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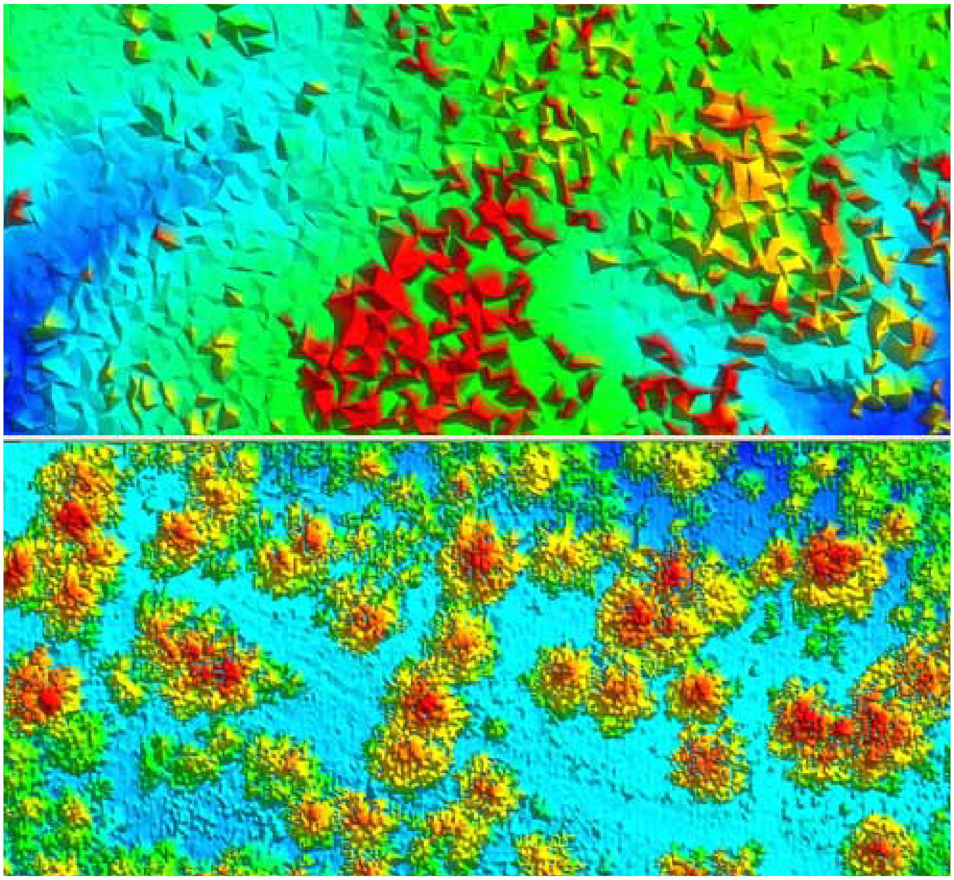
Scott A. Tweddale and Douglas Newcomb

March 2011



Construction Engineering
Research Laboratory

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Landscape Scale Assessment of Predominant Pine Canopy Height for Red-cockaded Woodpecker Habitat Assessment Using Light Detection and Ranging (LIDAR) Data

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Final Report

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Abstract: Use of spatially explicit Red-cockaded Woodpecker (RCW) population models to determine the habitat potential and conservation value of land parcels requires coupling of such models with actual landscape features on the ground. Development of spatially explicit maps that characterize forest metrics across a regional or landscape scale with Light Detection and Ranging (LIDAR) data is cost prohibitive, both in terms of data acquisition and analysis. Small scale, regional assessment of RCW habitat potential must be completed using regional, statewide, or national scale remotely sensed data sources. Therefore, assessment of forest structure at regional scales requires the use of larger footprint, lower sampling density LIDAR data and coarser resolution multispectral imagery. This research demonstrates the use of multispectral imagery and LIDAR data on a statewide and national scale to estimate mean predominant stand height for pine forest stands in the regions surrounding Fort Bragg, NC and Camp Lejeune, NC.

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Preface

This study was conducted for the Construction Engineering Research Laboratory (ERDC-CERL) under Strategic Environmental Research and Development Program (SERDP) project Sustainable Infrastructure (SI - 1472), "A Decision Support System for Identifying and Ranking Critical Habitat Parcels On and In the Vicinity of Department of Defense Lands." The CERL technical monitor is Dr. Timothy Hayden, CEERD-CN-N.

This work was managed by the Ecological Processes Branch (CN-N) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The ERDC-CERL Principal Investigator (PI) was Scott A. Tweddale. The Lead PI for this SERDP project was Dr. Jeffrey Walters, Virginia Polytechnic Institute and State University. Special acknowledgement is owed to the North Carolina Floodplain mapping program for providing all LIDAR data used in this research and for their assistance in acquiring the data and Fort Bragg, NC for providing forest inventory data. Acknowledgement is also given to Alexa McKerrow of North Carolina State University and Ken Convery of Virginia Tech University for their assistance in acquiring Gap Analysis Program (GAP) landcover maps for the study regions. Natalie Myers and James Westervelt of U.S. Army Corps of Engineers, ERDC-CERL are recognized here for their invaluable assistance with data processing. Alan Anderson is Program Manager of the Habitat-centric Species At Risk (SAR) Research To Avoid Future Training Restrictions Program. William Meyer is Chief, Ecological Processes Branch (CN-N) of the Installations Division (CN), and Dr. John Bandy is Chief, CN. The Deputy Director of CERL is Dr. Kirankumar V. Topudurti, and the Director of CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary E. Johnston, and the Director of ERDC is Dr. Jeffery P. Holland.

Unit Conversion Factors

Multiply	By	To Obtain
Acres	4,046.873	square meters
feet	0.3048	meters
hectares	1.0 E+04	square meters
miles (U.S. statute)	1,609.347	meters
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
yards	0.9144	meters

1 Introduction

Background

Large scale assessment of Red-cockaded Woodpecker (RCW) habitat potential requires spatial characterization of pine species, pine basal area by size class and the spatial distribution of mid-story hardwoods. Analysis of high posting density Light Detection and Ranging (LIDAR) data and high spatial and spectral resolution multispectral imagery does provide some capability for assessing the spatial variability of these critical forest metrics. However, development of spatially explicit maps that characterize these same forest metrics across a regional or landscape scale with LIDAR data is cost prohibitive, both in terms of data acquisition and analysis. Small scale, regional assessment of RCW habitat potential must be completed using remotely sensed data sources on a regional, statewide, or national scale. Therefore, assessment of forest structure at regional scales requires the use of larger footprint, lower sampling density LIDAR data, and coarser resolution multispectral imagery.

