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Assessment on Slope Mapping using Airborne Laser Scanning and Terrestrial Laser Scanning

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ABSTRACT

This study is about the evaluating the differences of two techniques of Airborne Laser Scanning (ALS) and Terrestrial Laser Scanning (TLS), by carried out an assessment on slope mapping. This study is carried by assessing the Digital Terrain Model (DTM) of a slope in Habu, Cameron Highland Pahang. The further slope assessment is done based on the difference slope class using slope map and slope aspect by ALS technique and TLS technique. These two techniques of data collection provide a three-dimensional data point. However, since both techniques is operating in a different platform where the ALS is a kind of data collection from the air platform while TLS is only based on the ground surface, there might be a slight differences in data production even though the use of the same slope is controlled. Hence, at the end of this study, the differences between these two data collection of ALS and TLS could be compared.

Keywords: *Airborne Laser Scanning, Terrestrial Laser Scanning, Digital Terrain Model, Slope Mapping.*

INTRODUCTION

The slope mapping is a topographic map showing changes in elevation on a highly detailed level. There are many ways to gather data and information for slope mapping. Airborne Laser Scanner and Terrestrial Laser Scanner are among the best two instruments for data collection in slope mapping studies. Slope mapping is normally been used to evaluate particular site and to visualise the surface of earth at slope area.

Airborne Laser Scanning (ALS) is the laser scanner systems are installed in an airplane for the purpose of measuring the height or elevation of the terrain. The system is fully automatic method from the very beginning of flight planning, data acquisition and the generation of digital terrain model. ALS is operated with the principle of laser (Ruijin Ma, 2005). It can determine the distance to the Earth's surface by measuring the time-of-flight of a short flash of infrared laser radiation, by emitting laser pulses which travel to the surface. The distance is obtained by taking the speed of the light (Wehr and Lorh,1999). Accuracy can be defined how closely the measured values are believed to the true values. In ALS, the accuracy is based on the elevation of the data points, where the ALS produced about 5-15cm for vertical (Z) accuracy and the horizontal (X and Y) accuracy is 30-50cm (Baltsavias, 1999). With these two accuracies, ALS data can obtain precise topographic features.

ALS has the specialty in less time consuming for processing with about 12 hours needed for acquisition of 1000km^2 and 24 hours for processing the generation of DEM of the same area, 1000km^2. Besides, ALS is known as weather and light friendly as the data collection is not affected by the sun inclination and at night or even during bad weather (Frank et al., 2013). The ALS is proven to have the minimum cost for the data collection to complete the job by considering the speed, accuracy and density data (Veneziano et al., 2002). ALS could provide DEM for topographic and bathymetric survey in shoreline mapping. Shoreline mapping used LiDAR points of topo-bathy and then transformed to tidal datum using specific software (eg: VDatum software), followed by creating shoreline contour from DEM and presented in the graphics (White, 2011). In urban modelling, the ALS could help in the process of modelling the building forms by attempting to fit standardised building types to the residual data points after an estimated bare earth terrain surface has been removed (Zhou, 2012).

Terrestrial Laser Scanning (TLS) is a ground base device that used to scan at a range of scales from very small objects to very large monuments. The scanner scans an object's surface recording shape and produced XYZ points. Same as ALS, TLS is also used the principle of laser in data collection. The distance and direction of the laser beam are measured, and processed to produce 3D coordinates. Accuracy of the TLS could be said that 1: 10,000 which is stand for 1mm accuracy for 10m range (Pfeifer et al., 2014). TLS produced a very high-density data where the distance between adjacent measured points can be up to several tenth of a millimetre which provides information on every detail of the object.

