Determining Tree Canopy Height of Mangrove Forests in Chiapas, Mexico via the Analysis of Airborne LiDAR Data

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Introduction

The goal of this project was to determine how the tree canopy heights of mangrove forests vary in relation to archaeological mound sites found in southern coastal Chiapas, Mexico (Figure 1) using Light Detection and Ranging (LiDAR) data. LiDAR is a remote sensing technique that uses pulsed lasers to measure distances by generating precise, three-dimensional information about the shape of the Earth and its surface characteristics. Processed LiDAR imagery show that the study area has a high density of archaeological mound sites, indicating that human impacts have been substantial and have left a permanent signature on the land surface. The mounds date to about 3500 BC and suggest that humans had been engineering the mangrove zone through pyro-industrial activities such as salt and ceramic production, which would have required intensive harvesting of wood for fuel. These dominant activities would have had consequent impacts on the surrounding forest resources.

Figure 1. *Study Area – Southern Coastal Chiapas, Mexico*

Data and Data Sources

The raw LiDAR data and the point data of Mound Sites were both provided by Dr. Hector Neff, Professor of Archaeology in the Anthropology Department at California State University, Long Beach. The LiDAR data was stored in LAS Datasets. A file geodatabase was created to store and manage all processed raster and vector data.

Dataset	Source
LiDAR Data	Acquired from the Airborne 1 Corporation
Point Data of Mound Sites	Provided by Dr. Hector Neff

Table 1. *List of data and data sources used in the project*

Parameters of the LiDAR data

- Flight Date – April 29, 2011
- Julian Date – 119
- Type of Scanner – Riegl VQ 480
- Scanner Angle – 600
- Scanner Frequency – 100 khz
- GPS / IMU – SPAN-SE (Glonass available) / LN200
- Software: Grafnet 8.20 / Inertial Explorer 8.30
- Resolution: 1 meter
- Accuracy: 0.30 meter horizontal, 18.3 cm vertical at 95% confidence
- Coordinate Projection: WGS 1984 UTM Zone 15N

Methodology

Raw LiDAR data (.las files) for both the first return and ground return points were stored and managed in newly created LAS datasets by using the '*Create LAS Dataset*' tool in ArcGIS.

To determine canopy height from the LAS datasets, raster images were created from the first return surface – Digital Surface Model (DSM), and the ground return – Digital Elevation Model (DEM), with the '*LAS Dataset to Raster*' tool.

The Canopy Height Raster was calculated by using the 'Minus' tool to subtract the DSM from the DEM. A hillshade was created from the DEM using the 'Hillshade' tool to visualize the archaeological mound sites on the bare earth.

These processes are outlined in the spatial model (Figure 2).

The tree canopy raster was displayed with 40% transparency over the hillshade showing how the tree canopy heights vary in relation to each archaeological mound site.