Associated with decreased LIDAR posting density is a reduced capability to assess detailed forest structure parameters. Lower posting densities do not allow for assessment of individual forest stems and result in significantly fewer LIDAR returns that penetrate the canopy and intercept understory vegetation. Therefore, it is not possible to assess basal area by size class and understory conditions with such data. Similarly, lower spatial and spectral resolution multispectral imagery does not allow for separation of pine species. However, analysis of larger footprint, lower sampling density LIDAR data in combination with multispectral imagery does provide some capability to delineate pine forest and estimate mean stand heights from which stand age can also be estimated. Regional, landscape scale assessment of forest stand height and age are useful for initializing and establishing parameters for landscape scale habitat models.

Objective

The general objective of this research was to investigate methods to exploit traditional multispectral imagery and small scale, coarsely sampled LIDAR data for characterizing forest metrics that are critical for determining RCW habitat suitability. The primary focus of this research was to develop a method to use statewide, larger footprint, lower sampling density LIDAR data and statewide landcover classifications for the state of North Carolina to estimate mean predominant canopy height of forest stands in the regions surrounding Fort Bragg, NC and Camp Lejeune, NC.

Approach

A generalized, landscape-scale RCW habitat classification scheme was developed and applied to regions surrounding Fort Bragg and Camp Lejeune, NC. The habitat classification identified pine forest, and secondly, for areas identified as pine forest, mean predominant canopy height for individual pine stands was estimated from LIDAR data.

Mode of technology transfer

It is anticipated that the results of this analysis will be used by a Decision Support System (DSS) to help identify and prioritize habitat parcels on and in the vicinity of installations in the southeastern United States.

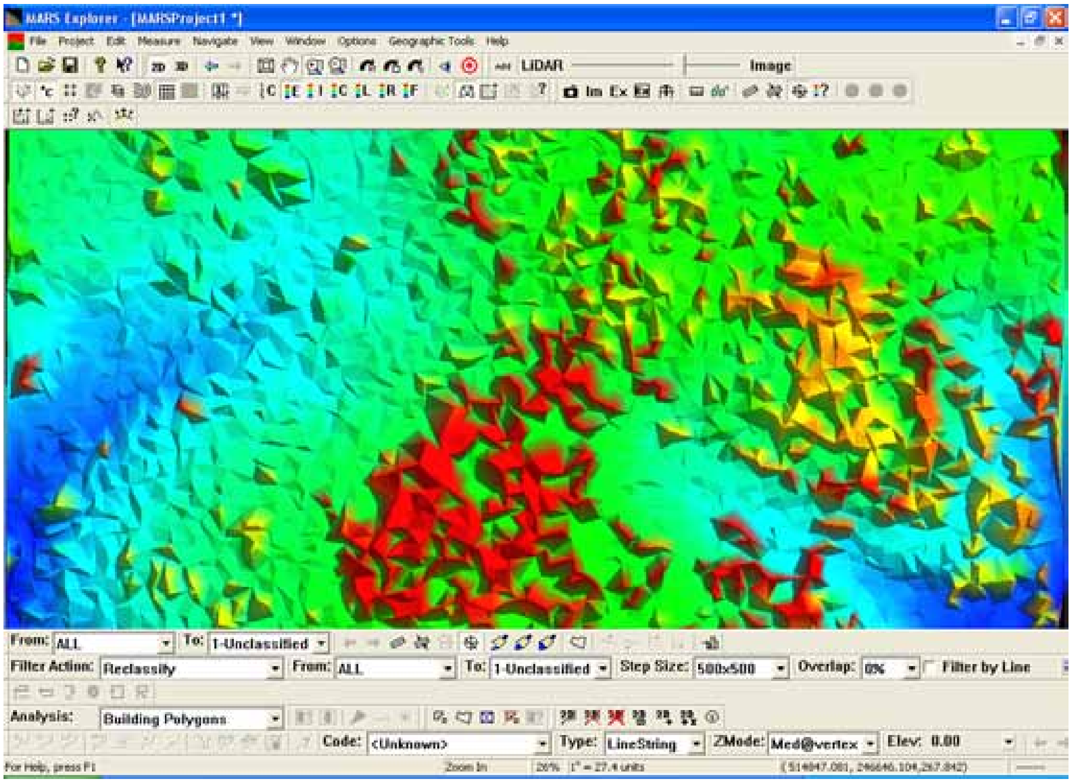
Also, this report will be made accessible through the World Wide Web (WWW) at URL: http://www.cecer.army.mil

2 Background on LIDAR Sampling Density

Assessment of species composition with national scale satellite imagery and derived landcover products provides a reasonable method for assessing of pine vs. hardwood canopy composition. However, small scale, regional or statewide LIDAR data acquisitions are typically collected at a posting density of one return per 5 m^2 or less. Therefore, at these coarser posting densities, it is not possible to identify individual stem locations from which one can infer diameter at breast height (DBH) and basal area for different pine size classes.

Figures 1–4 show examples of top of canopy terrain developed from high density LIDAR data (4.0 returns/m^2) used in a previous study (Tweddale et al. 2008) and coarser, statewide LIDAR data (1.0 return/5 m^2) used in this research. These examples are not for the same area, as statewide, all return LIDAR data that correspond to the case study area were not available. However, the figures do provide a comparison of similar forest conditions. The figures include both 2-D and 3-D perspectives. In the high density data (Figures 2 and 4), individual tree canopies can be identified. In the lower density LIDAR data (Figures 1 and 3), individual tree canopies are difficult to discern. These examples are taken from relatively open canopy forest.

Delineation of individual tree canopies becomes more difficult as canopy closure increases. Therefore, mean predominant canopy height for large geographic regions such as the study areas in this research must be estimated from the LIDAR derived canopy terrain models derived from large footprint, lower sampling density LIDAR data, and must be used as a surrogate measure of the mean height of individual stems. Using mean predominant canopy height estimates, it is possible to estimate relative age of stands using height-age relationships for a given site index. However, it is not possible to assess midstory structure with large footprint, lower sampling density LIDAR data, as the proportion of returns that penetrate the canopy will be greatly decreased.



