Comparison of individual tree counts from both airborne and terrestrial LiDAR systems analyzed individually and combined in a Web-LiDAR Environment

Bryan Keough [1], Carlos A. Silva [1], Andrew T. Hudak [2], Lee Vierling[1], Veraldo Liesenberg[3]

[1]College of Natural Resources, University of Idaho, 975 West 6th Street, Moscow, ID 83844, USA. E-mail: keou4407@vandals.uidaho.edu
[2]UDSA- Forest Service – Rocky Mountain Research Station –RMRS, 1221 South Main Street. Moscow, ID 83843, USA. E-mail: carlos_engflorestal@outlook.com
[3]Santa Catarina State University (UDESC) – Departament of Forest Engineering (CAV) Av. Luiz de Camões, 2090 - 88520-000 - Lages - SC, Brasil

Abstract. Extracting individual trees from remotely sensed data has become of increased interest for forest managers and government agencies. Previously released free Web-LiDAR applications have been shown to be a simple and effective tool to find this desired information. Two forms of Light Detection and Ranging (LiDAR) systems, both Airborne Laser Scanning (ALS) and Terrestrial Laser Scanning (TLS) have become increasingly popular forms of gathering forest measurements. These two systems used individually can only capture some of what exists in terms of forest attributes in a forest stand. Used in conjunction, however, they provide a higher resolution dataset that can provide a much more detailed description of forest structure. The purpose of this investigation was to find the difference in the generated outputs from the Web-LiDAR TreeTop application for detecting individual trees on a given plot. We testet both ALS and TLS derived data, both individually and combined, varying only the fixed window size (FWS) in the application (i.e. 3x3, 5x5, 7x7 and 9x9). The findings from this study found that when compared to the combined data, the ALS and TLS would often have less individual trees detected on a plot.

Keywords: Remote sensing, Web-LiDAR, ALS, TLS, FWS, individual trees.

1. Introduction

Remote sensing tools are increasingly used for operational forest inventory and management. Among the available tools, Light Detection and Ranging (LiDAR) has been found to be particularly useful for stand and individual tree metrics that are relevant to forest managers (Koch et al. 2006, Hudak et al. 2006, Lefsky et al. 2002). LiDAR is a powerful technology with which many products can be generated. High resolution stand maps, estimations of stand volume, canopy cover, biomass and carbon content are just some of the useful applications.

Airborne Laser Scanners (ALS) and Terrestrial Laser Scanners (TLS) are two LiDAR systems currently being used for remote sensing in forested ecosystems (Hilker et al. 2010, Hiker et al. 2012). Traditionally ALS has been the predominant system for use in these ecosystems. ALS systems can generate a point cloud by taking the x, y, z locations of the LiDAR returns, which can help to identify tree heights and locations from above the stand. Additionally LiDAR can adequately measure canopy cover and topographic metrics among others (Evans et al., 2009). However, due to the heterogeneity of a forest canopy, and that ALS can only scan from above that canopy, many areas below the canopy receive little or no coverage (Vega et al., 2014). TLS systems in contrast are able to scan areas underneath the canopy but are unable to capture more than what is directly visible from the stationary point the data is collected from. This means that points directly behind a tree for instance may not be scanned. In recent years it has become increasingly popular to combine both systems to capture a higher resolution view of the forest and improved measurements (Fowler & Kadatskiy 2011, Hilker et al. 2010, Hilker et al. 2012).

Individual tree detection is a product of LiDAR data that has become of increasing interest in the forest management and LiDAR communities. The data derived from individual tree detection applications can be used in conjunction with ground plot data to establish models that allow for very detailed and cost effective inventory at a large scale. These details can help forest managers make more informed decisions to better manage for current goals and desired future conditions.

The aim of this investigation was to use Web-LiDAR TreeTop application tool to detect individual trees in a conifer forest using ALS and TLS data separately as well as combined ALS and TLS data (ALS+TLS) with no canopy height model (CHM) filters (e.g. mean, median, Gaussian). Additionally evaluation of the influence of different fixed window sizes (FWS) (i.e. 3x3, 5x5, 7x7 and 9x9) on tree count.

