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Analysis of spatial variation of tree heights in an urban area using lidar data

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Abstract

Estimating with greater precision and accuracy the height of plants has been a challenge for the scientific community. The objective this study is to evaluate the spatial variation of tree heights at different spatial scales in areas of the city of Recife, Brazil, using LiDAR remote sensing data. The LiDAR data were processed in the QT Modeler (Quick Terrain Modeler v. 8.0.2) software from Applied Imagery. The TreeVaW software was utilized to estimate the heights and crown diameters of trees. The results obtained for tree height were consistent with field measurements.

Keywords: Remote sensing, LIDAR, Tree, Urban area, TreeVaW.

1. Introduction

Knowing the variation of heights of plants from certain areas are of great importance for different areas of knowledge, such as forest inventories, quantification of biomass, carbon sequestration, hydrology, climatology, economics, etc.. Estimate with greater precision the height of plants has been a challenge for the scientific community working with this theme.

Examples such as, estimates of the volume of wood in forest inventories include sampling error and non-sampling errors. Sampling errors are controllable, being dependent, for example, the sampling and sample size. On the other hand, the non-sampling errors are difficult to identify. There are several sources of this second type of error, among them the use of inappropriate equations to estimate the height and volume of individual trees (Leite and Andrade, 2003).

In the aggregation of forest inventory plots is common to use volumetric equations, plotting the volume (V) to the diameter (dbh) and total height (Ht), fitting to mention the model of Schumacher and Hall (1933).

However, in most cases, only a few heights are obtained from the plots of the inventory. In this case, the equation is used to estimate the height of the other trees. These traditional methods lead to error in the estimate because often the samples are not statistically sufficient to represent the reality of the place. With the advancement of remote sensing, in particular the LiDAR sensor, is possible to obtain plant height in large geographic areas with detailed spatial scales, eg in inches.

Furthermore, remote sensing has the advantage of obtaining data quickly and economically when compared to the time and money spent on the offsets of field teams.

Second Ku et al. (2012) the Light Detection and Ranging (lidar) is an active remote sensing system that significantly differs from passive remote sensing systems in that it provides its own energy source instead of relying on energy reflected off of or radiated from the object under observation. Because of this, passive remote sensing cannot directly measure the terrain elevation and the height of objects, while lidar acquires three-dimensional information (Lefsky et al., 2002). Lidar systems can be mounted on a variety of platforms, such as satellites, aircraft, or terrestrial.

Second Popescu and Wynne (2004) “The laser scanner systems currently available have experienced a remarkable evolution, driven by advances in the remote sensing and surveying industry. Lidar sensors offer impressive performance that challange physical barriers in the optical and electronic domain by offering a high density of points at scanning frequencies of 50,000 pulses/second, multiple echoes per laser pulse, intensity measurements for the returning signal, and centimeter accuracy for horizontal and vertical positioning. Given a high density of points, processing algorithms can identify single trees or groups of trees in order to extract various measurements on their three-dimensional representation.”

Second Hopkinson et al. (2007) “during recent years, airborne laser scanning or lidar (light detection and ranging) has increasingly been demonstrated as a highly efficient method of data collection for a variety of high-resolution topographic (Flood and Gutelius, 1997) forest (Lim et al., 2003), wetland (Töyra et al., 2003), snowpack (Hopkinson et al., 2004), coastal (Webster et al., 2004), and other mapping applications Jaakkola et al. (2008)”.

Currently the municipality of Recife has invested in the deployment of more than 50,000 trees. To understand the transformations in space, benefits and impacts that these actions will have on future this city is important to know and to characterize the current situation of existing trees in the city and what the main features of them . For this, the council has invested in obtaining data from remote sensing LIDAR.

The investment cost for the municipality an approximate value of two million dollars. Various products can be obtained from these data. The city has used for different applications.