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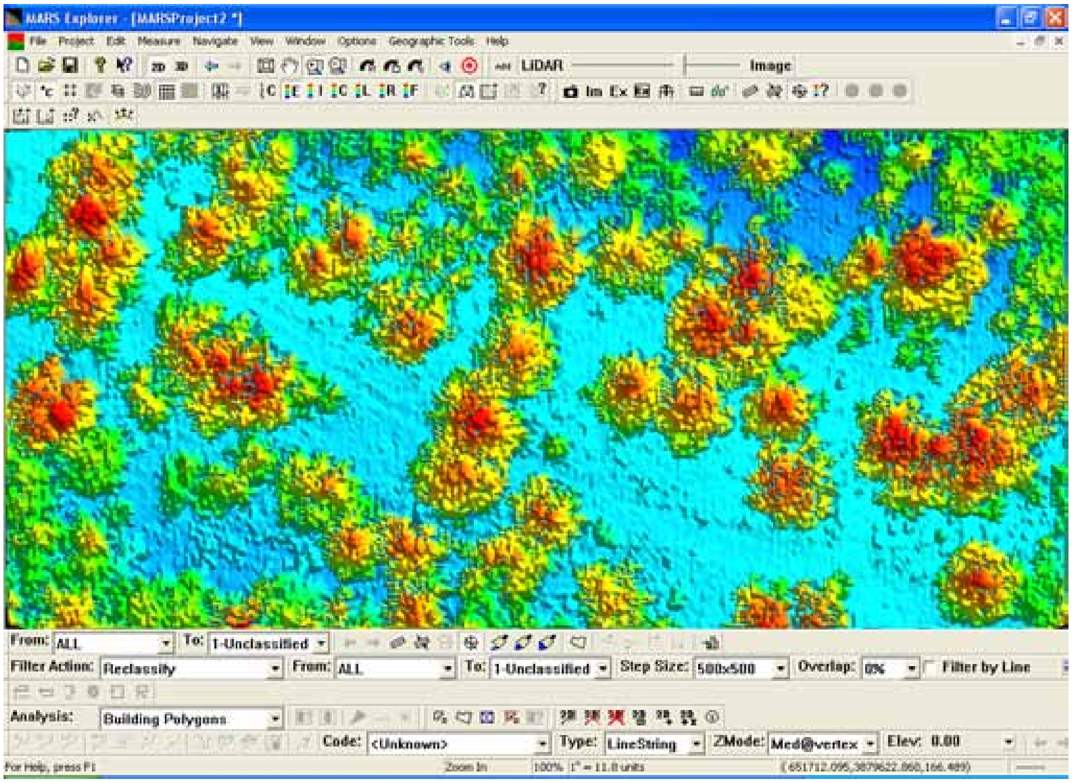
26% 1" = 27.4 units

Figure 1. Top of canopy digital terrain model (DTM) from statewide, large footprint, lower sampling density LIDAR data provided by the North Carolina Floodplain Mapping Program.



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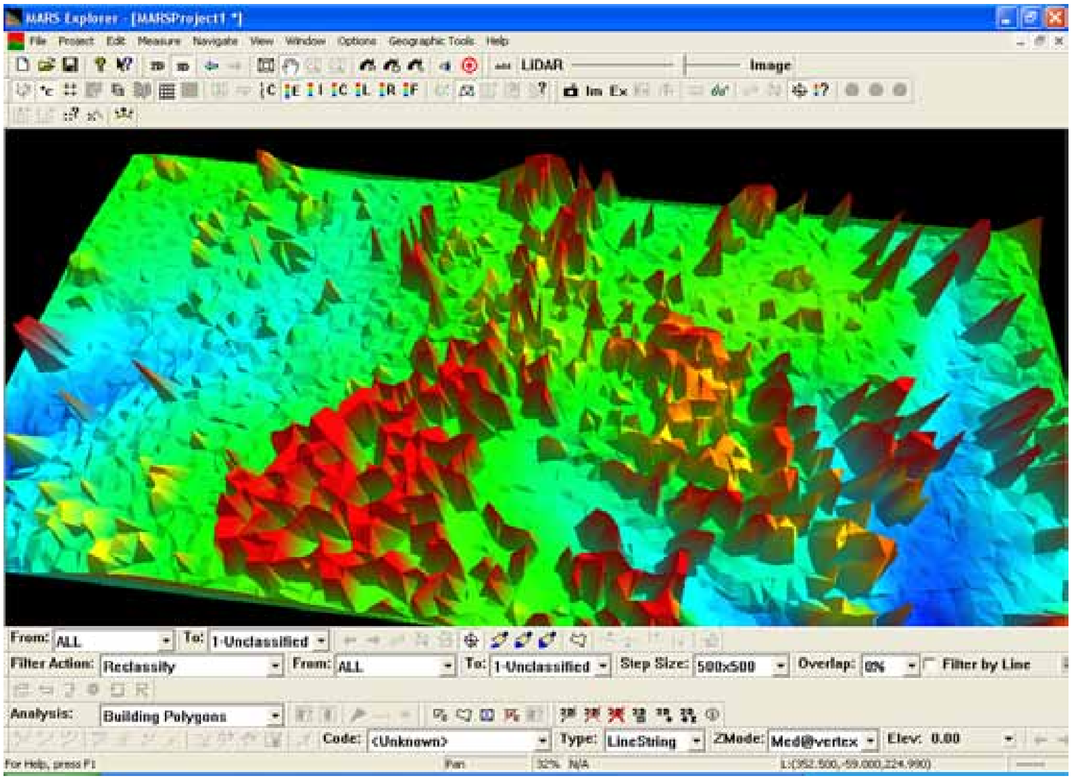
100% 1" = 11.8 units

Figure 2. Top of canopy DTM from small footprint, higher sampling density LIDAR data.



MARS Explorer - [MARSProject1 *]

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Elev: 0.00
For Help, press F1
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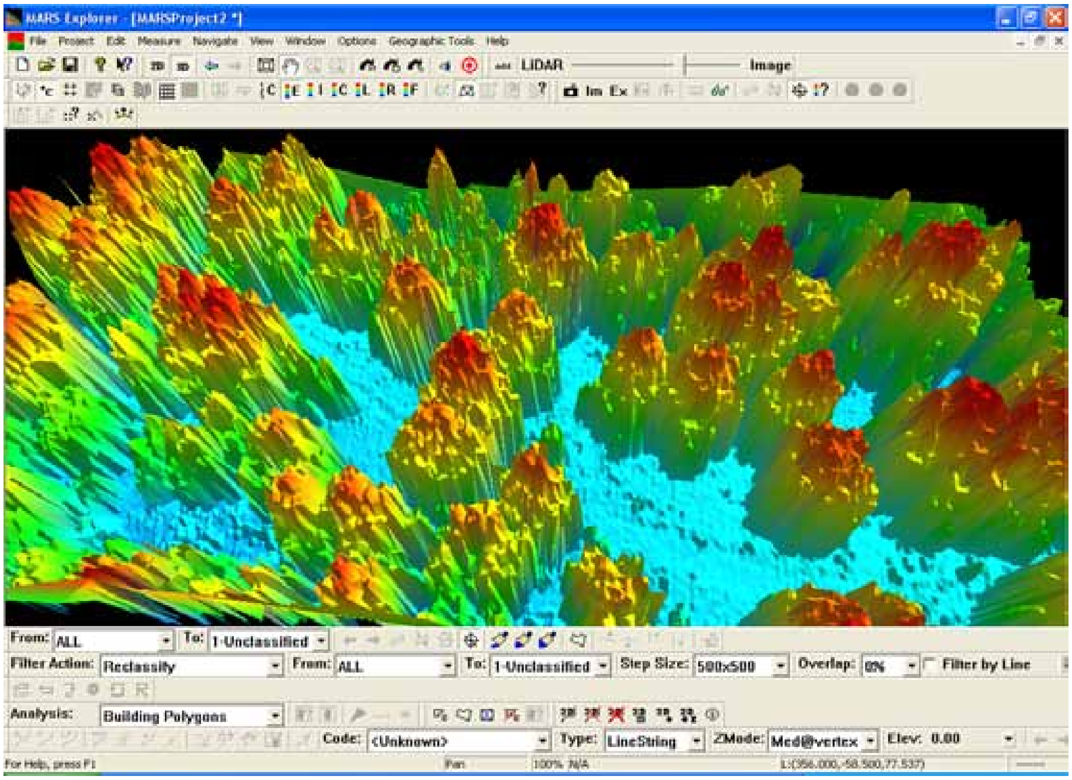
Figure 3. Top of canopy DTM from statewide, large footprint, lower sampling density LIDAR data provided by the North Carolina Floodplain Mapping Program (3-D perspective).