2. Material and methods

2.1 Study area

The study area is located at Eglin Air Force Base, Niceville, Florida, USA (Figure 1). The climate is characterized by warm, humid summers and generally mild to cool winters. The forest type is longleaf pine forest that has an open canopy structure (up to 50% canopy cover). The location of the plot analyzed is: 526129.9E 3377958.3N, UTM Zone 16N, with an area of 7853.9m^2.

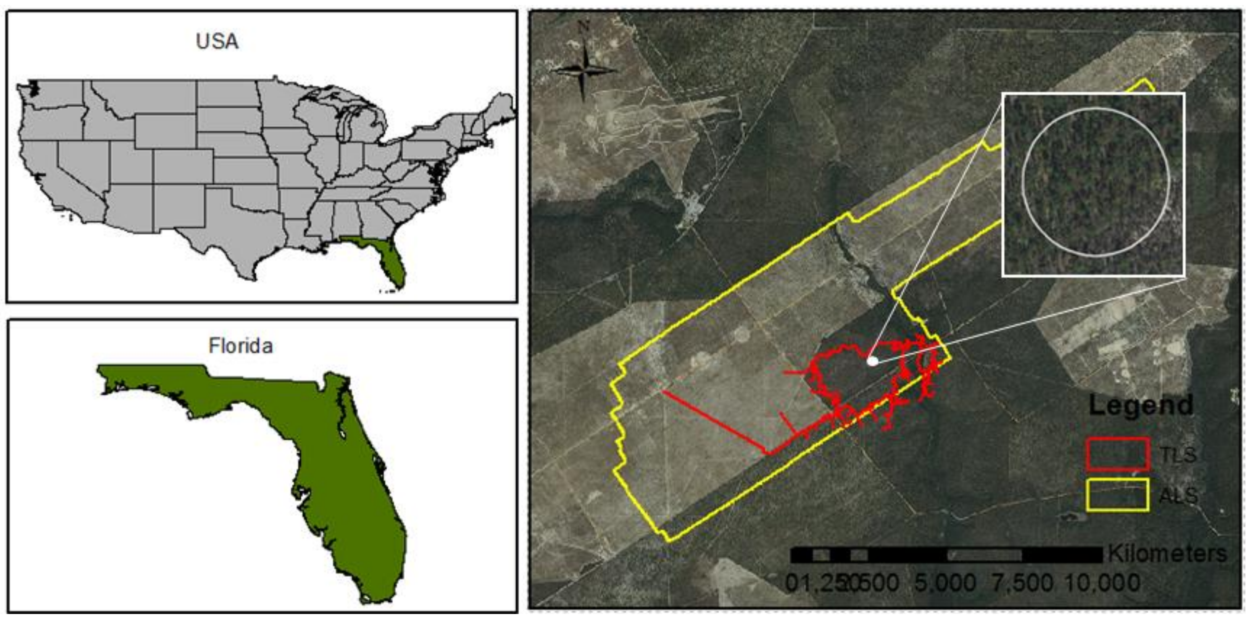

Figure 1. Study Area – Longleaf pine forest at Eglin Air Force Base. The plot analyzed is the inset.

2.2 The Web-LiDAR TreeTop Application

The Web-LiDAR application is an interactive, user friendly tool with which a user can analyze, visualize, and download the generated results of the individual tree detection. This application is available on the web at http://forest.moscowfsl.wsu.edu:3838/LiDARTreeTop/. The Web-LiDAR application was developed by the USDA Forest Service - Rocky Mountain Research Station (RMRS) laboratory, and it is free for use. The requested data input for the individual tree detection algorithm through the Web-LiDAR Treetop application is a LiDAR-CHM.

2.3 LiDAR data acquisitions

2.3.1 ALS

The ALS LiDAR data was acquired by Kucera International using a Leica ALS60 sensor operating in MPiA mode. The survey parameters are given in Table 1.

Table 1. ALS LiDAR Survey Parameters.

Parameter	Value
Laser point density (nominal)	8.72 points/m^2
Laser pulse rate	176,100 Hz
Maximum returns per pulse	4

2.3.2 TLS

The TLS LiDAR data was acquired using an Optech ILRIS 3_6D ER Scanner. The survey parameters are given in Table 2.

Table 2. TLS LiDAR Survey Parameters.

