

Extraction of Forest Plantation Resources in Selected Forest of San Manuel, Pangasinan, Philippines Using LiDAR Data for Forest Status Assessment

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Abstract—Forest inventories are essential to assess the composition, structure and distribution of forest vegetation that can be used as baseline information for management decisions. Classical forest inventory is labor intensive and time-consuming and sometimes even dangerous. The use of Light Detection and Ranging (LiDAR) in forest inventory would improve and overcome these restrictions. This study was conducted to determine the possibility of using LiDAR derived data in extracting high accuracy forest biophysical parameters and as a non-destructive method for forest status analysis of San Manuel, Pangasinan. Forest resources extraction was carried out using LAS tools, GIS, Envi and .bat scripts with the available LiDAR data. The process includes the generation of derivatives such as Digital Terrain Model (DTM), Canopy Height Model (CHM) and Canopy Cover Model (CCM) in .bat scripts followed by the generation of 17 composite bands to be used in the extraction of forest classification covers using ENVI 4.8 and GIS software. The Diameter in Breast Height (DBH), Above Ground Biomass (AGB) and Carbon Stock (CS) were estimated for each classified forest cover and Tree Count Extraction was carried out using GIS. Subsequently, field validation was conducted for accuracy assessment. Results showed that the forest of San Manuel has 73% Forest Cover, which is relatively much higher as compared to the 10% canopy cover requirement. On the extracted canopy height, 80% of the tree's height ranges from 12 m to 17 m. CS of the three forest covers based on the AGB were: 20819.59 kg/20x20 m for closed broadleaf, 8609.82 kg/20x20 m for broadleaf plantation and 15545.57 kg/20x20m for open broadleaf. Average tree counts for the tree forest plantation was 413 trees/ha. As such, the forest of San Manuel has high percent forest cover and high CS.

Keywords—Carbon stock, forest inventory, LiDAR, tree count.

I. INTRODUCTION

FORESTS are one of the most important natural resources of the Philippines. It plays vital ecosystem functions to a healthy environment such as water and air purification, prevents soil erosion and plays a major role in climate change mitigation as healthy forest is a major carbon sink. But in the latest study of the Philippine Tropical Forest Conservation

Foundation, Inc, about 755,000 x 10⁴ square meters are still unclassified and the use of these forest areas has not yet been determined. In fact, two thirds of the country's total land area was designated as forest areas [1]. From the 2001-2003 satellite imageries of the National Mapping and Resource Information Authority (NAMRIA), the estimation of actual forest coverage is at 7.168 million x 10⁴ square meters or 24.27% of the country's total land area [2]. From then on, the need to conduct more studies towards the classification of the Philippine's forest cover as well as the forest inventory was recognized to provide more data in the Philippine forests and detailed forest resources database. Forest inventories are designed to measure the extent, quantity, composition, and condition of forest resources [3].

Countries all over the world are requested to provide data and estimates for forest areas [4]. The emerging method for estimating forest areas and resources is through LiDAR surveys due to its data accuracy and non-destructive method of estimation. Forest characterization with LiDAR data has recently garnered much scientific and operational attention. However, the number of forest inventory attributes that may be directly measured with LiDAR is limited; but, when considered within the context of all the measured and derived attributes required to complete a forest inventory, LiDAR can be a valuable tool in the inventory process [5].

In this paper, researchers presented the forest inventory, using different parameters for Forest Resources Extraction from LiDAR Surveys. LiDAR derivatives used in the study determine the level of terrain in the forest area, intensity of vegetation in the area and the canopy height of trees. On the other hand, classification of forest cover determines the different forest covers present in the area as well as the corresponding area of each cover type. DBH of trees, as well as AGB are important in CS determination. CS estimation enables us to assess the amount of carbon that a forest can store when a forest is generated, as well as the carbon loss if the forest will be deforested. Lastly, Tree Count Extraction allows us to assess the number of trees present in the forest plantation area.

