Quantification of terrestrial laser scanner (TLS) elevation accuracy in oil palm plantation for IFSAR improvement

N A Muhadi¹, A F Abdullah¹ and M S M Kassim¹

¹Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
tiramuhadi@gmail.com

Abstract. In order to ensure the oil palm productivity is high, plantation site should be chosen wisely. Slope is one of the essential factors that need to be taken into consideration when doing a site selection. High quality of plantation area map with elevation information is needed for decision-making especially when dealing with hilly and steep area. Therefore, accurate digital elevation models (DEMs) are required. This research aims to increase the accuracy of Interferometric Synthetic Aperture Radar (IFSAR) by integrating Terrestrial Laser Scanner (TLS) to generate DEMs. However, the focus of this paper is to evaluate the z-value accuracy of TLS data and Real-Time Kinematic GPS (RTK-GPS) as a reference. Besides, this paper studied the importance of filtering process in developing an accurate DEMs. From this study, it has been concluded that the differences of z-values between TLS and IFSAR were small if the points were located on route and when TLS data has been filtered. This paper also concludes that laser scanner (TLS) should be set up on the route to reduce elevation error.

1. Introduction
Site selection is one of the essential factors that affect yield productivity of oil palm plantation. It is required during the early phase to determine potential plantation area and throughout the life cycle of oil palm plantation. Climate condition, soil type and slope are some factors that need to be considered in choosing a good site for better yield productivity and plantation management. A good map of the plantation area together with elevation information is required in order to evaluate and manage the plantation wisely. In order to do that, Digital elevation models (DEMs) are used to produce the map of plantation area. Thus, it is crucial to obtain DEM data that are accurate. Light Detecting and Ranging (LIDAR) and Interferometric Synthetic Aperture Radar (IFSAR) are the most commonly used sources for creating DEMs. Airborne LIDAR data has been used in many applications such as in individual tree identification in forest area [1] [2] [3], flood modelling in urban area [4] [5] [6], detection of roads for road network [7] and hydrologic modelling [8]. Airborne LIDAR has the capability to collect three-dimensional information very densely over a large area. It provides high accuracy of DEMs and this is the reason why LIDAR data is costly compared to other data sources. Due to its price, airborne LIDAR data is found to be not economical to be used in agricultural sector. Therefore, an alternative approach to generate DEMs is introduced.

Terrestrial LIDAR data or can also be known as terrestrial laser scanning (TLS) is a technique that provides detailed information for small-scale area. The use of TLS in many applications has been done successfully previously. It has been applied in recognition of building structures [9], recording
historical building [10], forestry management [11] and in agricultural sector [12] [13]. In agricultural sector, oil palm plantation normally covers over large areas, so multiple scans should be done to cover all areas. TLS dataset contains millions of data points, which take longer time to process even for one scanned data. Hence, it is not practical to use TLS data alone in oil palm plantation. IFSAR data has become the ultimate choice in using space borne data due to its ability to operate in day and night and during unwanted weather such as haze, rain and fog. Furthermore, the main reason why users are prefers to purchase IFSAR data is because of its affordable price with acceptable accuracy. For wide area coverage, IFSAR has been proved to be more economical compared to other data sources including airborne LIDAR [14].

Thus, the combination of IFSAR data and TLS data is proposed to overcome this problem. The main aim of this on-going research work is to develop a new method or algorithm to combine both airborne IFSAR and terrestrial LIDAR specifically for development of DEMs in oil palm plantation. However, this paper focuses on the evaluation of elevation value of TLS points and selection of TLS position in oil palm plantation. Besides, this paper also studied the importance of filtering process while using TLS data.

2. Methodology
The study was carried out in oil palm plantation in UPM using FARO laser scanner Focus 3D and RTK-GPS. The point clouds data were collected using FARO laser scanner. FARO laser scanner uses laser technology to acquire millions of three-dimensional points in a few minutes. It sends infrared laser beam to the centre of the rotating mirror before projecting it outward from the scanner to the surrounding. Once the infrared light is in contact with the object, it is then reflected back to the scanner. This FARO laser scanner Focus 3D can provide detailed scanning between 0.6 m up to 130 m. The distance accuracy of Faro laser scanner is up to 2 mm based on the specifications given by manufacturer. Nevertheless, this measurement accuracy is actually based on several factors such as the distance and incidence angle of scanner, air temperature gradients and wind. This study used Trimble R6 receiver and applying RTK positioning technique which manufacturer claimed the given error is 15 mm vertically. The base position of FARO laser scanner station was determined using Real Time Kinematic (RTK-GPS) to geo-reference the data. Figure 1 shows the mounted FARO laser scanner during field data collection.