Parameter	Value
Laser point density (nominal)	68.14 points/m^2
Laser pulse rate	10,000 Hz
Scan Altitude	16-27m AGL

2.4 LiDAR data processing

Initial processing and normalization of the ALS and TLS data was done with the FUSION software (McGaughey, 2014). Additional metrics for the data were also calculated with FUSION and R Project for Statistical Computing (R Project, 2014). The height normalized data sets were merged into one comprehensive data set. A 0.5m resolution CHM for ALS, TLS, and ALS+TLS was generated using Lastools (Lastools, 2014) according to the methodology proposed by Khosravipour et al. (2013). A flowchart for the processing of the data is shown in Figure 2.

The 0.5 m CHMs were input into the Web-LiDAR TreeTop application. In this study, individual tree detection was tested using data from ALS, TLS and ALS+TLS with four window sizes (i.e. 3x3, 5x5, 7x7 and 9x9 m) and no CHM filters.

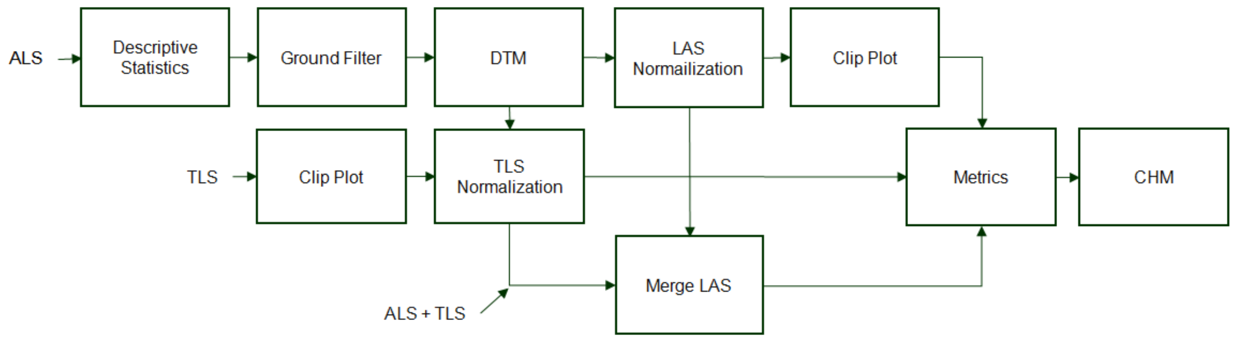

Figure 2. Flowchart for processing and merging the LiDAR data to arrive at individual and combined CHM.

2.5 Performance of Individual Tree detection

The accuracy of the number of the individual detected trees was evaluated using:

$$\text{Absolute difference}(\text{N}^{\text{o}}\text{tree}) = \text{N}^{\text{o}}\ \text{tree detected}(\text{ALS or TLS}) - \text{N}^{\text{o}}\ \text{tree observed}(\text{ALS} + \text{TLS})$$
Equation (1)

$$\text{Relative Difference }(\%) = \frac{(\text{N}^{\text{o}}\ \text{tree detected (ALS or TLS)} - \text{N}^{\text{o}}\ \text{tree observed (ALS+TLS)})}{\text{N}^{\text{o}}\ \text{tree observed (ALS+TLS)}}\ \text{x}\ 100$$
Equation (2)

3. Results and Discussion

3.1 Tree detection performance

We hypothesized going into the analysis the two systems combined would be a higher level of accuracy, as in theory it provides a higher resolution point cloud to find trees (Figure 3). FWS along with the different acquisition combinations were important influences in total number of trees detected. In all but one instance it was found that the ALS and TLS detected fewer trees when processed individually compared to ALS+TLS (Figure 4).

The relative difference for the number of individual trees detected between ALS and TLS compared to the ALS+TLS ranged from -31.9 to 1.5% for ALS, and -26.4 to -5.3% for TLS (Table 3). The relative difference closest to the combined data set for ALS was a FWS of 7x7 (-0.6%); for TLS a FWS of 9x9 (-5.3%) (Table 2). In all but the one instance, the number of individual trees detected by the Web-LiDAR TreeTop application was less than that of the combined data, when assuming the combined data as true.

The next step for evaluation of these data sets would be to collect detailed ground data for this plot to compare with the LiDAR results, as currently plot data has not been collected to get the actual tree counts.