Second Hopkinson et al. (2007) the technology and manipulation of the lidar data is still treated with caution, and even considered somewhat esoteric by many potential users. “There are several reasons why relatively new technologies are treated with caution, and in the case of lidar mapping, the potentially high costs and huge volumes of data involved, and significant investment in time required by the end user to derive the information required are certainly major factors. Another factor is the generally low profile of lidar technology and applications in mainstream mapping, remote sensing, and geomatics curriculum”.

In this study, these data will be used to evaluate the spatial variation of tree heights at different spatial scales to areas of the city of Recife, such as LiDAR remote sensing data. This information is valuable not only for the social, economic, climatic, hydrological and environmental planning of the city, but also to advance the scientific knowledge of environmental and urban characteristics of large cities with similar existing physiography in Recife .

2. Materials and methods

2.1 Study area

This study area has coordenate: X 285999 to 286997 and Y 9103997 to 9103499, in part of Recife, Pernambuco-Brazil, Figure 1.

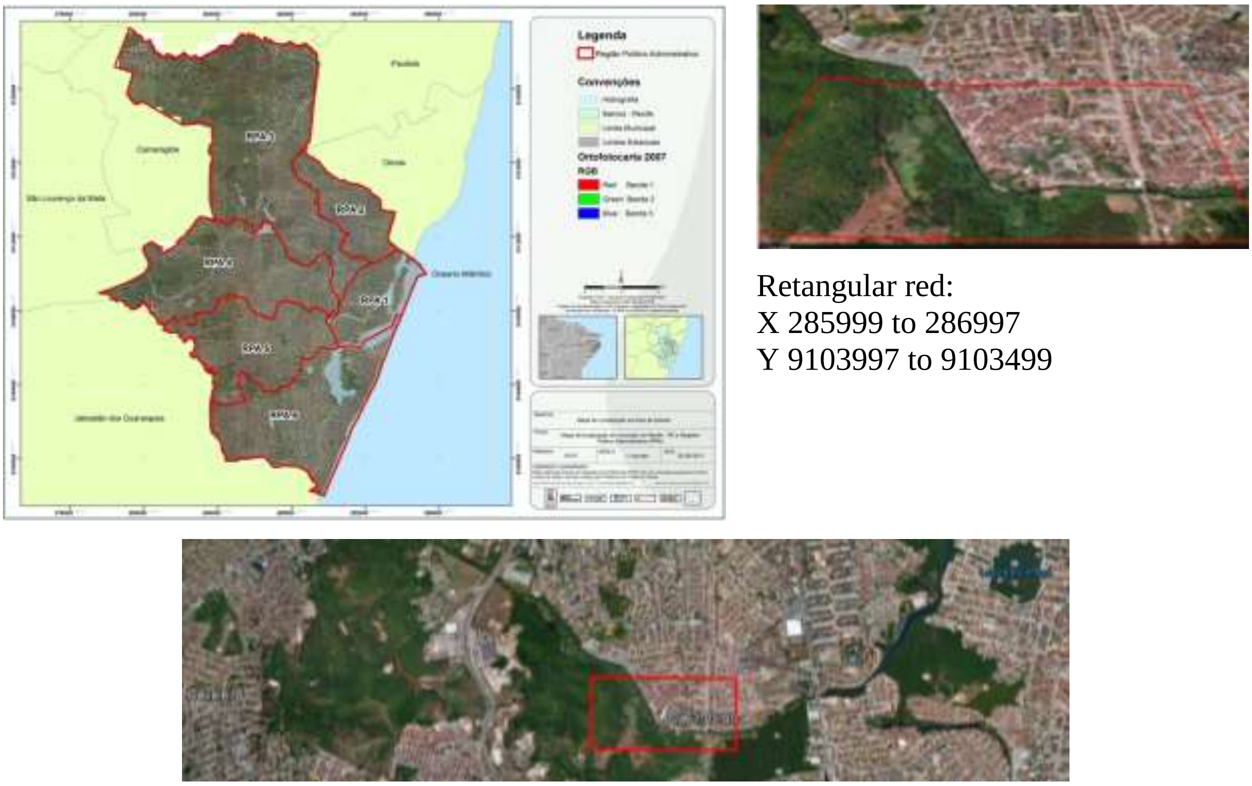

Figure 1 - Spatial localization of the study area.

