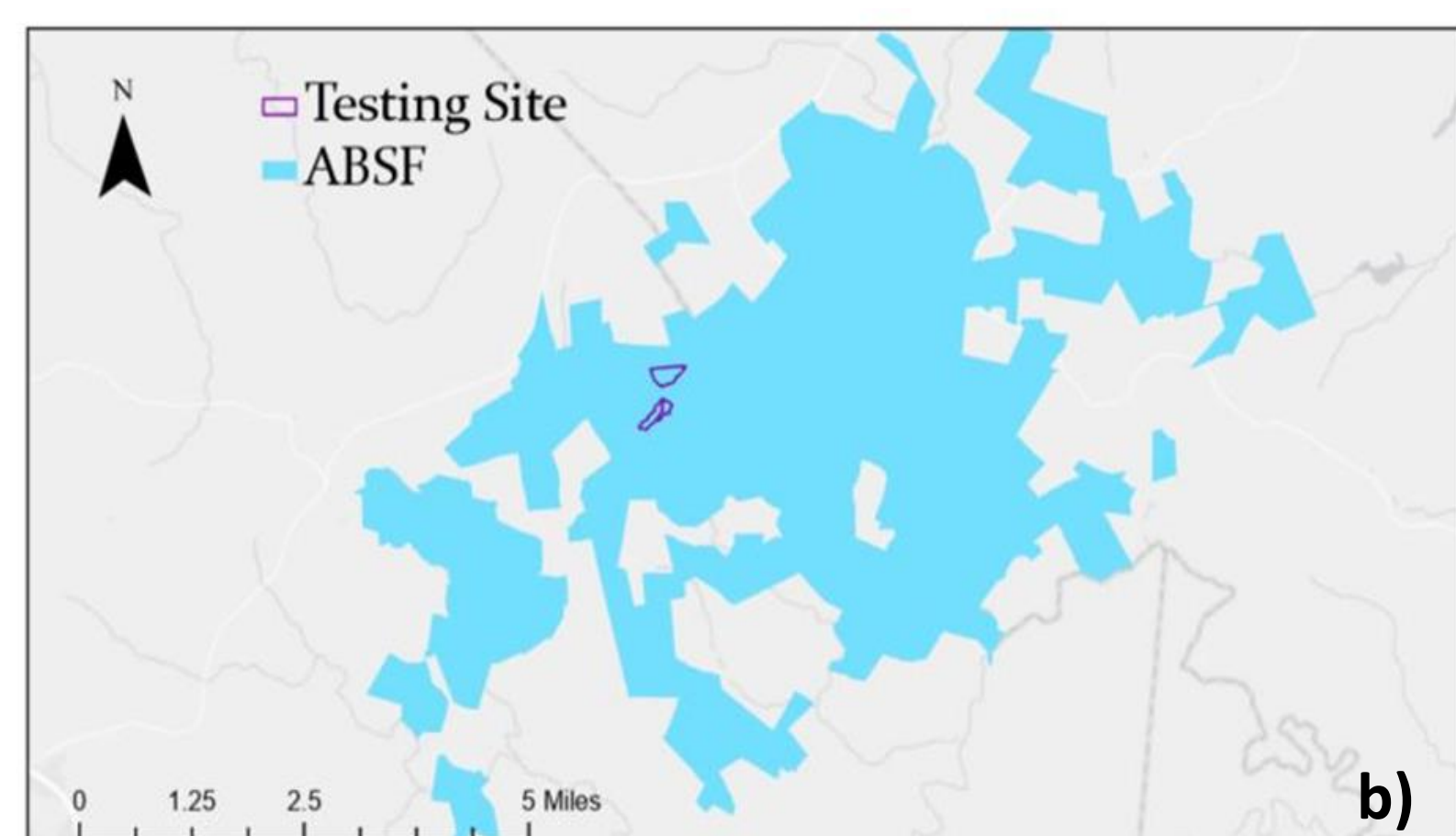
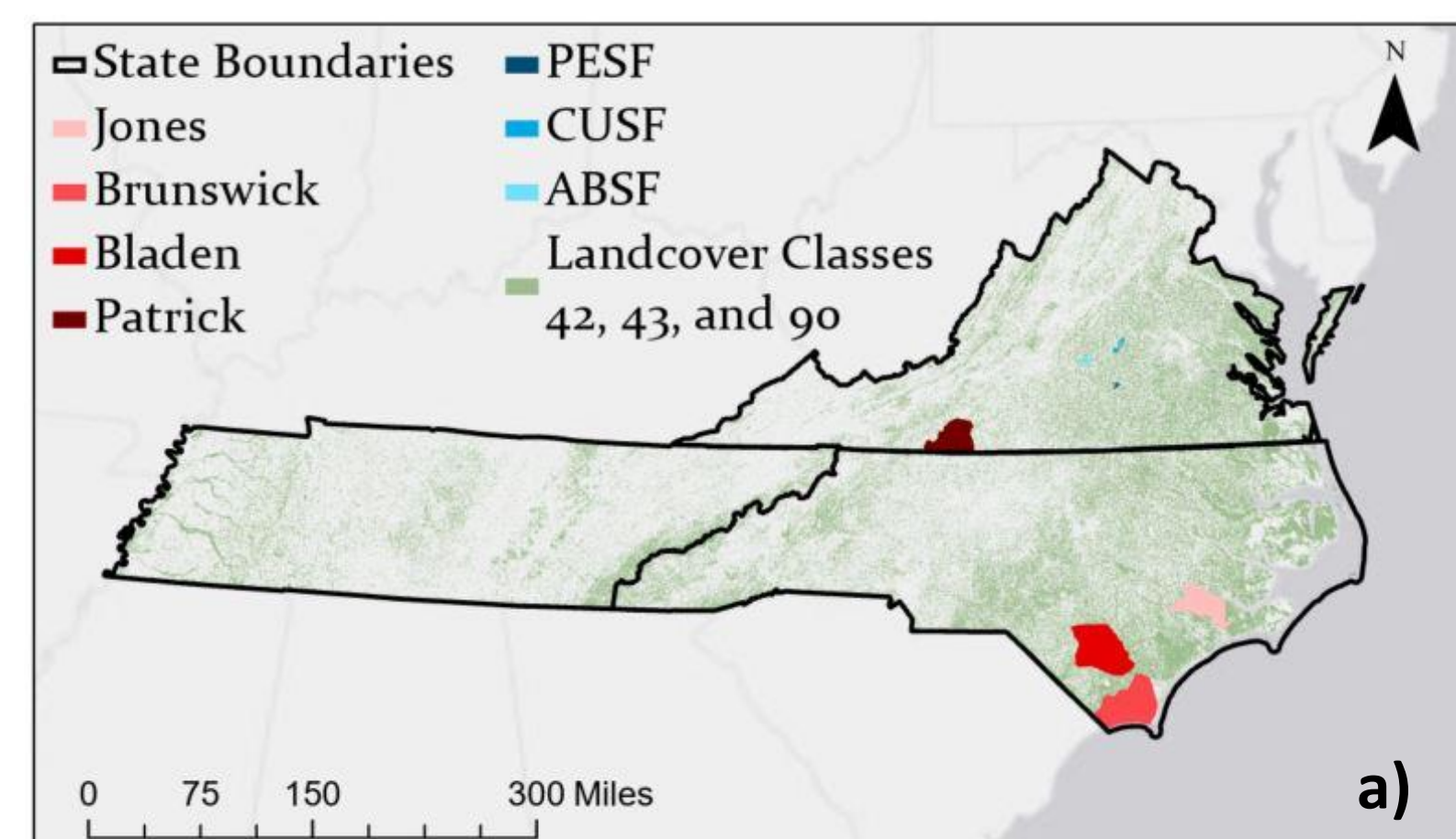
**Region of Interest:** Pine forests, natural and managed, in Virginia, North Carolina, and Tennessee.