The advantages of using TLS method is that its data acquisition's rate is very high resolution and about up to several thousand points per second. The precision is high since it can detect even in centimetre length. The possibility to get the data on subvertical or overhanging rock wall is very high due to the high sensitivity of the scanner. Nowadays, TLS is widely been use in various field such in power industry where the raw data (point cloud) could create 3D models and topographic maps. While in mine survey, TLS data could be used to compute quantities of earthwork, DTM and 3D of quarries and pits. The applications of TLS in hydrotechnic field also can be found while measuring the different hydrotechnic structures (Fryskowska *et al.,* 2009). It can measure the navigation of lock gates which consists of two parts and are fastened in two bearing positioned on vertical line. Its measurements cover the measurement for gates form, the measurement for determination and measuring the gate deformation. TLS is also could be used in the reconstruction of 3D tree stem model of plant. The TLS is said could automatically reconstruct tree stem models and it is the step towards virtual forest scene generation. The TLS technique could provide valuable data on canopy structure. It works like the scanner scan the trees from 20 or 21 different positions and the 3D- point cloud of every tree was translated into a point cloud grid with defined distances between the data points to standardise the spatial resolution data (Kelbe *et al.,* 2014).

In Malaysia, there are many landslide incidents which involve slope area. The slope needs to be monitored in order to prevent any major problem happen in future. The monitoring of slope required high resolution data to determine the condition of slope during landslide incident. Therefore, the study will investigate the high-end technology using ALS and TLS for slope mapping application. A specific study of slope attribute of each slope classes will be conducted to determine the different product from ALS and TLS.

STUDY AREA

The site area for this study is in Habu, Cameron Highland. The study area is only limited with dimension of 100 m height by 180 m width. This site is selected for this study is due to the condition of the area that has many slopes. Some of the slope had undergone slides for several times. Since the slides occurred, the slopes are now being under supervision and several studies had been carried out. Figure 1 shows the condition of slope of the site area.

Figure 1: Slope Condition of Site Area of Habu (Source: Google Earth Map)

METHODOLOGY

Figure 2 resembles the phases that involved in this study. There are five phases altogether. The first phase is about the preliminary study. Generally, preliminary study is done by carried out some research about previous study on related topics. The previous study is based on the journal, conference paper and thesis. The second phase is data acquisition. This study consists of two sources of data acquisition, which are from ALS and TLS. The ALS data is capture from a scanner in a flight of airborne while the TLS is obtaining from a scanner on the ground of survey work. The third phase is data processing. There are two software used for this phase. The fourth phase of this study is the gaining the result outcome. The expected outcome for both data is a slope map and aspect map, which are generated using DTM. The result of slope map and aspect map will be analysed on the data analysis section of the last phase for this study based on their attribute and classes.

ALS Data Capture

ALS data is provided by a private company that offers ALS services. The data came with the resolution of 50cm point and it is a filtered data and already in the form of Digital Terrain Model (DTM).

TLS Data Capture

TLS data is captured with the Topcon Geodetic Laser Scanner-1500, as shown in Figure 3.2. It is a scanner with built in digital camera. The advantages of this scanner is it is a high-speed scanner with the data collection of emitting the laser beam up till 30,000 points per second which is ten times faster than the previous invention of scanner model and this results that the higher density point clouds can be captured in a shorter time. Besides, it produces clean and ultra-low-noise scan data which can produce a very finest textured of scanned objects. It also provides the data collection in a wide and long range of 500m in range and a very accurate scanner with 4mm distance accuracy at every distance of 150m. Last but not least, this scanner requires ScanMaster Software for powerful Data Processing.