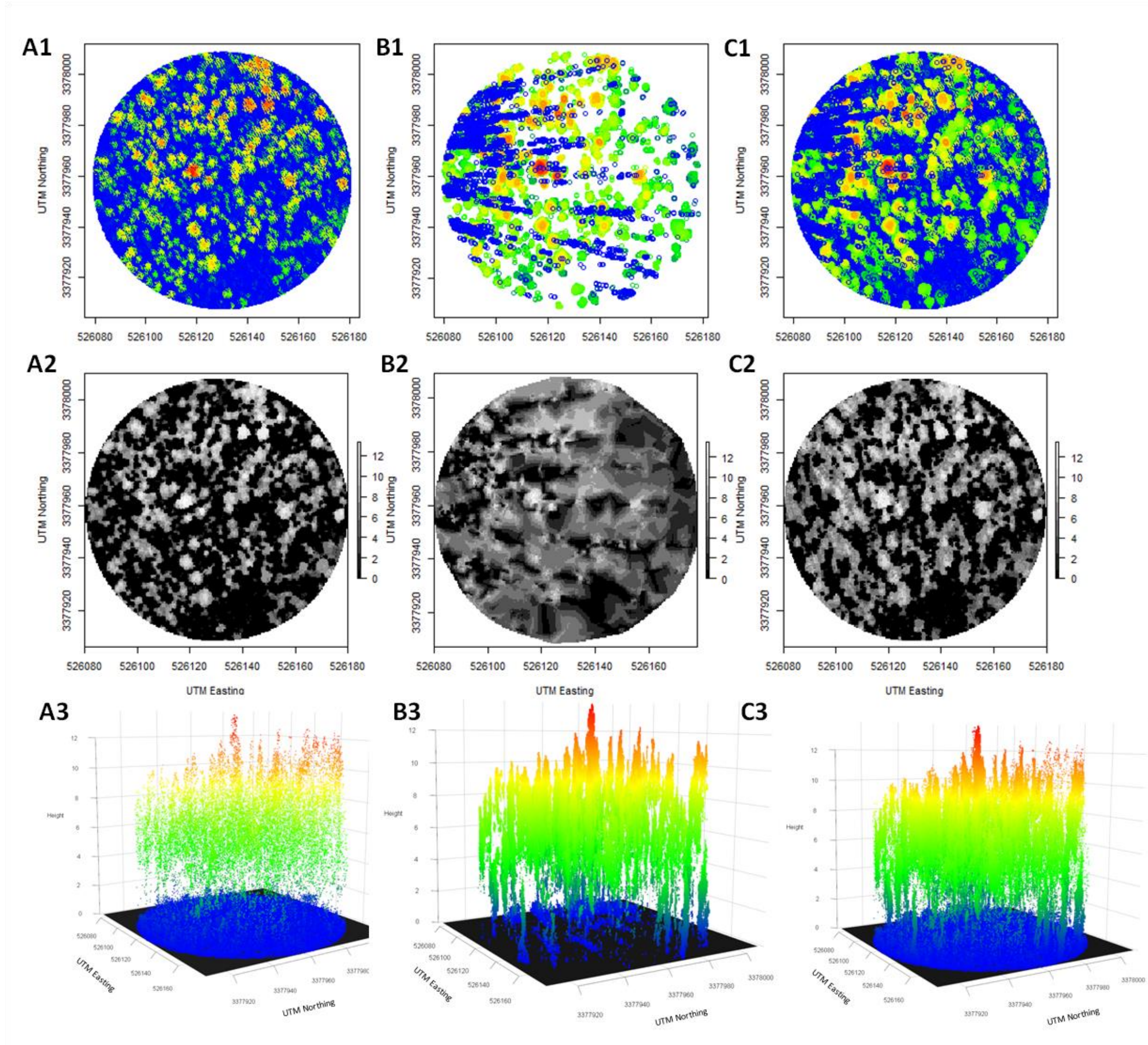

Figure 3. The static plot view, canopy height model (CHM), and 3D point cloud for ALS (A1-3), TLS (B1-3), ALS+TLS (C1-3).