II. OBJECTIVE

The main objective of this study is to extract forest inventory parameters such as CCM, CHM, DTM, Forest Classifications, DBH, AGB, CS and Tree Count in the selected forest areas for forest status assessment.

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III. METHODOLOGY

A. Study Area

The selected study area is a part of the protected forest plantation in San Manuel, Pangasinan ($120^{\circ} 39' 31''\text{E}$, $16^{\circ} 04' 23''\text{N}$) with an area of 0.445 square kilometers or 44.5×10^4 square meters. Trees planted in the area composed mainly of broadleaf trees (Fig. 1).

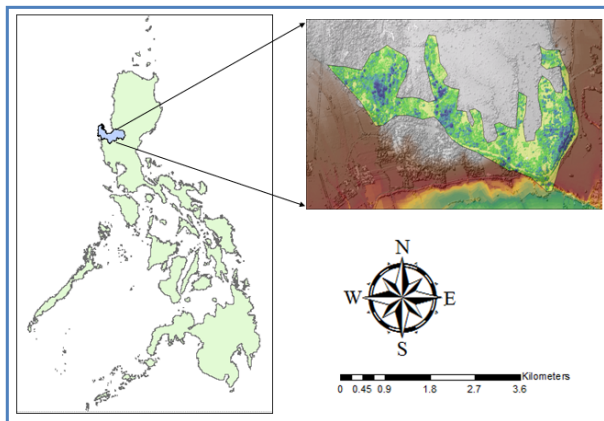


Fig. 1 Selected forest plantation area of the study

B. LiDAR Dataset

To have a more appropriate result or nearest true value of DTM, the laz files of Airborne LiDAR and partially processed data were shifted to WGS to EGM followed by converting the shifted laz files in LAS tools using LAS boundary. Output shape files processed in LAS boundary were superimposed in ArcGIS MAP to select overlaid tiles included in the municipality to be processed.

C. Tools/Software Used

Extraction of forest resources such as canopy height, forest cover, CS and tree count were carried out using LAS tools, .bat scripts, Envi tools and in ArcGIS MAP. Aside from the foremost tools, Anaconda2 and Phyton2.7 software were also used to run the programs, particularly the .bat scripts.

D. Processing of Derivatives

Processing of Derivatives were carried out in batch using LiDAR derivatives script to generate DTM, Hill Shade of DTM (DTM_HS), CHM, Hill Shade of CHM (CHM_HS), CCM and Veg.laz. The programmed .bat script for generating derivatives comprises LASboundary, LAsStile, Las2las, Blast2Dem, LASheight, LASnoise, LASmerge, LASthin and LASgrid. The above parameters were generated as prerequisites in generating raster bands and a composite band to classify different forest types in the forest area.

E. Generation of Bands

There were 17 raster bands and one composite band which was generated in open_check .bat script of classification. The generated bands were average, class_dtm, cover, density, maximum, quadratic average, standard deviation, bincenile bands such as nc10, nc20, nc30, nc40, nc50, nc60, nc70, nc80,

nc90, nc99 and the composite band of the municipality to be classified. These bands in tif format are prerequisite in classifying LiDAR point clouds to forest cover classes.

F. Forest Cover Classification

This particular method is applicable for forested areas and the basis of its forest extent was the NAMRIA land cover classification. Composite band of the municipality was used in ENVI to classify LiDAR point clouds to different forest classes, wherein a spectral angle mapper was used as the classification method. Moreover, majority analysis was applied in ENVI to produce a smoother classification with a kernel size of 15 m x 15 m.

Generated type of classification (lower class, upper class or mangroves class) was the input to finally classify and separate the type of forest classification in Arc GIS using added classification toolbox.

G. DBH, AGB and CS Estimation

After classifying the different types of forest cover, each forest cover were manually loaded and processed in the forest type derivatives batch file. From then, the extracted parameters using script were Diameter at DBH, AGB, CS and CCM calculation for Broadleaf Plantation and Coniferous Plantation forest cover types.