MARS Explorer - [MARSProject2 *]

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To: 1-Unclassified
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Type: LineString
ZMode: Med@vertex
Elev: 0.00
For Help, press F1
Pan
100% N/A
L:(356.000,-58.500,77.537)

Figure 4. Top of canopy DTM from small footprint, higher sampling density LIDAR data provided by ERDC-CERL and used in the case study (3-D perspective).

3 Methods

Study area

Regional study areas were delineated around Fort Bragg, NC and Camp Lejeune, NC by establishing a 5 km buffer around each installation to include all known locations of active RCW cavity trees. The resulting study area for Fort Bragg was approximately 5484 km^2, and the study area for Camp Lejeune was approximately 8404 km^2 (Figure 5).

Pine forest delineation

National Landcover Data (NLCD 2001) (www.epa.gov/mrlc/nlcd-2001.html) and Gap Analysis Program (GAP) analysis landcover data for North Carolina (McKerrow, Wentworth, and Cheshire, in prep), which is a derivative product of the NLCD, were extracted for both study regions and the extent of pine forest was delineated. The GAP landcover data are similar to the NLCD data, but have been altered to reflect local conditions and incorporates local knowledge with respect to landcover conditions. Comparison between NLCD and GAP landcover products indicated that GAP landcover provided a more detailed breakout of pine forest types. For this reason, GAP landcover data were selected for analysis.

Specific GAP landcover categories that were identified as ”pine forest” for the Fort Bragg and Camp Lejeune study areas were reclassified into a single pine forest category. Figures 6 and 7 show the original GAP landcover categories that were grouped into the “pine forest” category. Individual pine forest patches less than 0.5 ha were eliminated from the analysis. After removal of forest patches less than 0.5 ha, 12,349 individual pine forest patches were identified in the Fort Bragg study area and 18,081 were identified in the Camp Lejeune study area.

LIDAR data

The North Carolina Floodplain Mapping Program (www.ncfloodmaps.com), which is a partnership and cooperative program with the State of North Carolina and the Federal Emergency Management Agency (FEMA), was developed to produce updated, accurate, statewide flood hazard data, floodplain mapping, and Digital Flood Insurance Rate Maps (DFIRMS).

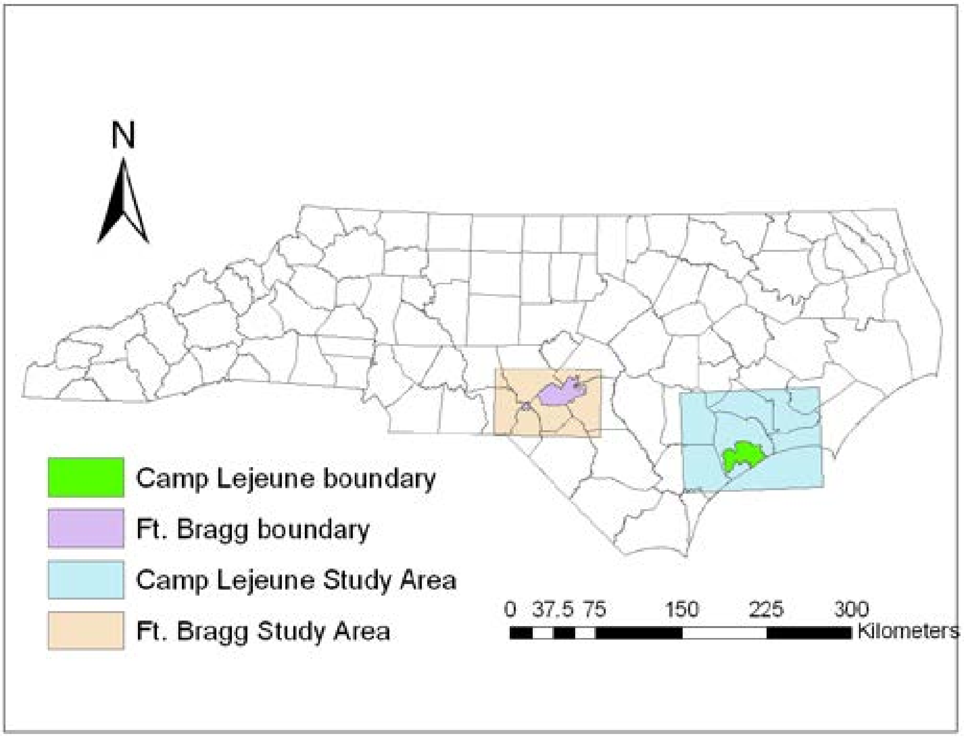

Figure 5. Fort Bragg, NC and Camp Lejeune, North Carolina study areas.