**Data:** NAIP imagery collected with the Leica ADS-100 sensors by the USDA FSA APFO NAIP program.

**Methods:** Training data points from seven stands across VA and NC, normalization using lidar DEMs, statistical analysis, predictive canopy height model creation, and application of the model on a statewide basis based off NLCD classes (42, 43, and 90).

**Results:** Preliminary results indicate the following: (1) for areas of pine, specifically loblolly pine, NAIP can be used to produce a reliable predicted canopy height model, (2) NAIP should be considered as a means for mapping pine height in other states in the southern pine belt to create a canopy height model of loblolly pine plantations that can be updated routinely from NAIP's routine acquisitions.

Remote sensing offers many advantages to previous forest measurements, such as limiting costs and time in the field. Light detection and ranging (lidar) has been shown to enable accurate estimates of forest height. Lidar does produce precise measurements for ground elevation and forest height, where and when it is available. However, it is expensive to collect and does not have wall-to-wall coverage in the United States. Recent studies have investigated the ability of digital aerial photogrammetry (DAP), and more specifically NAIP, as an alternative to lidar as a means of estimating forest height due to its lower costs, frequency of acquisition, and wall-to-wall coverage across the United States.



**Figure 1.** Study areas in Virginia, North Carolina, and Tennessee. a) Training sites and the extent of the state-wide modeling, b) the application sites in ABSF

## NAIP and Field Data Analysis

After removing outliers in the data, each NAIP image band point cloud (RGB, RGB Thinned, FCIR, FCIR Thinned) was analyzed with various statistical tests to determine the best model for predicting top of canopy height. FCIR was determined to be the strongest model with a high  $R^2$  and low RMSE.

Metrics	Correlation	Adjusted $R^2$	Intercept	Coefficient of x	RMSE	n	$R^2$ Press Statistic
RGB vs Field	0.96	0.93	-0.48	1.10	1.48	528	0.92
RGB Thinned vs Field	0.81	0.66	2.99	0.84	2.92	528	0.65
FCIR vs Field	0.96	0.93	-0.43	1.09	1.44	528	0.93
FCIR Thinned vs Field	0.82	0.66	2.99	0.85	2.92	528	0.66

**Table 1.** Correlation, summary statistics and RMSE for the training site's 90th percentile height metrics after the outliers were removed

Data	Min (m)	Max (m)	Median (m)	Mean (m)	Standard Deviation (m)	Variance ( $m^2$ )	Count
Field	0.98	26.59	11.92	12.96	4.55	20.10	528
NAIP (FCIR)	0.96	24.43	11.90	12.24	3.95	15.62	528

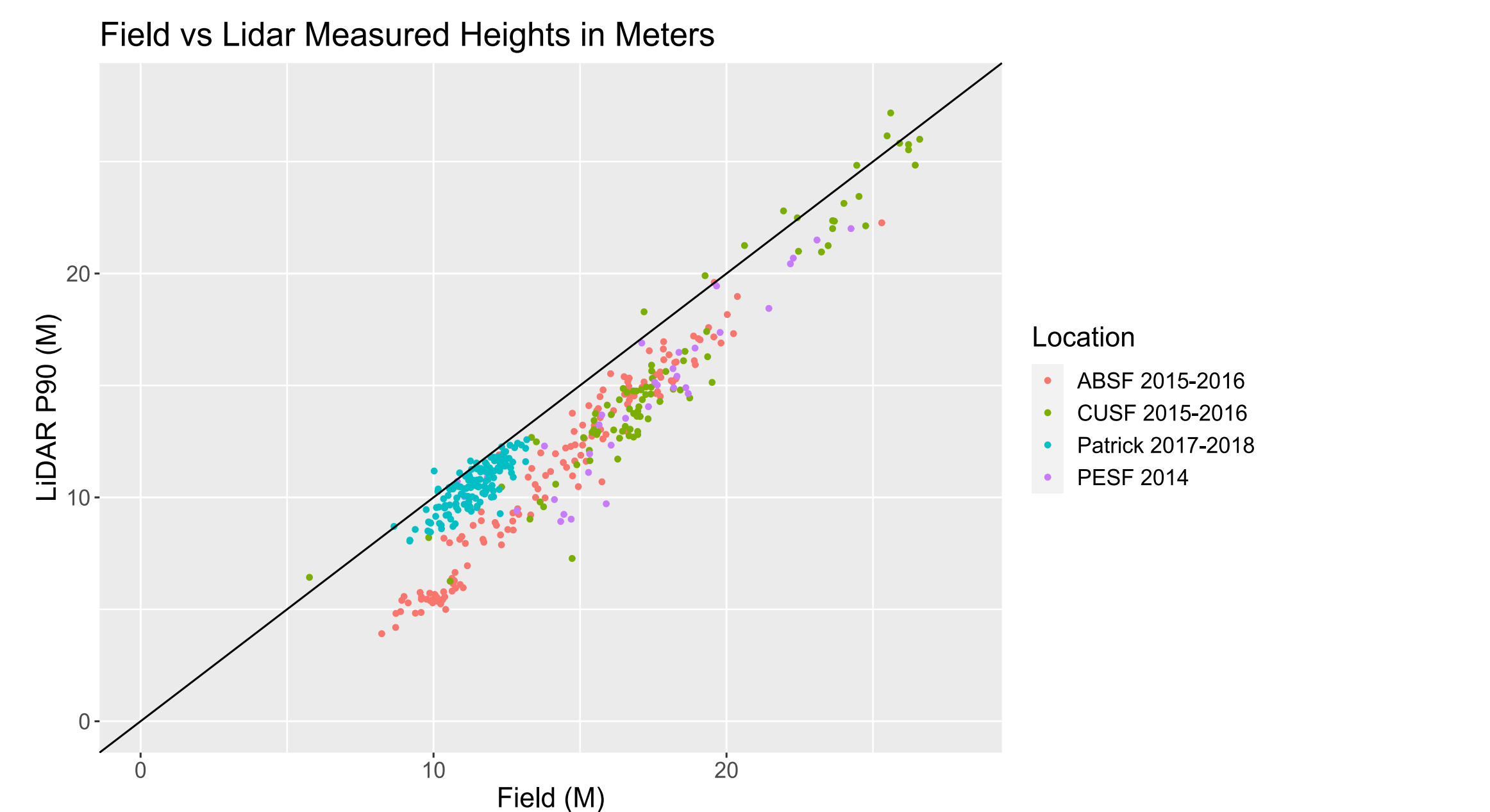
**Table 2.** Summary statistics of the data in the training plots

