Geodetic laser scanning technique for characterizing landslides along high-risk road zone: Applications and limitations

Khamarrul Azahari RAZAK, Rabieahtul ABU BAKAR, Netherlands, Quek Yong WAH, Wan Abdul Aziz WAN MOHD AKIB, Malaysia

Key words: Terrestrial-based LIDAR; Topography analysis; Malaysian Tropical Rainforest

SUMMARY

This paper presents a new insight of geodetic laser scanning (GLS), which is synonym to terrestrial laser scanning (TLS) for geometrically characterizing landslides along high-risk transportation zone in the tropics. This paper provides recommendations at planning stages and measurement phases particularly on data acquisition in the tropical environment. More emphasizes are given to application and limitation of medium-range laser scanner towards large-scale landslide investigation. Several data acquisitions on landslide cut-slopes were carried out during the field campaign in 2009 at the Cameron Highlands, Malaysia. The space-based geodetic technique was applied for establishing a local geodetic network and providing an accurate local coordinate to the GLS observation. Benefits of Topcon's GLS over conventional surveying techniques revealed in the form of its high accuracy and precision data, its large capturing area, its very high speed data collection and its unique ability to acquire characteristics of structurally complex landslide anomalies (e.g. tilted trees) and geomorphic features. A high density of point cloud on such an unprecedented scale permits a detailed topographic analysis and subsequently improves the certainty of a local landslide inventory. Despite the remarkable development in laser-based technology, few numbers of limitations are highlighted in this paper, with regards to complexity of tropical landscape, accessibility, practicability, and technicality (e.g. data handling). This paper deals on how GLS-derived products can be intensively utilized to investigate landslides in the tropics, associated to utilization of advanced technology for landslide mapping in Malaysia as revealed in National Slope Master Plan 2009-2023. We concluded that GLS is of great interest to supersede the capability of traditional surveying techniques in providing highly accurate and reliable topographic data in equatorial regions. It is an important tool to support for emergency response in the context of disaster management and in dealing with hazard and risk assessment in the tropics.

Geodetic laser scanning technique for characterizing landslides along high-risk road zone: Applications and limitations

Khamarrul Azahari RAZAK, Rabieahtul ABU BAKAR, Netherlands, Quek Yong WAH, Wan Abdul Aziz WAN MOHD AKIB, Malaysia

1. INTRODUCTION

The acquisition of precise terrain information has been of utmost importance for a better understanding of natural disasters particularly that occurs in the equatorial forest regions. This paper illustrates further on landslides, one type of mass movement which is defined as a moving down slope of soil, rock, and organic materials under the forces towards the gravity (Montgomery, 1997). The International Disaster Database EM-DAT (CRED, 2010) released that more than 15 million people were directly affected and over 60,000 were killed caused by landslides over 110 years period. There is a need to acquire faster, utilize more accurate and more efficient terrain data over the affected regions. Recent advances in sensor electronics open up the rapid development of exisiting remote sensing techniques. Thus, landslide investigations become more interesting with possibility of collecting highly accurate 3D terrain information within a relatively short period of time.

Nowadays, Geodetic Laser Scanning (GLS) is synonym to several other names such as terrestrial laser scanning, ground based remote sensing or 3D laser scanning. It has become a significant technology for topographic mapping to-date. A GLS uses laser scanner device that rapidly emits controlled pulsed waveforms of laser light and analyzes the returned waveform. This makes it possible to measure the *x,y,z* positional information of the objects struck by the laser pulse (Buckley et al., 2008; Heritage and Large, 2009). The output is delivered in the forms of very high density 3D point clouds. This technology has advantages over conventional surveying techniques particularly over the areas that are hitherto, too inaccessible, dangerous to survey or limited in line of sight observation.

GLS is widely used for acquiring accurate and dense 3D geo-landscape in which landslide geometry can be properly observed and topographical-landslide based analysis can be done. High resolution point clouds of the topography demonstrates several applications for landslide investigations (Hobbs et al., 2002; Gibson et al., 2003; Rowlands et al., 2003: Bitelli et al., 2004; Hsaio et al., 2004; Ruiz et al., 2004; Rosser et al., 2005; Mikos et al., 2005; Armesto et al., 2009; Jaboyedoff et al., 2009; Jaboyedoff et al., 2010). They are primarily applied over the non-forested terrain area. As compared to traditional methods (e.g. surveying or photogrammetric techniques), GLS is superior in the context of providing a large data coverage over many discrete points on measurement surface, less labour intensive and relatively short in data acquisition time. They offer advantages to be utilized for landslide study over densely or rapidly re-vegetated areas. Up to date, there has been little effort to utilize the GLS for landslide investigation along the transportation route in the tropics. This paper tries to fill this gap.