![Figure 1. The mounted FARO laser scanner.](image)

After all data were collected, pre-processing and post-processing steps were conducted in FARO laser scanner software called SCENE software version 5.1.2. The scanning project is then being processed in SCENE software for point clouds registration. In order to get the ground values, the scan points need to be filtered. Several algorithms have been developed for filtering process. However, Abdullah
et al. [15] stated that not all algorithms are competent to produce good DEM data. The filtering algorithms should be chosen based on their ability to produce desired result. In this study, the scan points were filtered using TerraScan software. TerraScan is a commercial software that has been commonly used to remove non-ground points. The results were then exported to ArcGIS for further analysis. To evaluate the accuracy of scan points, 50 random points were collected using RTK-GPS as a reference point within the same area. These random points would be used to compare the elevation value or also known as z-values from both RTK-GPS and FARO laser scanner.

3. Results and discussions
This study was carried out to evaluate the elevation value of TLS. The scanner station was set up at longitude 414834.66 m and latitude 329855.23 m which located on the field route. For the first part, this study used raw scan points to compare the z-values from TLS and RTK data. Figure 2(a) shows map of the study area that contains the whole TLS scan points in preliminary study. It is clearly seen that the area within 10 m radius from the scanner position contained more scan points compared to the area outside the range.

In order to evaluate the TLS values, 50 points were measured randomly inside the study area using GPS-RTK. Therefore, only 50 points at the same spot were selected from the whole TLS points so that the z-values from both data could be evaluated. Figure 2(b) shows the map of RTK and selected TLS points in the study area. When RTK points were measured in dense area, the total of TLS scan points in that area was abundant. The laser could hit the surrounding thoroughly. Therefore, there were TLS points that available on the same coordinates. However, if the RTK points were measured in area with fewer points, there were possibility of having no TLS points on the same coordinate. Thus, the nearest TLS point from RTK data was selected to compare the elevation value. The range of distance between RTK and TLS points was within 0 to 1 meter. The difference between z-values from both TLS and RTK points were plotted in figure 3.
Based on the graph, it could be seen that there were some points that had huge differences of z-values. It was confirmed that most of these points were representing trees rather than the ground because the points were located inside the plantation area. The distance between the points and the scanner position that were far from each other could also affect the z-value of TLS points. This situation might happen because laser could not reach that far away area. Thus, laser could not hit the ground as it was being blocked by the canopy or neighbouring trees. Figure 4 shows the location of both RTK and selected TLS points.

The ground points could be obtained easily when the points were dense and in the field route area. However, the ground points were barely obtained in less dense area and in tree planted area. This was because laser from the scanner could not hit the ground as the distance was too far from the scanner. Besides, the laser might only hit the canopy of trees due to the instrument limitation. To quantify the TLS z-values, root mean square error (RMSE) for each point was calculated. Table 1 shows that only 21 points had obtained RMSE values less than 0.1. Most of these points were located on the field route with abundant scan points available.

Figure 3. The difference of z-values between RTK and TLS points.

Figure 4. Map of RTK and selected TLS points in study area. (a) Selected TLS and RTK points with the whole TLS data (b) Location of the points on Earth.
### 3.1. Filtering process

The covered area of raw TLS data after processed from SCENE software was huge. The process is done to reduce noise and to limit the scanned so that it will cover the interested area only. The subject of this study was the ground points of the area. Nevertheless, the raw data contained millions of points including unnecessary object points. The process of extracting ground points from mixture of ground and objects is called as filtering. Therefore, filtering process was carried out to overcome this problem. Moreover, filtering could also help in reducing storage space and processing time. Thus, it could improve data processing performance.

Figure 5 shows TLS points after removing object points and the original TLS data. The ground points had been extracted from the raw TLS data using TerraScan software. Initially, there were 26,465,412 total points before filtering and the points reduced to 1,819,190 points after filtering process. In order to classify the position of each point, the data was segmented into three sections, section A, B and C as shown in figure 6. Section B contained 1,622,974 points that were located on the field route. On contrary, section A and C both consisted of 178,541 and 17,675 points that were located on the left and right sides of the field route respectively. More than half of the remaining points were located in section B. It is clearly shown that most of the points that had been removed were located in the