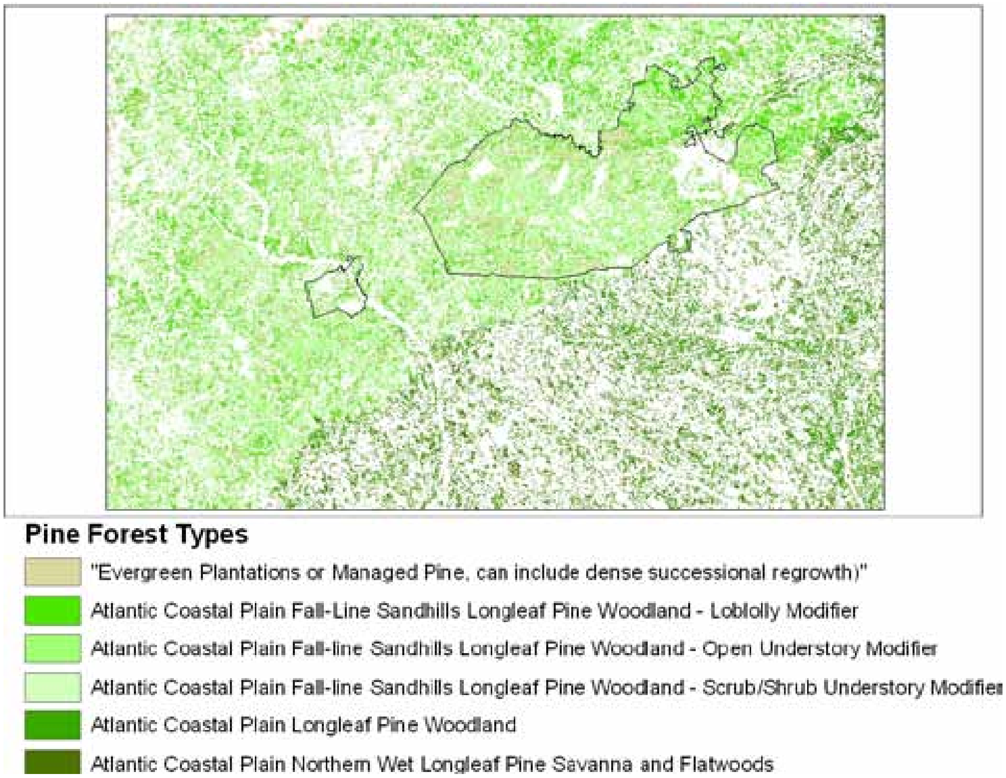

Figure 6. Individual pine forest patches extracted from GAP landcover for Fort Bragg study area.

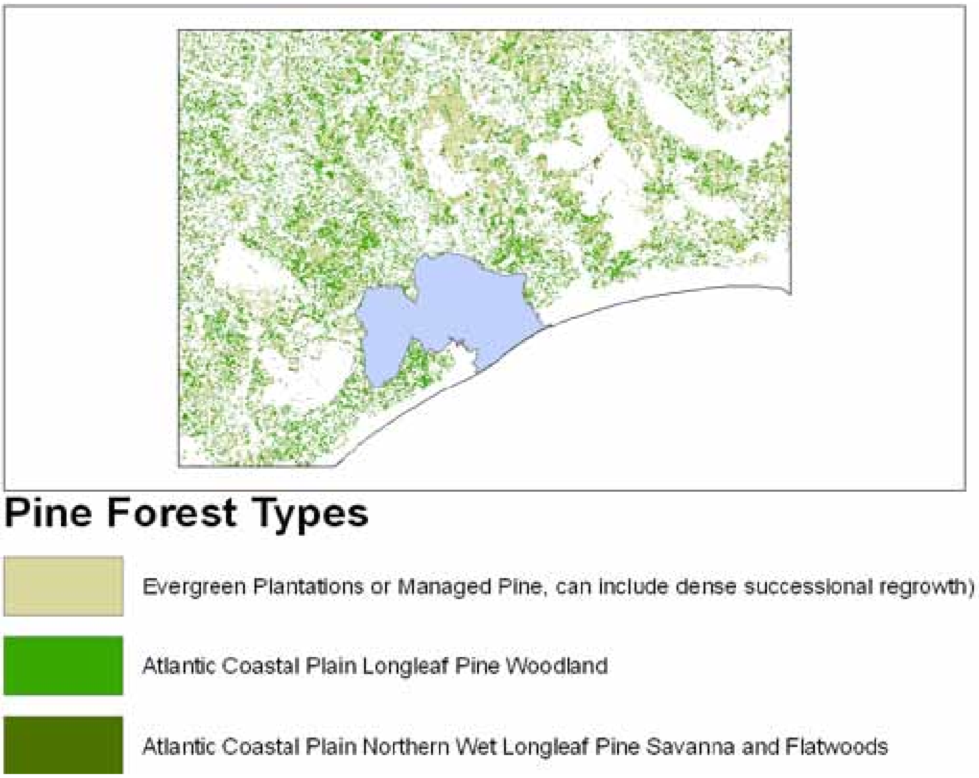

Figure 7. Individual pine forest patches extracted from GAP landcover for Fort Bragg study area.

As part of this multi-year effort, statewide coverage of high resolution (20 ft/6.1 m resolution) and accurate Digital Elevation Models (DEMs) of bare earth terrain have been created from LIDAR data collected in 2001. LIDAR data collection was divided into three phases: Phase I was defined by six eastern river basins; Phase II was defined by five central river basins; and Phase III was defined by six western river basins. LIDAR data were collected with a nominal point spacing of 5 m.

The primary objective of the LIDAR data collection was to use the data to derive high resolution and accurate DEMs of bare earth terrain. Several private LIDAR vendors were contracted to acquire LIDAR data and to post-process the data to identify and differentiate between individual LIDAR returns that intercepted the ground vs. those returns that intercepted features above ground, including natural vegetation and manmade structures. Although this was an automated process, automated procedures may still result in misclassification of some returns. Therefore, significant manual editing was required by private LIDAR vendors to accurately identify all LIDAR ground returns. Using all LIDAR ground returns as input, surfacing algorithms were used to create a bare earth surface from the LIDAR ground returns. Statewide coverage of bare earth DEMs have been produced from LIDAR data and were acquired from the North Carolina Floodplain Mapping Program.

Bare earth DEMS were stored and made available in tiles of 10,000 X 10,000 ft. There are 649 full or partial bare earth tiles within the Fort Bragg study area and 976 full or partial bare earth tiles within the Camp Lejeune study area. Originally, bare earth DEM tiles were acquired in an American Standard Code for Information Interchange (ASCII) format and were imported to an Environmental Systems Research Institute, Inc. (ESRI) grid format. For many of the tiles, multiple versions of the same tile were available. Manual inspection of these tiles was necessary because only one of the versions was the complete and correct version, and it was not possible to determine which was the correct version from the tile naming scheme.

In addition to these bare earth DEM products, all LIDAR returns, including both ground and non-ground, were also acquired from the North Carolina Floodplain Mapping Program. The all return LIDAR data have not been used to produce a Digital Terrain Model (DTM) of the top of canopy surface because this was not a primary objective of the North Carolina Floodplain Mapping Program. Therefore, a DTM of the top of canopy surface was created in this research using the all return LIDAR data.