2.2 Data

The LiDAR data were obtained in April 2013 through the aircraft. These aircraft have on board the following equipment: Trimble Aerial Camera AERIAL CAMERA X4, with four bodies with integrated camera P65 + four sensors and Apo-DigiTar and Laser Sensor OPTECH AIRBONE LASER TERRAIN MAPPER model ALTM Gemini 167. Moreover, aircraft are equipped with navigation systems consisting of autopilot and GPS guidance receivers.

For this activity we used the X4 Camera TRIMBLE AERIAL CAMERA, with four bodies with integrated camera P65 + four sensors and Apo - DigiTar. A resident in notebook connected to the camera and onboard GPS receiver program has full control of aerial photographs covering directing the crew and sending signals to the camera take photos automatically in the locations provided in the flight plan. This program is the Flight Commander, prepared by Geokosmos, related company to Engefoto.

For realization of the Airborne Laser profiler used the Laser Sensor OPTECH AIRBONE LASER TERRAIN MAPPER model ALTM Gemini 167. The LASER PROFILING System (ALS - Airborne Laser Scanning) or Airborne Laser System for Terrain Mapping (ALTM - Airborne Laser Terrain Mapper) works in data acquisition of the ground surface with accuracy proportional to the processing of GPS (Global Data Position System). For air cover with the laser profiler is being used the System Laser profiling (ALS - Airborne Laser Scanning) or Airborne System Laser Terrain Mapping (ALTM - Airborne Laser Terrain Mapper).

In implementing the surveys the following parameters were used: Flight altitude: 600 meters Opening angle (FOV): 20; Overlap side (between groups): 30% Min Number of tracks: 137; Density of MDE (average) points: 5.51 / m².

The characteristics of ALS GEMINI system are summarized in Table 1.

Table 1 - Characteristics of ALS GEMINI system.

	Parameter	Value
Scanner	FOV	Variable: 0 ^{0} to+_ 50 ^{0} (maximum)
	frequency	70 Hz maximum
	pattern	Saw tooth
Laser	Type	ALTM Gemini
	Classification	Class IV (FDA 21 CFR-US)
	Beam divergence	Dupla: 0.25 mrad (1/e) and 0.8 mrad (1/e)
	Distance of eyes	150 m AGL nominal
	Maximun range	4000 m AGL nominal
	Frquency pulse laser	33-167 KHZ
Pos	Recpetor GPS	
	IMU	
Control	Storage of data	SDSI
	Potency	28 V, 35 A
	Operational temperature	Rack +10 to 35 ^{0}C, sensor -10 ^{0} to 35 ^{0}C
	Umid	0-95 no condesation
	acuracy	± 5 ^{0}
Precision	Vertical Acuracy (elevation)	<5-30 cm, 1s
	Horizontal acuracy	15.500 x elevation (m AGL), 1s

The Horizontal Datum reference used was the Geocentric Reference System for the Americas - SIRGAS 2000 was adopted as Vertical Datum, the Network of National Reference Level (RRNN) - Imbituba (SC). The Projection System used was Universal Transverse Mercator (UTM).

2.3 Methods

Processing of LIDAR data

The LiDAR data in txt format were imported into QT Modeler (Quick Terrain Modeler v. 8.0.2) software from Applied Imagery. We calculated the height of the trees using the tool AGL (Above Ground Level) with different sample sizes (0.5m, 2m and 5m), generating the CHM (Canopy Heigth Model). We export to CHM tif and open the ENVI, derive the values less than zero (errors) and process the CHM in TreeVaW. Finally in TreeVaW calculating the heights and diameters of plants. With the height and diameter of plants is can make the calculation of biomass.