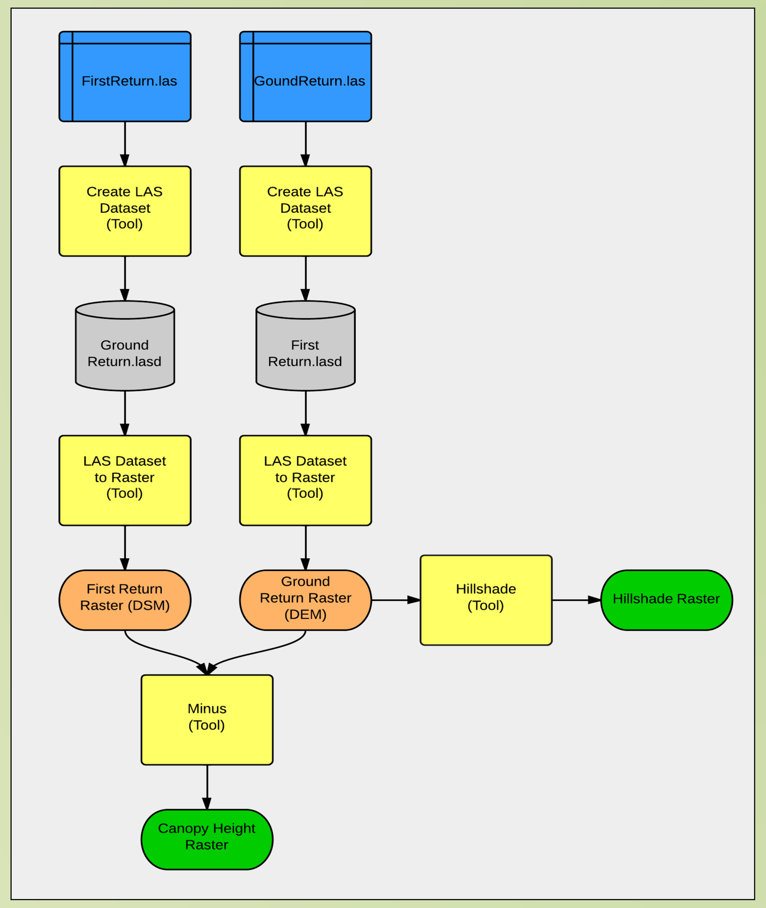

Figure 2. *Spatial Model Used to Calculate Tree Canopy Height and Create Hillshade*

Timeline

Summary Milestone Schedule	
Project Milestone	**Target Date**
Acquire Data	06/25/2014
Data Analysis and Processing	06/26/2014
Data Sources and Methodology	07/17/2014
Literature Review	07/24/2014
Peer Review	08/01/2014
Cartographic Output	08/06/2014
Project Poster	08/09/2014
Conclusions and Abstract	08/13/2014
Project Report	08/15/2014
Project Presentation	08/16/2014

Table 2. *Project Timeline*

Results

Using Data Driven Pages, a 202-page map book was produced that displays each of the 202 identified archaeological mound sites with the surrounding forest canopy height in the proximate area (Figure 3).

Additionally, using ArcScene, a 3D visualization of the study area's DEM, DSM, and tree canopy heights were created (Figure 4A, 4B, 4C).