All return LIDAR data were stored in a variety of spatial configurations, depending on which data collection phase and which LIDAR vendor was used to acquire and process the data. The Fort Bragg study area is located primarily in the Phase I collection area, but the western edge of the study area extends into the Phase II collection area. For the area of Fort Bragg that is located in Phase I, there were 240 tiles of all return LIDAR data. Each tile is 25 km^2. Phase II all return LIDAR data were stored in individual flight lines rather than tiles (Figure 8). Each individual Phase II all return LIDAR flightline varied in size and orientation.

The Camp Lejeune study area is located within the Phase I collection area. Some Phase I all return LIDAR data were stored and provided in individual tiles, while some data were stored in flightlines of varying size and orientation. Within the Camp Lejeune study area, there were 167 all return LIDAR tiles and 74 individual all return LIDAR flightlines of varying size and orientation (Figure 9).

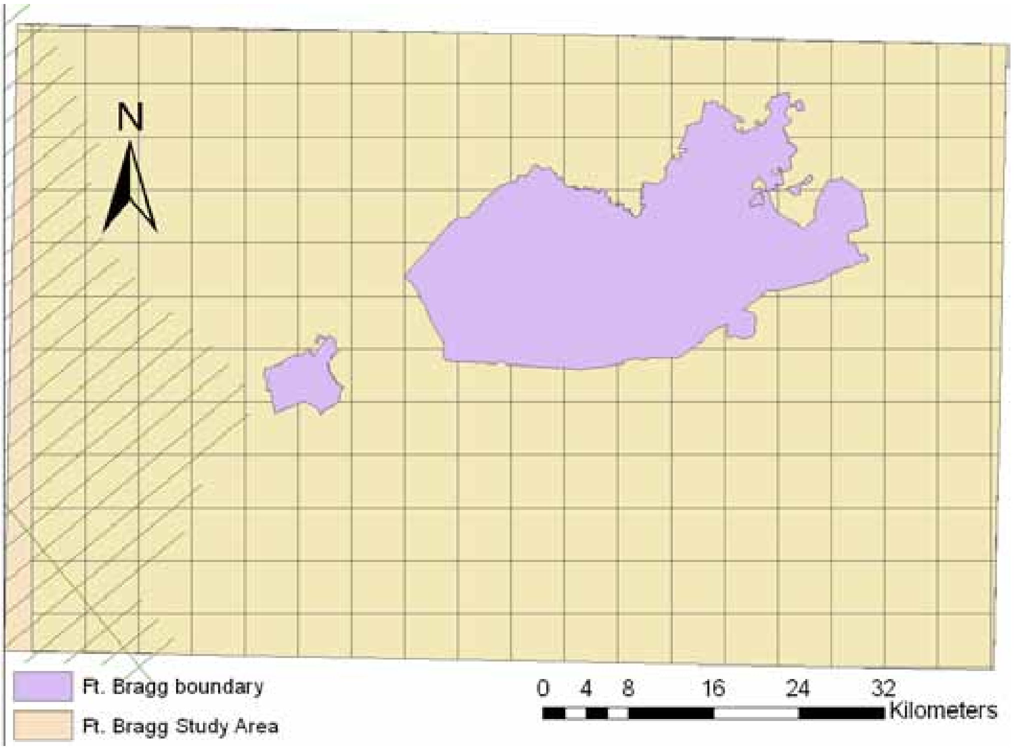

Figure 8. Individual tiles and flightlines containing all return LIDAR data for the Fort Bragg study area.

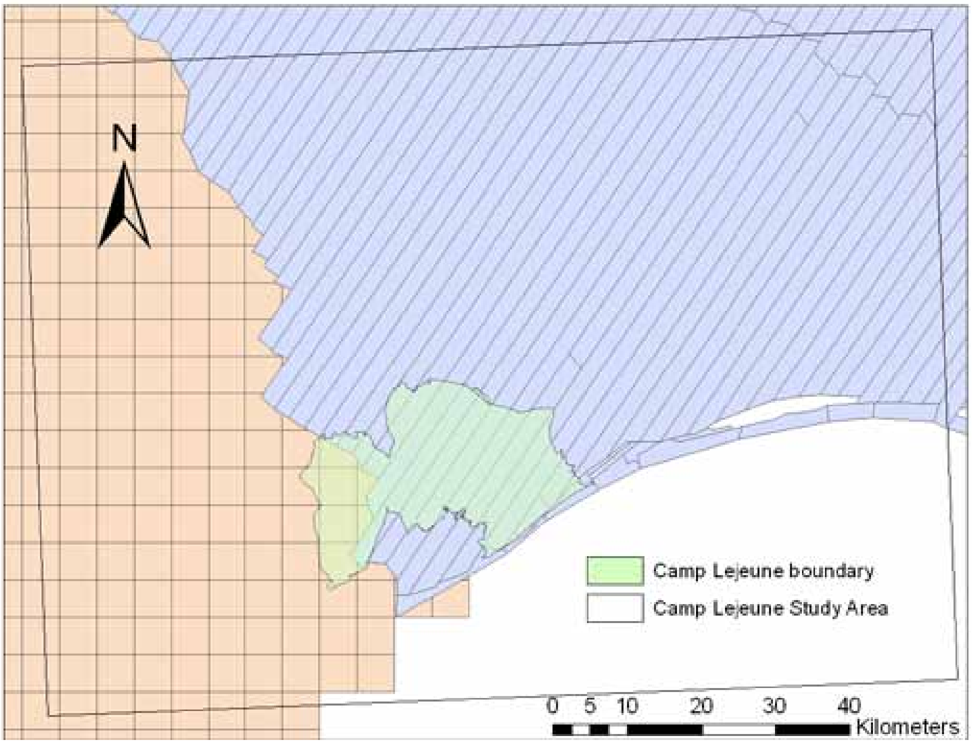

Figure 9. Individual tiles and flightlines containing all return LIDAR data for the Camp Lejeune study area.

The primary projection for the statewide North Carolina Floodplain Mapping Program LIDAR data was North Carolina State Plane Feet. However, for both study areas, some tiles and flightlines used North Carolina State Plane Meters. Therefore, each tile was manually inspected to determine projection and units and all data were ultimately projected to a Universal Transverse Mercator (UTM) [coordinate system] projection, NAD83 datum.

Forest height estimation

In this research, canopy height estimates for individual pine forest patches that provide potentially suitable RCW habitat were estimated from statewide LIDAR data collected by the North Carolina Floodplain Mapping Program. Two methods for estimating predominant canopy height from available LIDAR data were evaluated and tested using a test area within Fort Bragg where Fort Bragg forest inventory data were available. The first method used a DTM of top of canopy surface that was created from the all return LIDAR data and a matching DEM of bare earth surface that was provided by the North Carolina Floodplain Mapping Program. The difference in elevation between these two surfaces was used to estimate predominant canopy height. Specifically, bare earth elevations from DEMs were subtracted from elevations of the top of canopy surface DTM. Top of canopy DTMs were created from the all return LIDAR data using surfacing algorithms. The top of canopy DTMs were created at a spatial resolution of 20 ft or 6.1 m to match the spatial resolution of bare earth Deems provided by the North Carolina Floodplain Mapping Program.