|   | RTK   | TLS   | RMSE  | RTK   | TLS   | RMSE  |
|---|-------|-------|-------|-------|-------|-------|
| 1 | 68.924| 68.870| 0.008 | 26    | 69.076| 80.980| 1.683 |
| 2 | 68.742| 68.650| 0.013 | 27    | 68.455| 74.590| 0.868 |
| 3 | 68.144| 68.500| 0.050 | 28    | 67.681| 67.800| 0.017 |
| 4 | 67.895| 67.810| 0.012 | 29    | 67.364| 78.470| 1.571 |
| 5 | 67.717| 67.700| 0.002 | 30    | 67.141| 80.890| 1.944 |
| 6 | 67.625| 67.500| 0.018 | 31    | 67.462| 76.270| 1.246 |
| 7 | 67.526| 67.260| 0.065 | 32    | 67.364| 73.310| 0.841 |
| 8 | 67.675| 67.730| 0.432 | 33    | 67.885| 68.820| 0.009 |
| 9 | 67.384| 73.070| 0.804 | 34    | 67.656| 75.360| 1.102 |
| 10| 67.157| 72.390| 0.740 | 35    | 67.423| 70.470| 0.431 |
| 11| 67.064| 78.200| 1.575 | 36    | 67.653| 68.440| 0.018 |
| 12| 66.751| 67.340| 0.083 | 37    | 69.247| 69.560| 0.044 |
| 13| 66.642| 72.250| 0.793 | 38    | 69.247| 69.560| 1.629 |
| 14| 66.656| 77.340| 1.511 | 39    | 68.703| 80.220| 0.022 |
| 15| 68.594| 68.480| 0.016 | 40    | 68.581| 72.600| 0.568 |
| 16| 68.422| 74.020| 0.792 | 41    | 68.653| 78.160| 1.344 |
| 17| 68.383| 68.230| 0.022 | 42    | 68.547| 68.520| 0.004 |
| 18| 68.465| 68.290| 0.025 | 43    | 68.265| 68.570| 0.043 |
| 19| 68.651| 75.510| 0.970 | 44    | 67.915| 67.700| 0.030 |
| 20| 68.962| 69.150| 0.027 | 45    | 67.648| 72.250| 0.651 |
| 21| 69.239| 75.220| 0.846 | 46    | 67.269| 72.330| 0.716 |
| 22| 71.548| 68.760| 0.394 | 47    | 67.733| 72.650| 0.695 |
| 23| 68.234| 76.740| 1.203 | 48    | 68.029| 68.720| 0.098 |
| 24| 68.881| 76.290| 1.048 | 49    | 68.252| 73.980| 0.810 |
plantation areas. This is mainly because lots of scan points in those areas were classified as object points, thus resulted in removal of points.

50 RTK points from the first part were used again to determine the difference of z-values between RTK and filtered TLS points. Based on the same coordinate between those points, the elevation values were compared. If there were no TLS point available on the same coordinate, the nearest point would be selected within 1 meter range. As a result of filtering process, only 31 TLS points had met the requirement. The points had reduced from 50 to 31 because several points nearby RTK data had been removed during the process. Figure 7 shows the map of RTK and selected TLS points after filtering process in the study area.
The difference between z-values from both TLS and RTK data were plotted in figure 8. The figure clearly showed that there was no significant difference between Z value of RTK and TLS points after filtering process. The difference between those values was less than 1 meter.

Figure 8. The difference between TLS and RTK data after filtering process.

The RMSE values were also calculated to measure how much error between TLS and RTK points. The result showed that all 31 points were having small RMSE with no point obtained RMSE value more than 0.1. Table 2 represents the RMSE value for each of the TLS points.

Table 2. RMSE of TLS data after filtering process.

| No. | RTK   | TLS   | RMSE | No. | RTK   | TLS   | RMSE |
|-----|-------|-------|------|-----|-------|-------|------|
| 1   | 68.924| 68.870| 0.009| 16  | 67.681| 67.780| 0.017|
| 2   | 68.742| 68.650| 0.016| 17  | 67.141| 67.610| 0.082|
| 3   | 67.246| 67.260| 0.002| 18  | 67.462| 67.700| 0.041|
| 4   | 67.384| 67.570| 0.032| 19  | 67.601| 67.470| 0.023|
| 5   | 67.064| 67.140| 0.013| 20  | 67.362| 67.140| 0.039|
| 6   | 68.594| 68.480| 0.020| 21  | 67.885| 67.780| 0.018|
| 7   | 68.422| 68.350| 0.013| 22  | 67.566| 67.540| 0.005|
| 8   | 68.383| 68.220| 0.028| 23  | 67.423| 67.380| 0.007|
| 9   | 68.465| 68.260| 0.036| 24  | 68.57 | 68.440| 0.023|
| 10  | 68.651| 68.660| 0.002| 25  | 68.703| 68.700| 0.001|
| 11  | 68.962| 69.240| 0.048| 26  | 68.643| 68.480| 0.028|
| 12  | 69.239| 69.240| 0.000| 27  | 68.581| 68.480| 0.018|
| 13  | 68.234| 68.180| 0.009| 28  | 68.653| 68.660| 0.001|
| 14  | 68.881| 69.110| 0.040| 29  | 68.547| 68.420| 0.022|
| 15  | 69.076| 69.280| 0.036| 30  | 67.648| 67.760| 0.019|
|     |       |       |      | 31  | 67.733| 67.760| 0.005|