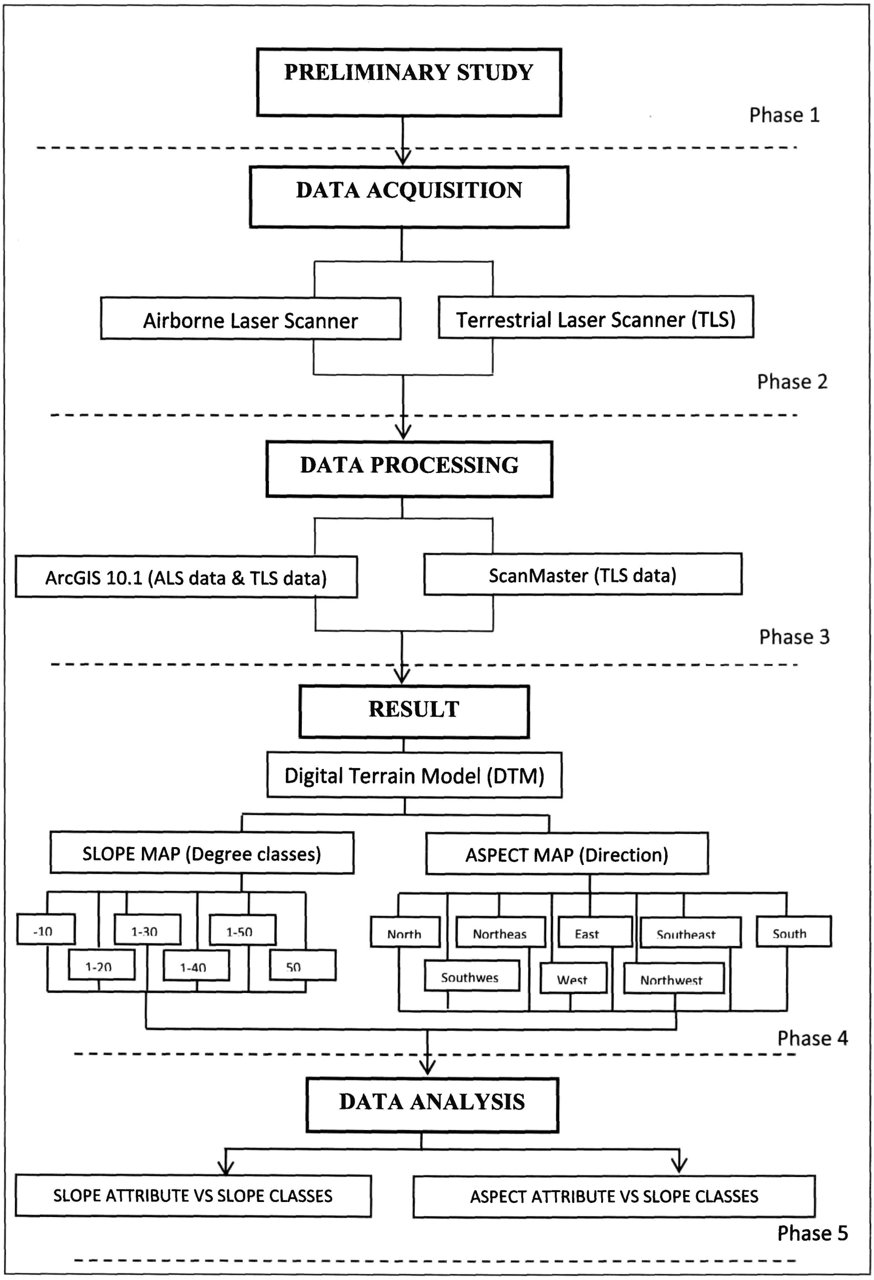

Figure 2: Methodology Flowchart

RESULTS AND ANALYSIS

The data of both scanners are processed until the formation of Digital terrain Model (DTM) which is known as a model to represent the earth surface in digital form. Then, the slope map and aspect map are generated from the DTM. Further analysis is carried out regarding the slope map and aspect map and their attribute against each class for both laser scanners.

Slope Map Analysis

The slope map is produced as in figure 3 from the DTM using ArcGIS 10.1 software. The slope is calculated by the differences between vertical distance to the horizontal distance and the comparison can be expressed in three forms of as an angle, a percentage or as a ratio. For this study, the comparison is made in the form of percentage of slope degree. The generation of slope map for both laser scanners are classified into six classes according to their slope degree within the classes range of 0-10°, 11-20°, 21-30°, 31-40°, 41-50° and >50°. The slope map is then represented in the form line graph in order to ease the process of analysing (Figure 4).