The all return LIDAR tiles and flightlines used to create the top of canopy DTMs were large datasets that contained a record for each individual recorded LIDAR pulse. Standard geographic information system (GIS) software such as ESRI geospatial products is not optimized to analyze extremely large LIDAR datasets. Therefore, specialized software developed to process and analyze LIDAR data efficiently was used to create top of canopy DTMs. Both QTModeler, from Applied Imagery LLC and Merrick Advanced Remote Sensing (MARS) LIDAR Software System, developed by Merrick & Co. were evaluated for this purpose. Each has similar surfacing algorithms and provides a method to export surfaces to ESRI GRID format. MARS software was selected for final analysis.

Once each tile was surfaced, they were mosaicked to create a single top of canopy DTM for the test study area. Using raster map calculator utilities, the bare earth DEM was subtracted from the top of canopy DTM for the study area to produce a canopy height above ground surface. All canopy heights < 2.0 m above ground were masked from this surface to eliminate low shrub and small saplings. Similar to previous studies, a local maximum filtering algorithm was applied to identify local maximums in the canopy height surface, which were presumed to be individual stem locations (McCombs et al. 2003, Popescu and Wynne 2004). In previous studies, small footprint LIDAR data were used to create canopy surfaces, and therefore there was a higher probability that local maximums were representative of individual stem locations. With large footprint LIDAR data such as the data analyzed in this research, it was known that it would be difficult to discern individual stems from local maximums in the canopy height above ground surface. However, a local maximum filter was still applied to eliminate pixels in the canopy height surface that were most likely on the canopy shoulders rather than on crown peaks. For each pine forest patch identified in the NLCD/GAP landcover classification that was >0.5 ha in size, mean predominant canopy height was determined by calculating the mean canopy height above ground surface for all canopy height pixels identified as local maximums within the forest patch.

A second method used only the original, all return LIDAR data collected by the North Carolina Floodplain Mapping Program. This data included individual returns that were identified as ground returns and used to create the bare earth DEMs and also individual returns that intercepted above ground vegetation. Instead of creating a separate canopy and bare earth surface as described for Method 1, a program in Geographical Resources Analysis Support System (GRASS) was used to overlay an arbitrary 15 m grid over the all return data. For each grid cell, the minimum and maximum individual return heights were subtracted to estimate predominant canopy height for each grid cell. This method eliminated the need to create separate surfaces of bare earth and canopy. Similar methods have been used to estimate forest height at plot and stand scales using higher sampling density LIDAR data for smaller study areas, but such an approach has not been applied to coarser LIDAR data across a study region comparable in size to the study area in this research (Nelson et al. 1988, Naesset 1997a., Naesset 1997b., Magnussen and Boudewyn 1998, Naesset and Bjerknes 2001). A predominant canopy height surface was created for each individual tile or flightline of LIDAR data within the test area at Fort Bragg. Similar to Method 1, all canopy heights < 2.0 m above ground were masked from this surface to eliminate low shrub and small saplings.

4 Forest Height Validation Results

Forest inventory and stand data collected at Fort Bragg, NC in 2001 and 2002 was used to validate estimates of predominant canopy height derived from LIDAR analysis. Mean height for each forest stand within Fort Bragg was calculated using data from the individual stem inventory. However, for many of the stands, individual stem heights were only measured for one or two stems. Therefore, these data were not an ideal dataset for validating estimates of predominant canopy height as it was not an accurate measurement of mean predominant canopy height due to the extremely small sample size. It would have been desirable to use accepted field measurement protocols for measuring predominant stand height (Naesset 1997a, Naesset and Bjerknes 2001, Naesset 2002). However, the forest inventory data were the only archival field data collected at approximately the same time as the LIDAR data. These data were therefore used as a validation dataset.

A preliminary assessment of both methods with a limited number of forest stands indicated that both methods provided reasonable estimates of predominant stem height. Method 1, which requires significantly more data processing because of the need to create two separate surfaces (bare earth DEM and top of canopy DTM), tended to underestimate heights, while Method 2 appeared to produce more accurate results.

A more rigorous assessment of LIDAR-derived estimates of mean predominant canopy height using Method 2 was completed for 383 forest stands on Fort Bragg, NC. Forest stands that occurred within areas where LIDAR data were not processed or where LIDAR data contained errors were removed from the validation set. Standard linear regression of field measured mean stand height with LIDAR-derived estimates of predominant stand height resulted in a coefficient of determination (R^2) = 0.70 (Figure 10). There was a slight bias that resulted in an underestimation of mean predominant canopy height derived from LIDAR data.

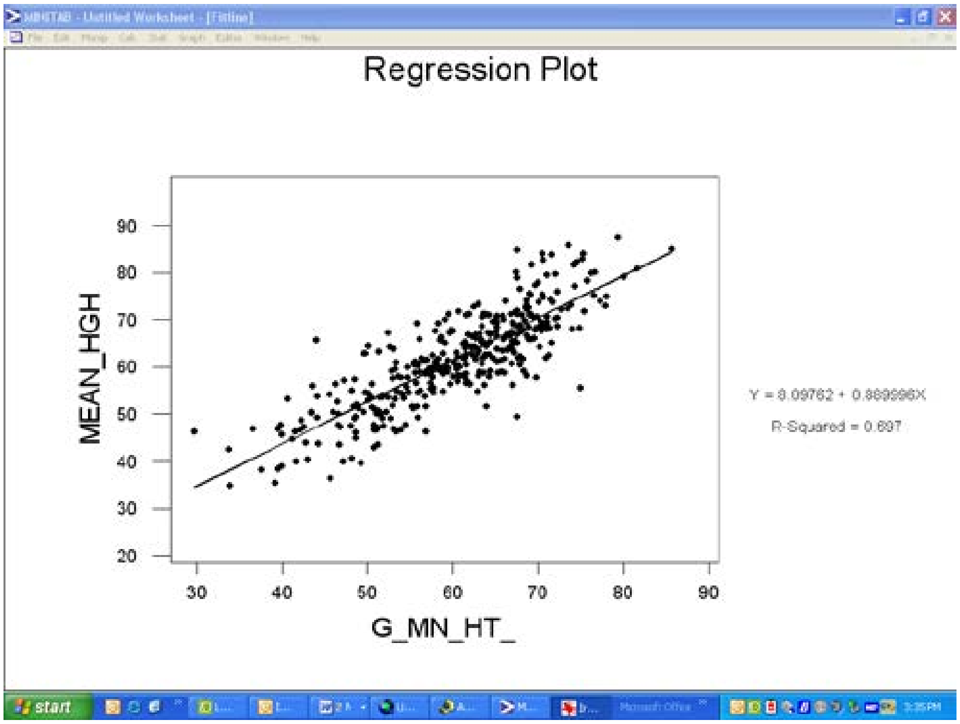

Figure 10. Best fit regression line between LIDAR-derived estimates of mean predominant stand height (G_MN_HT) and field measures of mean stand height (MEAN_HGH).