Model	K	AICc	Delta AICc	AICcWt	Cum.Wt	LL
FCIR	3	1689.72	0.00	1	1	-841.84
RGB	3	1717.76	28.04	0	1	-855.86
FCIR Thinned	3	2511.26	821.54	0	1	-1252.61
RGB Thinned	3	2513.57	823.85	0	1	-1253.76

**Table 3.** Model selection based on the AIC test. AICc is the information score of the model (smaller is better). LL is the log-likelihood of the model. (Beavans, 2020)

## Lidar Visualization

The lidar data in this study was found to be inadequate for a comparison in terms of height modeling due to the drastic difference in height from the various years and parameters of acquisition. However, this does present the argument that lidar cannot be relied on for collecting canopy height due to its lack of reliable coverage in the US.



**Figure 2.** Model of the Lidar P90 calculated height versus the field measured height. The P90 height represents the 90th percentile of height in each plot. The years noted in the Location key are the years the Lidar data was acquired.

Data	Min (m)	Max (m)	Median (m)	Mean (m)	Count
Field	5.76	26.59	12.95	14.26	402
Lidar	3.91	27.17	11.42	12.16	402

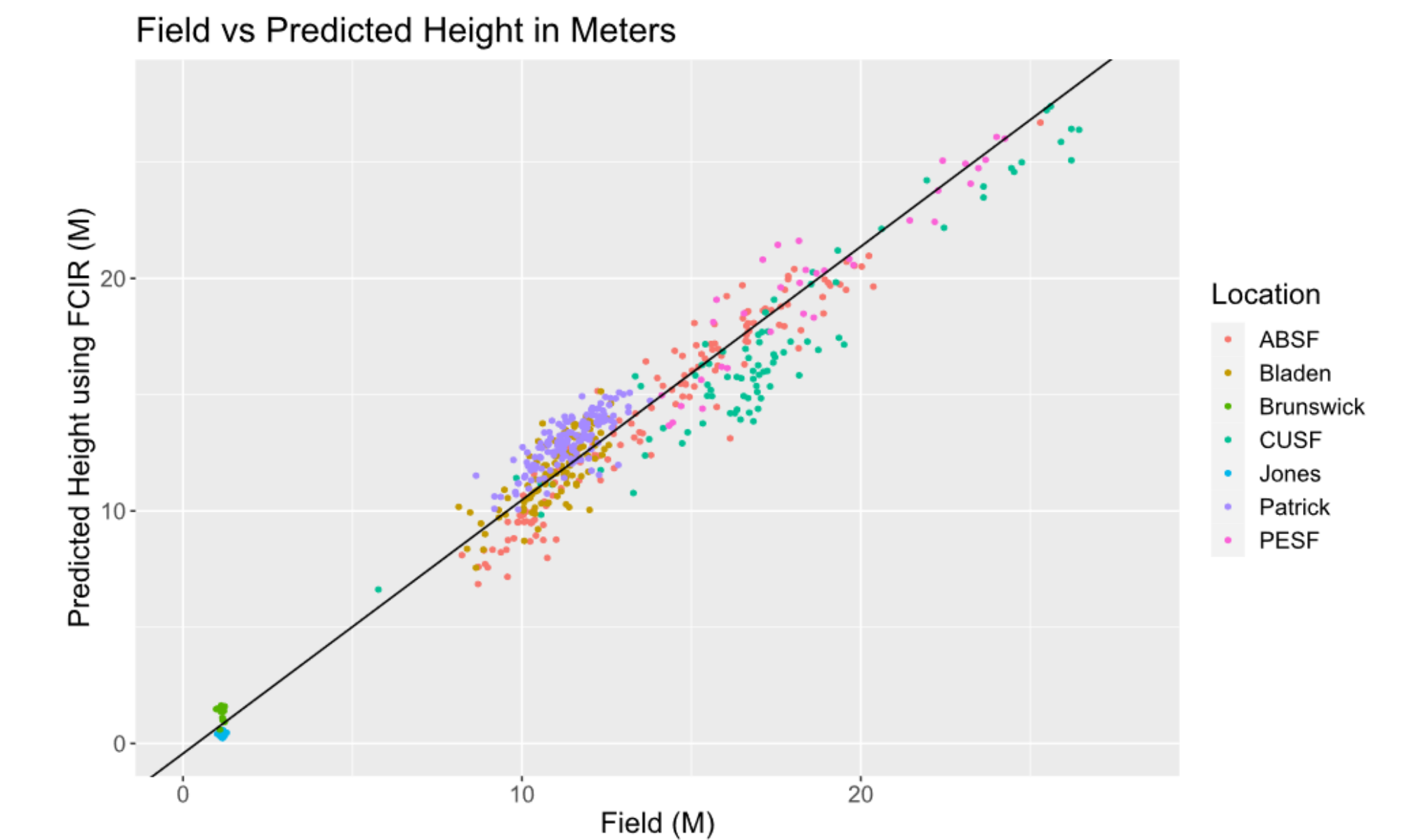
**Table 4.** Summary statistics of the data in the lidar plots

## Predicted Canopy Height Model

The FCIR model was selected for use in the remainder of the study as the basis for the predicted height of a pine stand:

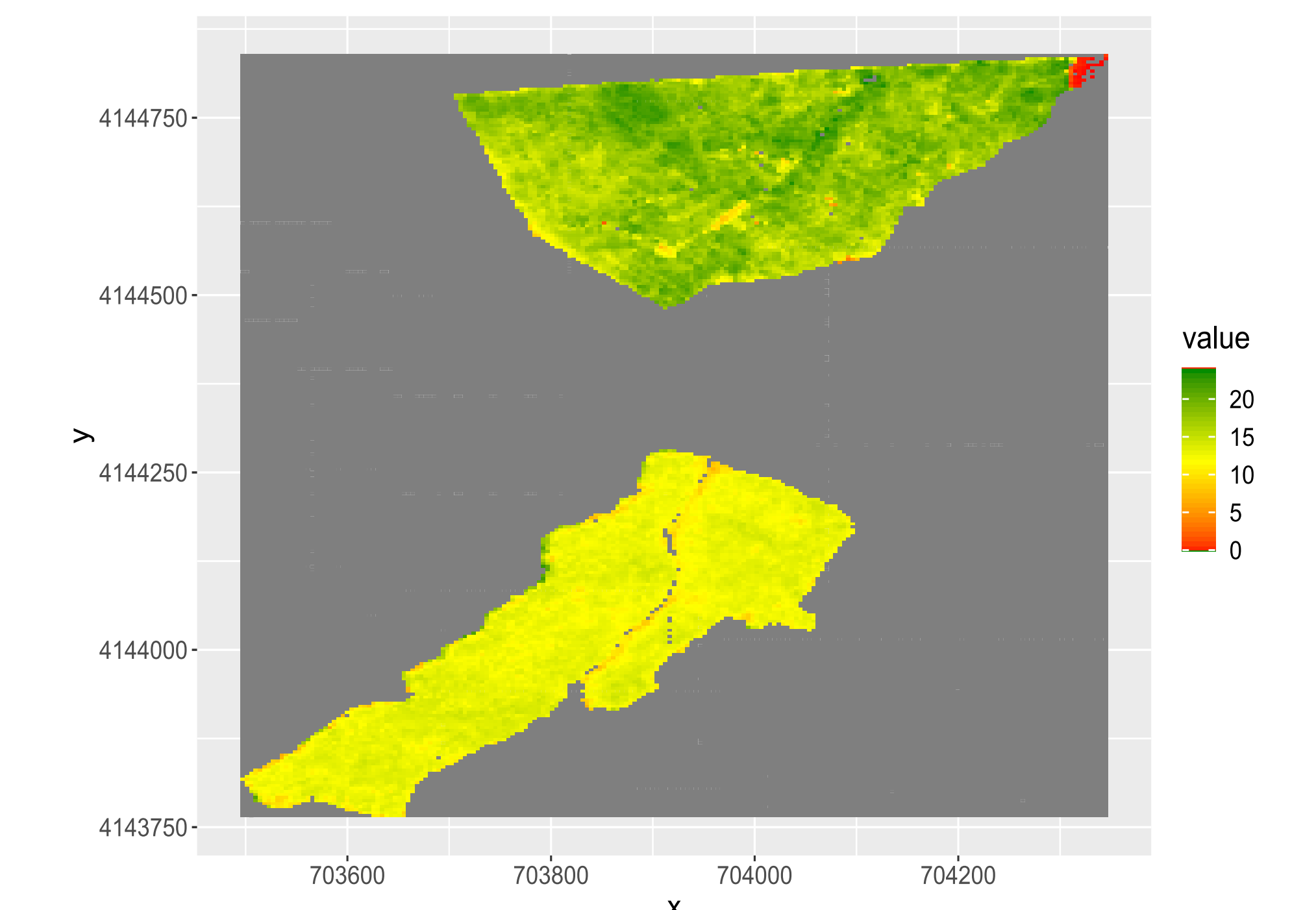
$$\text{Predicted Pine Height (PPH)} = 1.09X - 0.43, \quad (1)$$

where X is the 90th percentile of height from the normalized NAIP.



**Figure 3.** Model of the NAIP FCIR predicted height and field measured height with the PPH model represented in black.

Equation (1) was used to make a canopy height model of the three stands in the model application site. This was accomplished by computing the normalized NAIP point cloud for the stands and collecting the 90th percentile of height on a  $5m^2$  grid basis. The collected heights were then recalculated in the model to generate the predicted height.



**Figure 4.** Canopy Height Model (CHM) of the application site in ABSF. This is the CHM after running the FCIR normalized heights through the PPH model. X and Y axis are coordinates in projection GRS80 UTM 18N.

Task	Progress
Upload all NAIP files to ARC	Completed
Normalize all NAIP files with lidar DEMs	In Progress
Clip normalized point clouds to extent of NLCD fields 41, 42, and 90	Not Completed
Calculate 90th percentile of height metric on a $5m^2$ grid over each normalized, clipped point cloud	Not Completed
Apply the EPH model to each 90th percentile metric	Not Completed
Produce a CHM for each point cloud across the three states	Not Completed

**Table 5.** Progress of the Application of the PPH Model to VA, NC, and TN.

## Takeaways

- NAIP imagery in the FCIR and RGB bands are well suited for collecting canopy height.
- High-quality lidar DEMs are essential.
- NAIP imagery is not entirely accurate at predicting canopy height but is more reliable in availability and acquisition homogeneity than lidar.