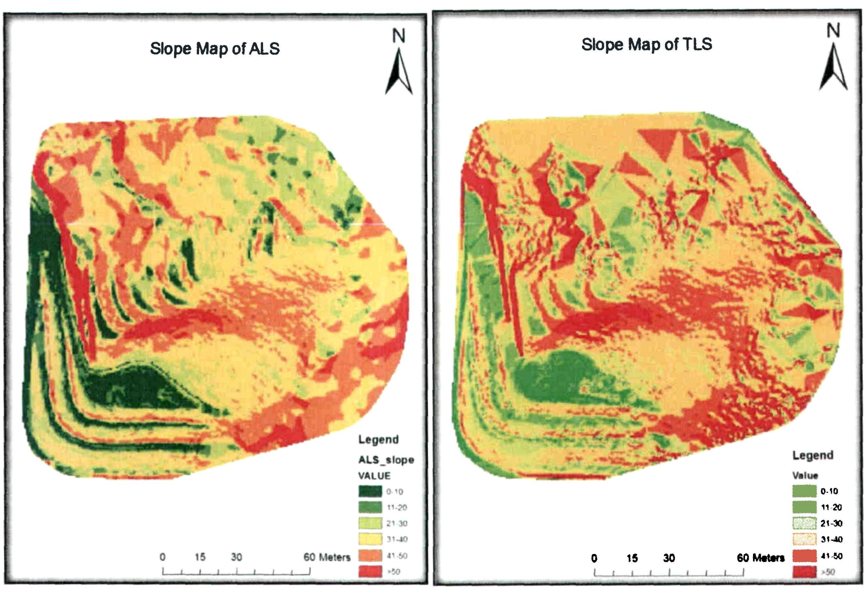

Figure 3: The Slope Map for Both Scanner of ALS and TLS

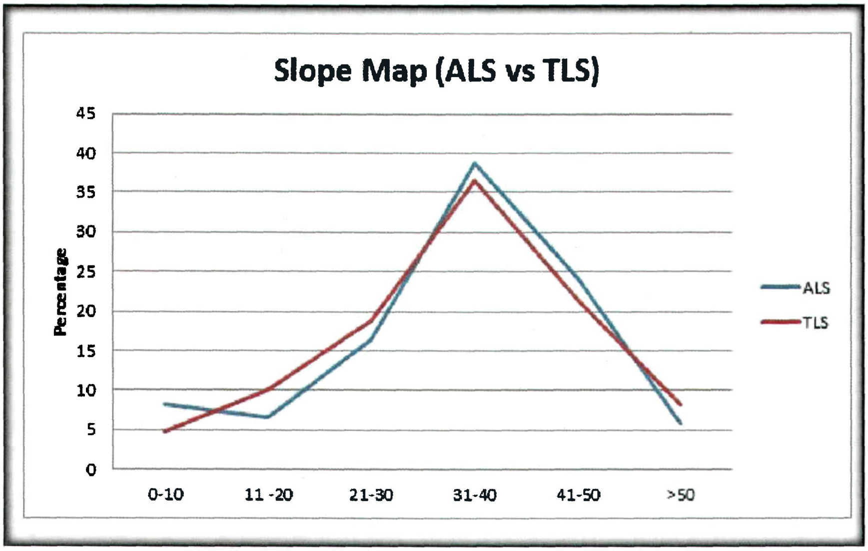

Figure 4: The Graph of Slope Map

Aspect Map Analysis

Figure 5 shows the aspect map of Habu for both scanners and from the figure 6, the ALS data has highest percentage of slope direction compare to TLS data in the direction of Southwest while TLS data has higher percentage in West direction. Since ALS data is able to detect more points at lower-slide area, we can conclude that the Southwest area of the study area has less slide compare to the West area, where in West area the TLS detects such a higher percentage of slope degree.