Based on the validation results and given the fact that it produced comparable preliminary results and that it was a more efficient method for estimating predominant height that required less data processing, Method 2 was adopted as the method for estimating predominant canopy height for stands across both study areas. Therefore, all remaining individual tiles and flightlines were then mosaicked to create a single canopy height surface for each study area using Method 2 (Figures 11 and 12).

Each tile and flightline was visually inspected to assess the quality of the LIDAR data and those tiles or flightlines containing erroneous data were removed from analysis. Larger gaps visible in the canopy height surface represent areas of erroneous LIDAR data or large water bodies that do not produce a LIDAR return. Several tiles internal to Fort Bragg were intentionally omitted to reduce data-processing time, as RCW habitat potential in these areas has already been characterized with field data. However, some tiles within Fort Bragg were processed for validation purposes.

For each forest patch identified in the NLCD/GAP landcover classification that was > 0.5 ha in size, mean predominant canopy height was determined by calculating the mean canopy height above ground surface for all canopy height pixels within the forest patch using Method 2.

Figure 11. Canopy height DTM for all canopy height pixels > 2.0 m in height for the Fort Bragg study area.

Figure 12. Canopy height DTM for all canopy height pixels > 2.0 m in height for the Camp Lejeune study area.

5 Conclusions

This work concludes that LIDAR-derived estimates of predominant stand height were acceptable given the unique limitations associated with the scale of the data analyzed and the extent of the area studied. The LIDAR data acquired from the North Carolina Floodplain Mapping Program were collected with a larger footprint and lower sampling density, which precludes the ability to identify individual stems. Therefore, mean predominant height for individual pine forest patches was estimated from the LIDAR derived predominant canopy height surface rather than deriving estimates from the mean height of individual stems identified with LIDAR data. A canopy height surface characterizes the entire canopy profile, including the shoulders of canopies and canopy overlap areas and not just the crown apexes (Nelson et al. 1988, Zimble et al. 2003, Lee and Lucas 2007, Vega and St. Onge 2008).

Although local maximum filters were used to eliminate canopy height surface pixels that did not represent stem peaks in Method 1, it was still recognized that the larger footprint and lower sampling density LIDAR data were not sufficient to delineate individual crown peaks. Method 2 located the maximum return height within a 15 m cell, and therefore was also functioning as a pseudo local maximum filter, with the assumption that the highest return in each 15 m cell should represent a crown apex or individual stem. Again, because of the LIDAR sampling density, many of these returns were most likely not intercepting the top of stems, but rather somewhere on the side or shoulder of the canopy. Therefore, the lower sampling density resulted in a bias towards underestimating canopy heights using both methods.

Previous studies have demonstrated that even with smaller footprint, higher sampling density LIDAR data, LIDAR-derived estimates of canopy height typically underestimate heights due to the fact that some local maximums in canopy height DTMs or maximum individual LIDAR return heights within an arbitrary sampling grid are assumed to be crown apexes when in fact they are often the sides of canopies (Nilsson 1996, Magnussen et al. 1999, Naesset 2002, Gaveau and Hill 2003). This known bias was likely magnified by the larger footprint, lower sampling density LIDAR data analyzed in this study. Errors associated with bare earth DEMs derived from LIDAR data also can result in an underestimation of canopy height

(Reutebuch et al. 2003). A second limitation was the lack of suitable ground validation data. The limited sample size of field measured individual stem heights was not suitable for calculating an arithmetic mean stem height, or mean dominant or predominant height for each stand.

Despite these concerns, the method used to estimate predominant height across large geographic areas with coarse resolution LIDAR data produced useful results for assessing general RCW habitat conditions across the region. The total size of the study area necessitated the use of large footprint, statewide-scale LIDAR data. An assessment of such a large area with small footprint, higher sampling density LIDAR data has never been accomplished because it would be too cost prohibitive in terms of data acquisition and data-processing requirements. However, the method used in this research to assess forest stand height at a regional scale was more efficient because estimates could be derived directly from the all return data and did not require the development of a top of canopy DTM surface over such a large area, which greatly reduced data-processing requirements. Although the method used would require some modification if it were applied in areas of significant topographic relief, it does present a feasible method that produces reasonable estimates of forest stand height from small scale LIDAR data over large geographic areas.

Acronyms and Abbreviations

Term	Spellout
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
CERL	Construction Engineering Research Laboratory
DBH	diameter at breast height
DEM	digital elevation model
DFIRMS	Digital Flood Insurance Rate Maps
DSS	Decision Support System
DTM	digital terrain model
ERDC	Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
ESRI	Environmental Systems Research Institute, Inc.
FEMA	Federal Emergency Management Agency
GIS	geographic information system
GRASS	Geographic Resources Analysis Support System
ISPRS	International Society for Photogrammetry and Remote Sensing
LIDAR	Light Detection and Ranging
MARS	Merrick Advanced Remote Sensing
NLCD	National Land Cover Data
GAP	Gap Analysis Program
NSN	National Supply Number
OMB	Office of Management and Budget
RCW	Red-cockaded Woodpecker
SERDP	Strategic Environmental Research and Development Program
TR	Technical Report
UTM	Universal Transverse Mercator

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14. ABSTRACT

Use of spatially explicit Red-cockaded Woodpecker (RCW) population models to determine the habitat potential and conservation value of land parcels requires coupling of such models with actual landscape features on the ground. Development of spatially explicit maps that characterize forest metrics across a regional or landscape scale with Light Detection and Ranging (LIDAR) data is cost prohibitive, both in terms of data acquisition and analysis. Small scale, regional assessment of RCW habitat potential must be completed using regional, statewide, or national scale remotely sensed data sources. Therefore, assessment of forest structure at regional scales requires the use of larger footprint, lower sampling density LIDAR data and coarser resolution multispectral imagery. This research demonstrates the use of multispectral imagery and LIDAR data on a statewide and national scale to estimate mean predominant stand height for pine forest stands in the regions surrounding Fort Bragg, NC and Camp Lejeune, NC.

15. SUBJECT TERMS

remote sensing data, LIDAR, red-cockaded woodpecker, habitat, natural resource management, Ft. Bragg, NC, Camp Lejeune, NC

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