Further details on the procedures for obtaining CHM can be seen in Popescu et al. (2002).

3. Results and discussion

Figure 2 show the spatial variation of height of image of raw data. Note that the height was 2 to 41m. The red areas are dense vegetation (Atlantic forest), Figure 1, height between 20 and 41m.

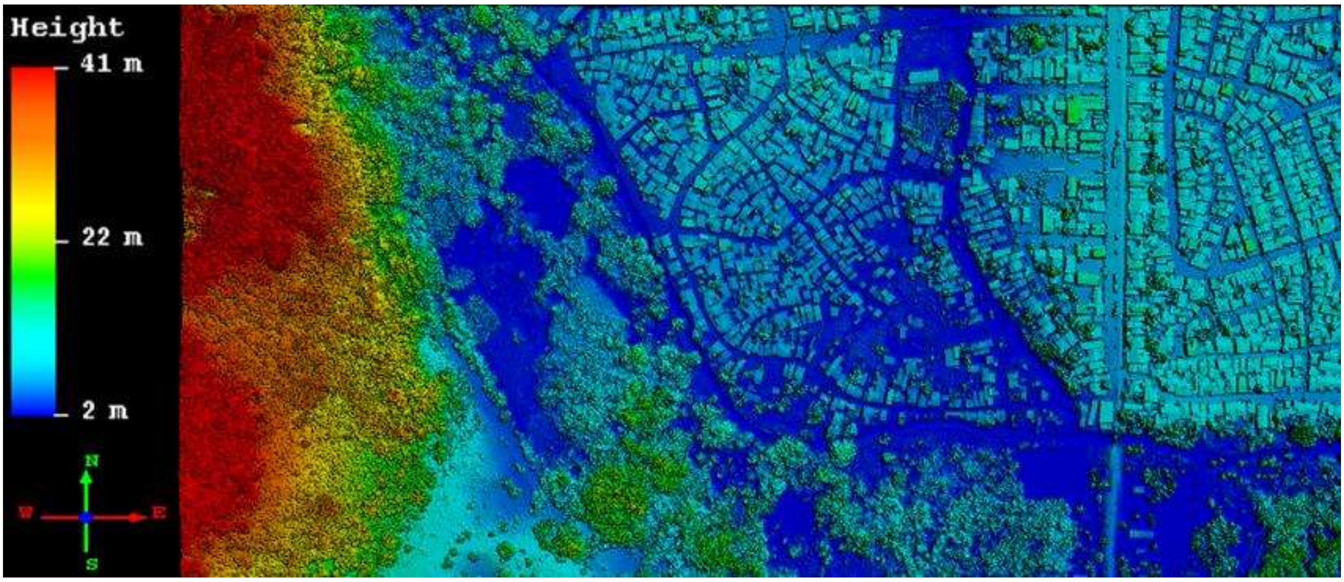

Figure 2 - Raw data of lidar for area in Recife City.

Figure 3 show the statistical data of raw data of lidar. Note that the minimum value was 0.3m and maximum value was 58m. The area have 4,604,922 points, 18,419 m^2. The mean was 12.27 and StdDEV= 11.95. In general, the height were under of 10 m.