4. Conclusion
This study showed that the z-values from terrestrial laser scanning (TLS) are totally reliable because the difference between z-value from TLS and RTK is small especially when the point is located in canopy-free area. Thus, this study proposes that laser scanner should be located on route and not placed in canopy area to reduce elevation errors. Another finding of this study is when using TLS data, filtering is a critical stage before doing further analysis. This paper showed that the RMSE value
decreased significantly after the filtering process. In addition, filtering process could reduce the size of data which results in reducing the storage space and processing time.

References
[1] Warner T a, Lee J Y, McGraw J B, Hill D a and Leckie D G 1999 Delineation and identification of individual trees in the Eastern Deciduous Forest Automated Interpretation of High Spatial Resolution Digital Imagery for Forestry, Int. Forum pp 81–91
[2] Samal A, Brandle J R and Zhang D 2006 Texture as the basis for individual tree identification Inform Sciences 176(5) 565–76
[3] Reitberger J, Heurich M, Krzystek P and Stilla U 2007 Single Tree Detection in Forest Areas With High-Density Lidar Data Int. Arch Photogram Remote Sens Spatial Inform Sci 36/(3/W49B)) pp 139–144
[4] Haile A and Rientjes T 2005 Effects of LiDAR DEM resolution in flood modelling: A model sensitivity study for the city of Tegucigalpa, Honduras Proc. of ISPRS Workshop Laser Scanning 2005 pp 168–73
[5] Sarker L R, Nichol J and Mubin A 2013 Developments in Multidimensional Spatial Data Models ed Abdul Rahman A et al (Berlin, Heidelberg: Springer Berlin Heidelberg) pp 69-83
[6] Abdullah, A. F., Vojinovic, Z., Price, R. K., & Aziz, N. A. A. (2012). Improved methodology for processing raw LiDAR data to support urban flood modelling accounting for elevated roads and bridges. Journal of Hydroinformatics 14(2) 253–69
[7] Li Y, Yong B, Wu H, An R and Xu H 2015 Road detection from airborne LiDAR point clouds adaptive for variability of intensity data Optik 126(23) 4292–98
[8] Jones K L, Poole G C, O’Daniel S J, Mertes L a K and Stanford J a 2008 Surface hydrology of low-relief landscapes: Assessing surface water flow impedance using LIDAR-derived digital elevation models Remote Sense of Environ 112(11) 4148–58
[9] Vosselman G, Gorte B G H, Sithole G and Rabbani T 2004 Recognising strucutre in laser scanner point clouds Int. Arch Photogram Remote Sens Spatial Inform Sci vol XXXVI pp 33–8
[10] Vozikis G, Haring A, Evangelos Vozikis E, Kraus K 2004 Laser Scanning: A New Method for Recording and Documentation in Archaeology Proc. of FIG Working week 2004 “The Olympic Spirit in Surveying” (Athens Greece)
[11] Srinivasan S, Popescu S C, Eriksson M, Sheridan R D and Ku N-W 2014 Multi-temporal terrestrial laser scanning for modeling tree biomass change. Forest Ecol and Manage 318 304–17
[12] Barneveld R J, Seeger M and Maalen-Johansen I 2013 Assessment of terrestrial laser scanning technology for obtaining high-resolution DEMs of soils Earth Surf Proc Landforms 38(1) 90–4
[13] Ehlert D and Heisig M 2013 Sources of angle-dependent errors in terrestrial laser scanner-based crop stand measurement Comput Electron Agric 93 10–6
[14] Dowman I 2004 Integration Of Lidar And Ifsar For Mapping Proc. of XXth ISPRS Congress 12-23 July 2004 (Istanbul, Turkey Commission 2)
[15] Abdullah A F, Rahman A and Vojinovic Z 2009 Lidar algorithms for urban flood application: Review on current algorithms and filters test Int. Arch Photogram Remote Sens Spatial Inform Sci XXXVIII (Part 3) pp 30-6