H. Tree Count Extraction

Tree count extraction allowed us to assess if the forest has sufficient number of trees or how many trees should be planted to make it sufficient/healthy. However, this developed method is only for forest plantation. If not, the delineated crown polygons of other forest types are expected to be poorly segmented. The CHM of the municipality of San Manuel with LiDAR data was clipped using the NAMRIA coverage to delineate and to produce tree count only to the selected forest area regardless of the cover type present in the area.

I. Field Validation

Field validation is important in determining the ground truth of LiDAR data and to assess the accuracy of the produced map. Validation was conducted within the vicinity of the selected forest area. Two validation plots with an area of 400 m² per plot were established. The parameter that has been validated was the DBH, Forest Cover Type, Tree Height, Tree Species, Fractional Gap and the Estimated Percent Cover.

J. Workflow

Fig. 2 shows the workflow of the study, starting from the LiDAR data, down to the generation of the map.

IV. RESULTS AND DISCUSSION

A. LiDAR Derivatives

The generated derivatives were: DTM, Canopy Height and the intensity of CCM.

B. Digital Terrain Model

The minimum value of the DTM is a bit higher because the location of the forest area was away from the coastal area. Fig.

3 shows that highest elevation of the forest area ranging from 141 to 191 meters high. Hence, the elevation of the majority of the forest area ranged from 94 - 141 meters, followed by 66 meters to 94 meters high.

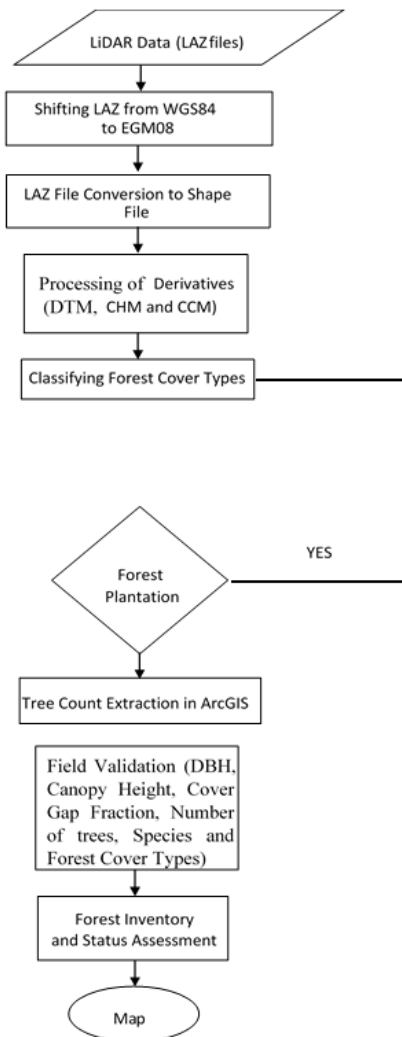


Fig. 2 Workflow of the study

C. Canopy Cover Model

The generated Canopy Cover Model shows 74% to 100% canopy cover. Field validation shows that only a few areas of the forest has an open canopy, and one of which is the area where the plot was established or located i.e. on the right side of the map model. Types of forest cover generated and present in the area were open broadleaf, closed broadleaf and broadleaf plantation. Among the three cover types, the broadleaf plantation has the highest canopy cover of approximately 80% (Fig. 4).

D. Canopy Height Model

The generated Canopy Height of trees in the forest ranged from 0 meters to 17 meters or greater than 17 meters; however, the height of the majority of the trees ranged from 8

meters to 17 meters. Overall, the mean average generated was 2 meters high (Fig. 5).