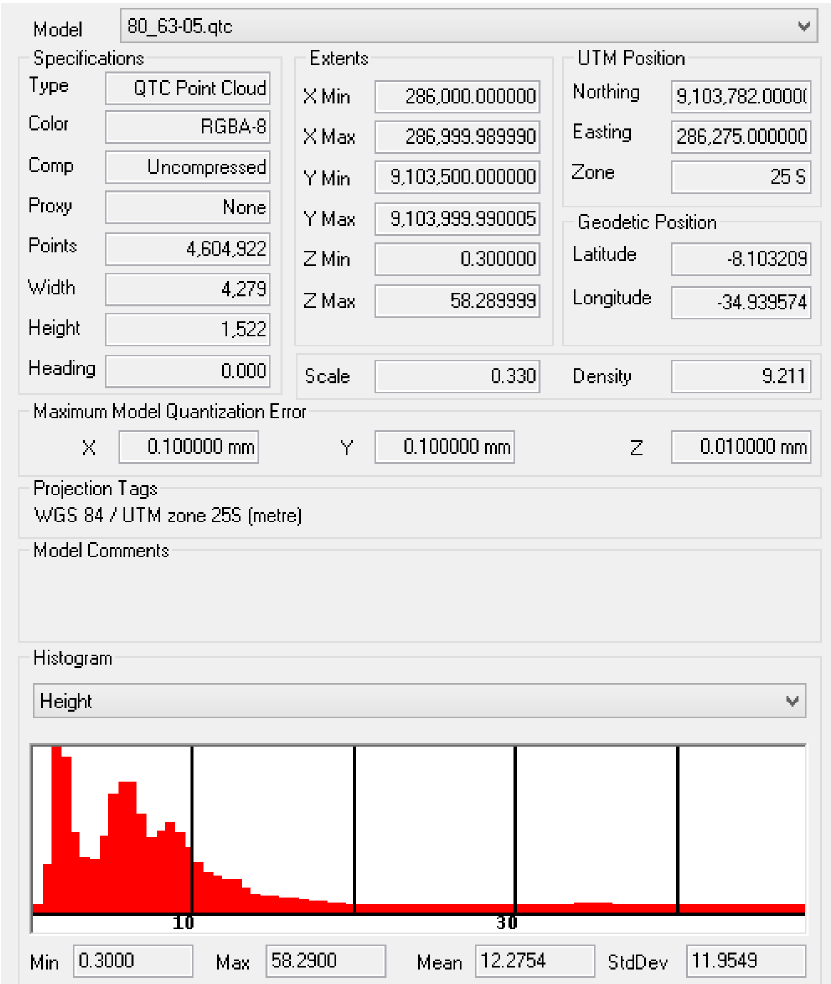

Figure 3 - Statistical raw data of lidar for area in Recife City.

Knowing that these gross figures are plants was made processing AGL, after the CHM and after obtained the heights of trees, Figure 4. As the city of Recife is practically at sea level the difference between the raw data and CHM was small. As an example, the maximum height decreased from 41 to 39. The study area have terrain elevation near of the sea level. The difference between raw data and process data (lidar height and terrain elevation) are similar (see Figures 2 e 4). The areas where only have vegetation was observed heights between 20-39 m approximately, Figure 4. included terrain height plus the height of the Second Magnanini and Magnanini (2003) some species of Atlantic forest can had 65m of height and this tree are see in litoral cost Atlantic of the Northest of Brazil to Prata river basin. Coelho (2013) using hypsometer see tree with 18 m of height in Mangrove forest localized near of this study area. Therefore, this results data with lidar this study are coerents with literature data. Yet, the lidar data area fast to obtain information than traditional methods with hypsometer that are boring.