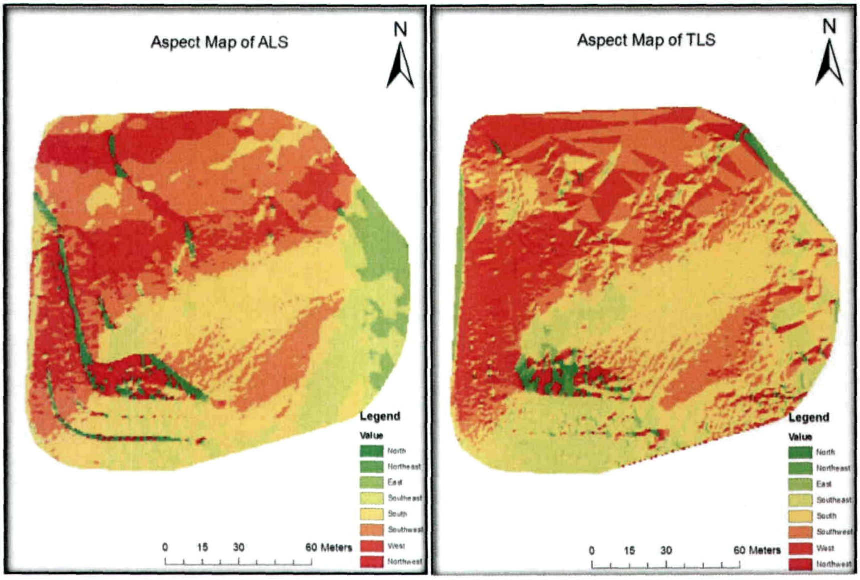

Figure 5: The Aspect Map for Both Scanner of ALS and TLS

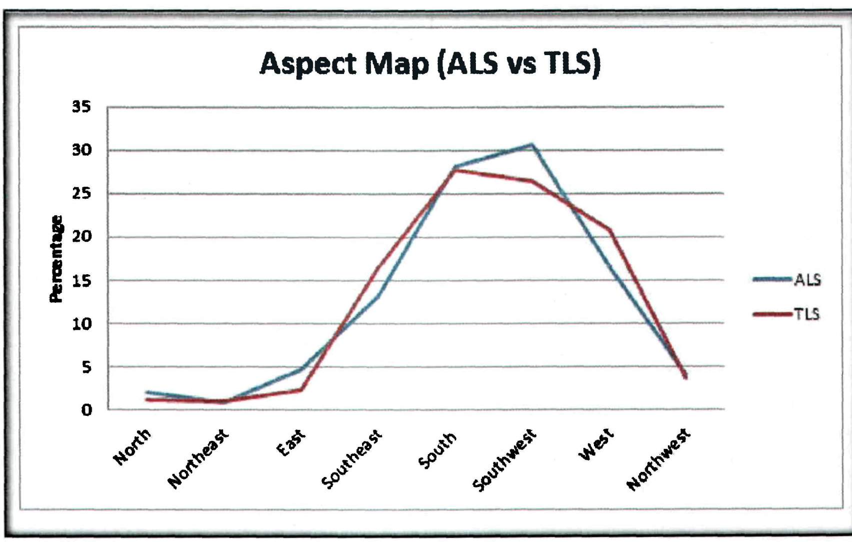

Figure 6: The Graph of Aspect Map

CONCLUSION

ALS data has less ability to scan point data slope with high gradient but still, ALS technique is considered as one of the most accurate data collection as compare to any photogrammetry technique. The ALS data has specialisation in covering the wide area during scanning process, plus it is one of the active remote sensing sensor that could be operate during night time, however the night time work operation might has barrier in terms of navigation issue with satellite system. Meanwhile for TLS, differ from ALS, it is able to scan slope data with high gradient. This indicates that TLS data produced better slope map compare to ALS data as it contains detail result. TLS is also well-known as an accurate data collection and could been applied in various field.

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