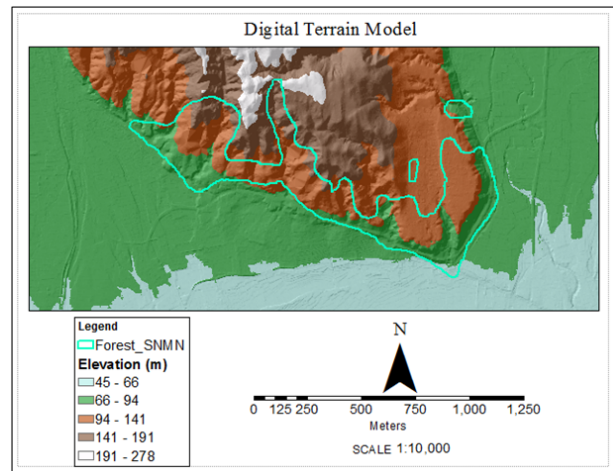


Fig. 3 DTM of the forest area

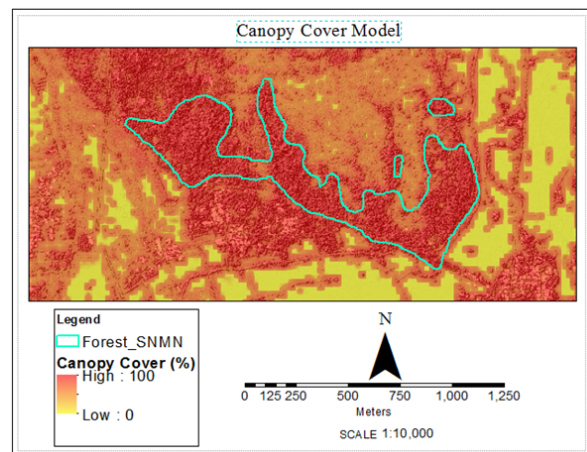


Fig. 4 CCM (%)

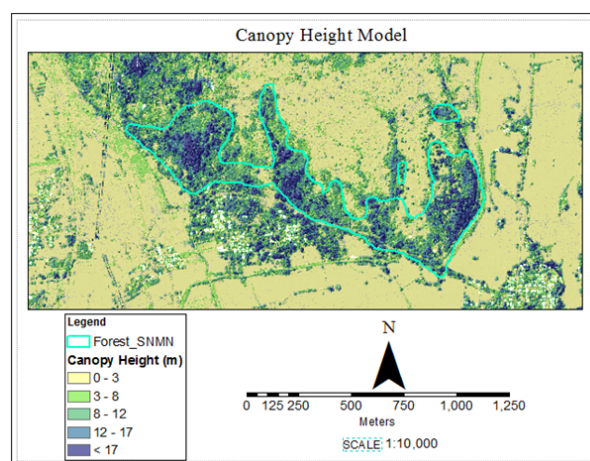


Fig. 5 CHM

E. Forest Cover Classification

Based on the model generated, there were three classes of Forest Cover in the study area, namely and as Fig. 6 shows: Broadleaf, Open Broadleaf and Closed Broadleaf. The area, however, was dominated by Closed Broadleaf with 21 hectares followed by Broadleaf with 20 hectares and the Open Broadleaf, which only occupies an area of 3.5 hectares (Table I).

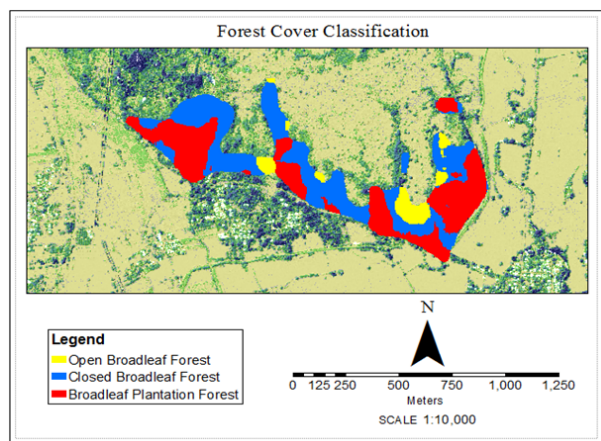


Fig. 6 Forest Cover Classification

TABLE I
AREA OF THE GENERATED DIFFERENT FOREST COVER TYPES

CANOPY COVER TYPE	AREA (ha)
Broadleaf Plantation	20.10
Closed Broadleaf	17.96
Open Broadleaf	2.50