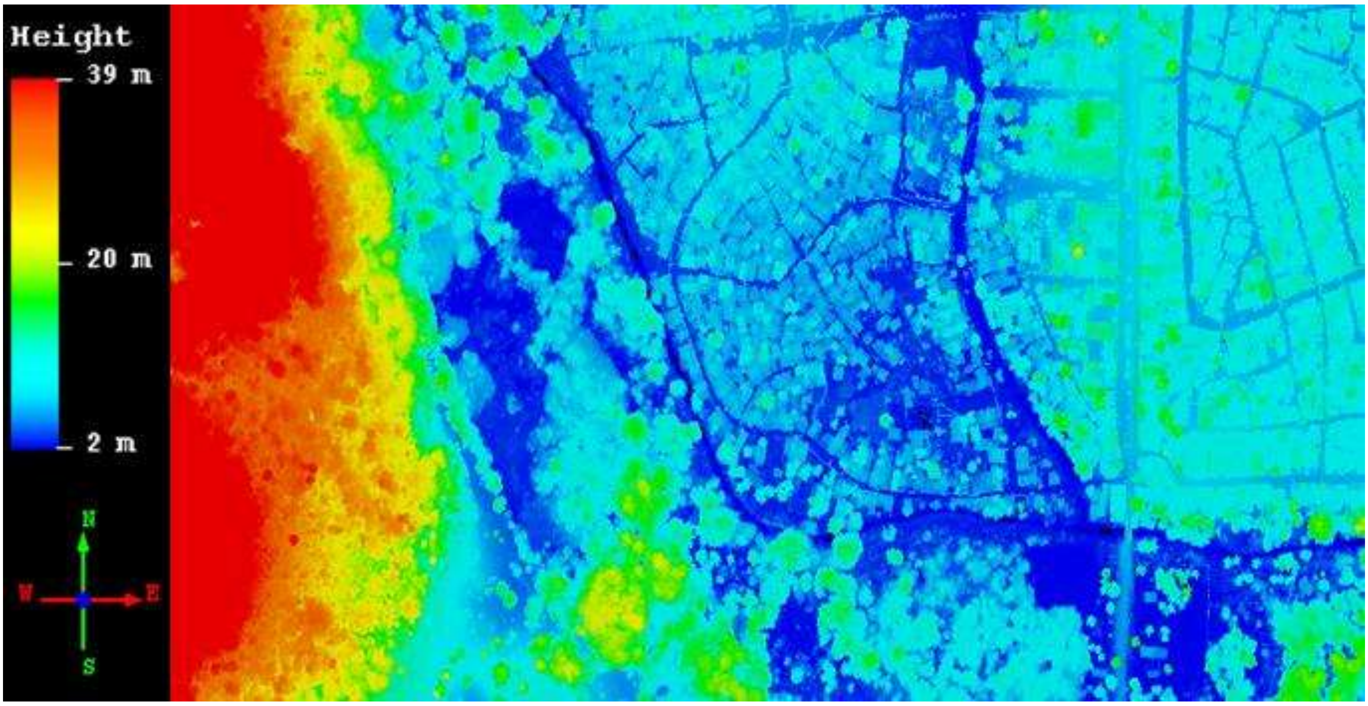

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Figure 4 - CHM – Canopy Heigth Model.

The CHM data, Figure 4, were processed in TreeVaW software to obtain the height of tree and canopy diameter. Figure 5 show the spatial variation of trees with 50 cm of grid. Note this grid was obtained high numbers of points (3947 points). This gris of 50 cm have errors in diffentiation between tree and another urban alvo, for exemple, eletric transmission line. Figure 6 show spatial variation of tree with grid of 2m. In this grid was obtained 128 points. In general, only in dense vegetation area showed points with tree. In this case, no have confusion between tree and another urban alvos. But, was extracted little points.