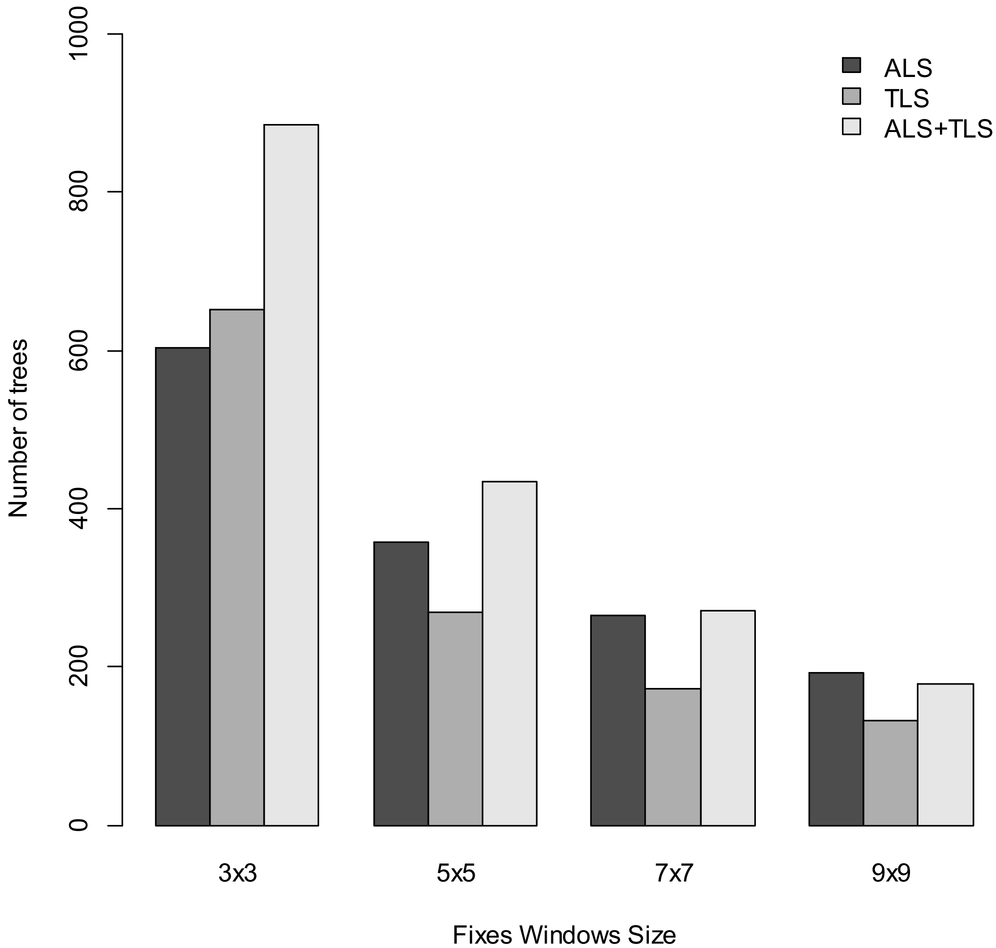

Figure 4. Number of the trees detected from the LiDAR CHM using the Web-LiDAR Treetop application

Table 2. Performance of the individual tree detection for the individual systems relative to the combined results.

FWS	Absolute Difference		Relative Difference (%)	
	ALS	TLS	ALS	TLS
3x3	-282	-234	-31.9	-26.4
5x5	-78	-166	-8.8	-18.8
7x7	-5	-99	-0.6	-11.2
9x9	13	-47	1.5	-5.3

5. Final Remarks

The results presented show the variation in estimated tree counts between the different forms of LiDAR acquisitions. While the actual tree count is unavailable, the results begin to help support our previous thoughts that by combining the ALS and TLS information, a more vivid picture of the forest structure can be painted to better understand forest composition. These results also help to present the influence of FWS on the number of individual trees detected over a given area.

This study reinforces the growing volume of research on the feasibility of LiDAR for forest inventory. Being able to get detailed information about tree counts, tree location, crown heights, and other metrics on a larger scale than can currently be captured with inventory plots has incredible potential for forest managers and government agencies. This study also reinforces the ability of the Web-LiDAR TreeTop application to quickly and efficiently produce valuable information that can be immediately used by managers who may have LiDAR data in hand but may not be trained in all aspects of LiDAR processing.

Future work with combined ALS and TLS data has potential to yield additional information for helpful for operational LiDAR customers.

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