TABLE II
ESTIMATED MEAN AVERAGE DBH, AGB AND CS OF DIFFERENT FOREST COVER

Forest Cover Type	DBH (mm)	AGB (kg)	CS (kg)
Broadleaf Plantation			
Minimum	265.16	2731.02	1283.58
Maximum	849.77	8609.82	4046.61
Mean	595.13	5912.65	2778.94
Closed Broadleaf			
Minimum	366.29	4955.69	2329.18
Maximum	1137.48	20819.59	9785.21
Mean	679.49	11276.03	5299.73
Open Broadleaf			
Minimum	191.97	1936.09	909.96
Maximum	801.09	15545.57	7306.42
Mean	500.86	6316.66	2968.83

D. DBH, AGB and CS

As Table II shows, among the three types of forest cover, the Closed Broadleaf was observed to have the highest DBH of 1137.48 mm, AGB of 20819.59 kg and CS of 9785.21 kg. This was followed by the Open Broadleaf with 801.09 mm DBH, 15545.57 kg AGB and 7306.42 kg CS, and the lowest value was Broadleaf Plantation that has 849.77 mm DBH, 8609.82 kg AGB, and 4046.61 kg CS.

It was observed further that the three parameters have a

direct relationship with each other, as obviously shown in the Open Broadleaf Plantation as well as the other two forest cover, whereby, a tree with a bigger DBH has a heavier AGB and with a concomitant high acquisition in CS. An indication that the forests are in a very healthy status as it has the capability to acquire high ground biomass and carbon from the atmosphere. Similar results were also observed in the other types of forest cover. Moreover, DBH, AGB and CS were also found to be highest in the Closed Broadleaf as compared to the Open Broadleaf and Plantation Broadleaf forest covers.

E. Tree Count

Shown in Fig. 7 is the delineated tree crown and tree count of the selected forest area. The red dots (local maxima) inside the Thiessen polygon are the representation of tree counts. The estimated total number of trees in the forest area is equivalent to of 18,824 trees for the three forests cover types. The average tree count for the forest plantation is 414 tree/ha. The red points or representation of tree counts were selected based on the height of each delineated tree. Trees having height greater than 1.37 meters from the ground were included in the final estimated count.

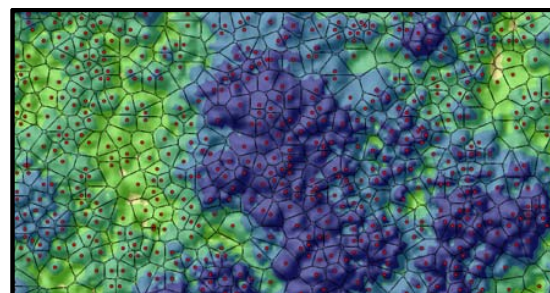


Fig. 7 Extracted Thiessen polygon and local maxima for the tree count of forest area. The red points are the representation of tree counts

V. SUMMARY AND CONCLUSION

In this study, researchers were determined and used the important parameters, namely: CCM, CHM, DTM Forest Cover Types, DBH, AGB and the generated Tree Count in forest status assessment. These parameters are of great help to assess forest inventory and general status of the forest. Based on the results, the Canopy Height of the forest ranged from 12 m to 17 m, with a mean canopy height of 2 m, while the elevation of the forest location was from 94 m to 141 m high. The selected forest plantation has high percentage Canopy Cover reaching as high as 80% of the forest area and with an estimated CS of 21138.24 kg. The total Tree Count is 18,824 trees or with an average of 414 trees per hectare at an approximate distance of 5 m X 5 m in between trees.

This study could provide the needed data to the Philippine data base on forest status assessment. By giving the forest inventory and forest status to the local communities, they will be able to plan on how to protect and manage their forests. It will indicate which areas should be conserved and areas which need rehabilitation.

It is recommended that development of a specific process for tree count delineation for accurate segmentation be considered as the tree count parameter is only applicable for forest plantations. Through this, estimating tree count on different forest types in the Philippines will be much easier.

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