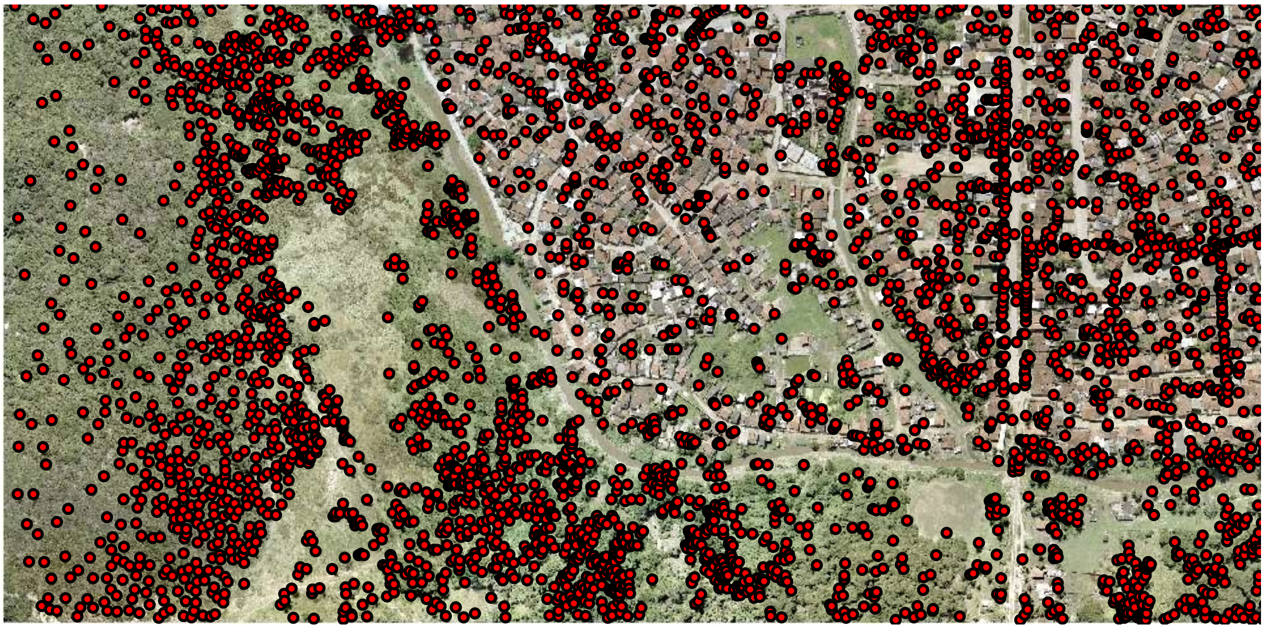

Figure 5 - Spatial variation of tree, when used grid of 50 cm.

Figure 6 - Spatial variation of tree, when used grid of 2m.

The results obtained in this study were with automatic process and fast obtain of data. This is a vantage of data use of lidar. But, it is important to say that these automatic processes are errors possible. Kaartinen et al. (2012) with the objective of the "Tree Extraction" project organized by EuroSDR (European Spatial data Research) and ISPRS (International Society of Photogrammetry and Remote Sensing) evaluated the quality, accuracy, and feasibility of automatic tree extraction methods, mainly based on laser scanner data. In the final report of the project, Kaartinen and Hyyppä (2008) reported a high variation in the quality of the published methods under boreal forest conditions and with varying laser point densities. Four automatic tree detection and extraction techniques were utilized. Several methods in this experiment were superior to manual processing in the dominant, co-dominant and suppressed tree storeys. In general, as expected, the taller the tree, the better the location accuracy. The accuracy of tree height, after removing gross errors, was better than 0.5 m in all tree height classes with the best methods investigated in this experiment. Second the authors, for forest inventory, minimum curvature-based tree detection accompanied by point cloud-based cluster detection for suppressed trees is a solution that deserves attention in the future.

In this study, was utilized TreeVaW automatic method for obtain of tree height in urban area. Urban area has different object. This object interfere in results because confuse tree with another's objects. The TreeVaW software was developing for Popescu in (Kini and Popescu, 2004) and after Popescu have developed varies study with TreeVaW. Popescu and Zhao (2008) with objective of to develop methods for assessing crown base height for individual trees using airborne lidar data in forest settings typical for the southeastern United States used a lidar software application, TreeVaW, to locate individual trees and to obtain per tree measurements of height and crown width. Tree locations were used with lidar height bins to derive the vertical structure of tree crowns and measurements of crown base height. Lidar-derived crown base heights of individual trees were compared to field observations for 117 trees, including 94 pines and 23 deciduous trees. Linear regression models were able to explain up to 80% of the variability associated with crown base height for individual trees.

4. Conclusion

The TreeVaW method and lidar data proved efficient in identification of height in urban area and can be used to obtain the structural caracterization of tree in urban area of fast form.

The medium height of tree in study area was 12m. This data is consistent with official information. The maximum height was near of 40 meters and this height localized in area of dense vegetation.

Acknowledge

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