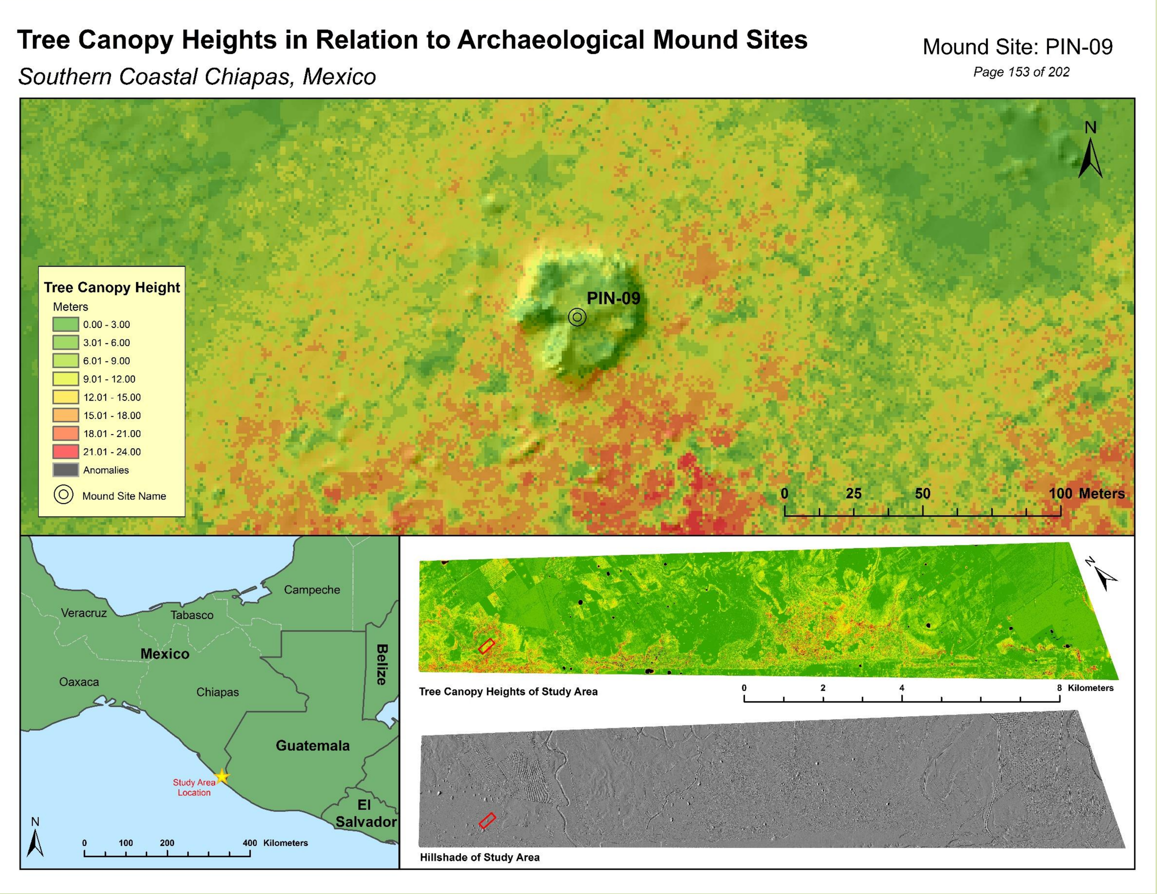

Figure 3. *A Data Driven Page from the Produced Map Book*

Figure 4A. *3D Visualization of Digital Elevation Model (DEM)*

Figure 4B. *3D Visualization of Digital Surface Model (DSM)*

Figure 4C. *3D Visualization of Tree Canopy and Mounds*

Discussion

From the analysis, it was observed that the tree canopy layer is generally lower in height in relation to their locations on archaeological mound sites compared with the rest of the terrain. The LiDAR data shows that there is very little to no presence of mangrove trees that grow on top of these specific mound sites (Figure 3 and Figure 4A-C).

The images produced from the map book of the tree canopy heights were classified using 8 classes. However, there were extreme values that did not accurately produce correct results. Any values that were negative and greater than 24 meters were excluded from the 8 classes and given its own classification as "*Anomalies*". Negative values are considered errors and the upper threshold was set at 24 meters because mangroves typically do not grow greater than 24 meters in height.

The 3D images provide a unique way to visualize the terrain and tree canopy layers. However, because there is little variation in elevation, the representation is not as dynamic as I hoped for. Additionally, there were limitations to hardware capabilities when processing the 3D images in ArcScene. The DSM and DEM were only able to be processed at a 4 meter cell size resolution, opposed to the original 1 meter cell size, thus image results were derived at a coarser grid cell resolution.

Conclusion

Mangrove tree growth height in Chiapas, Mexico can be affected by a number of different environmental factors, both biotic and abiotic. From the analysis of the LiDAR data, it was observed that most of the archaeological mound sites have little to no substantial tree growth on them. Though further study needs to address this issue, it can be assumed that historical human activity from past civilizations did have an impact on the land and mangrove health, particularly with salt production that required extensive harvesting of forest resources.

Potential future work includes in-situ studies that can provide additional data examining different variables. For example, measurements such as diameter at breast height (DBH) is necessary for determining vegetation biomass, which can be used to analyze the carbon storing potential of forests which affect greenhouse gas and climate change studies. Experts in the fields of archaeology, anthropology, and biology can work together to determine the accurate cause of tree canopy height variations in the study area.

From a geospatial perspective, future improvements to this project include the use of more capable computer hardware that is better able to process the visualization the 3D images of DEMs and DSMs at higher spatial resolutions.

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