In Malaysia, landslides mostly occur due to intense and prolonged rainfall. The instability problems in highland regions are associated to tropical residual soil cut slopes especially during the two monsoon seasons (Othman et al., 1991). JKR (2009) reported that almost 55% of reported landslides occurred in the hilly area, where Cameron Highlands is one of affected region. Pradhan and Lee (2009) assigned the road zone in the Cameron Highlands as the highest susceptible index to landslides. Heavy cloud coverage throughout the day restricts the application of airborne laser scanning, while the complexity of forest bottom layer limits the capability of surveying techniques over the areas. Figure 1 demonstrates scenarios in the tropics in which geodetic laser scanning is potentially to be utilized for landslide investigation along the transportation route over highland areas in Malaysia.

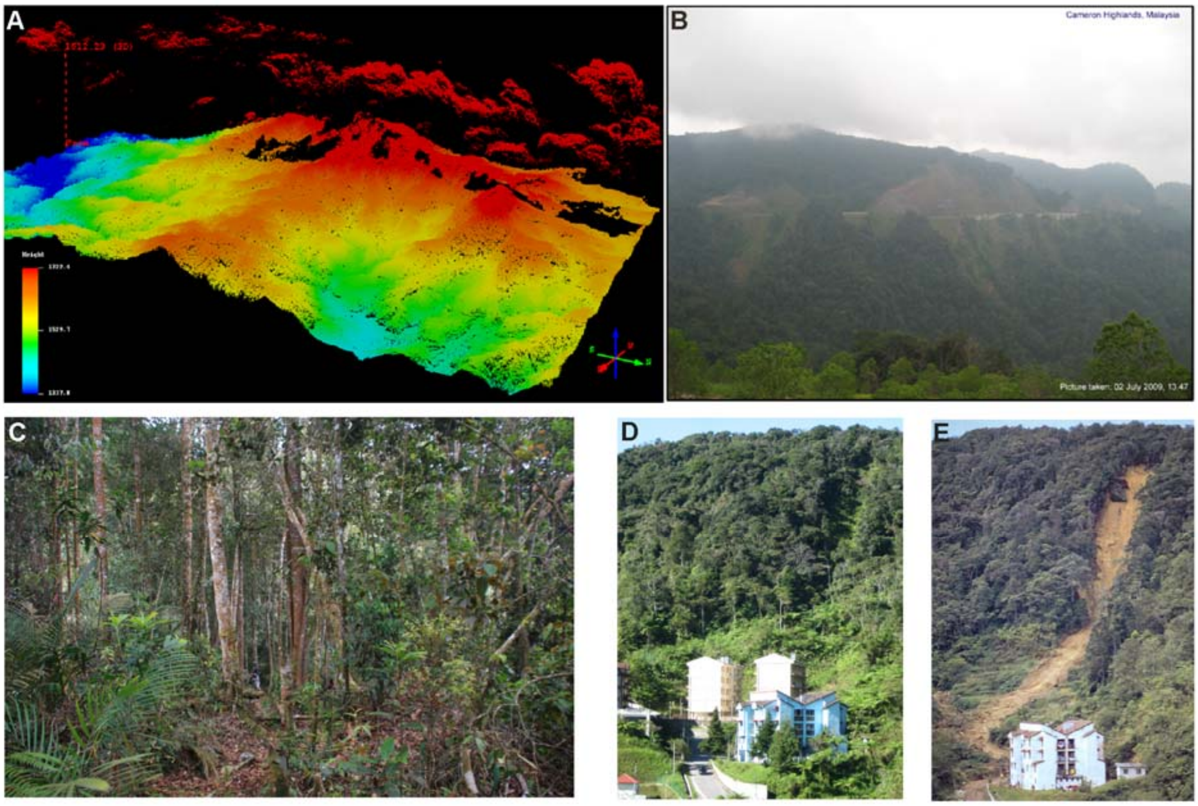

Figure 1: Scenarios in the tropics (Cameron Highlands, Malaysia). A) airborne LIDAR point clouds viewing the heavy clouds, B) photo showing road along the cut-slopes and cloudy landscape, C) complexity of bottom layer of high dipterocarp forest, D) & E) re-vegetated on landslide zone (left picture, adopted from Jasmi (1998) a debris flow occurred on Oct 1996, and right picture taken on Sep 2009).

This paper demonstrates the utilization of geodetic laser scanning for characterizing several landslides located along the main roads in the Cameron Highlands, Malaysia. Limitation of this technique is also highlighted. The space-based geodetic measurement was also elaborated, which particularly is needed for data acquisition in the tropics.

2.0 STUDY AREA

The study area is located within the lowland equatorial evergreen rainforest environment in the Cameron Highlands, Malaysia (Figure 2). Four specific study areas located along the main road were selected based on the principle that the past is the key to the future (Varnes, 1984). Typically, landslides will likely occur in the areas where they occurred in the past. Lithologically, Cameron Highlands is mainly characterized by megacrystic biotite granite. Due to tropical weathering process, this type of homogenous rock forms several residual soils at different thickness. They varied from Grade VI (a complete weathering profile – residual soils) to Grade V (complete decomposed rock) and Grade IV (highly decomposed rocks)(Brand, 1989). The construction of roadwork has taken place in hilly terrain particularly on the side slopes. The road-cut slopes generally create instability problem towards cohesion of the original residual soils. The intense and prolonged rainfall often triggered the slope failures over these areas (Othman et al., 1991).

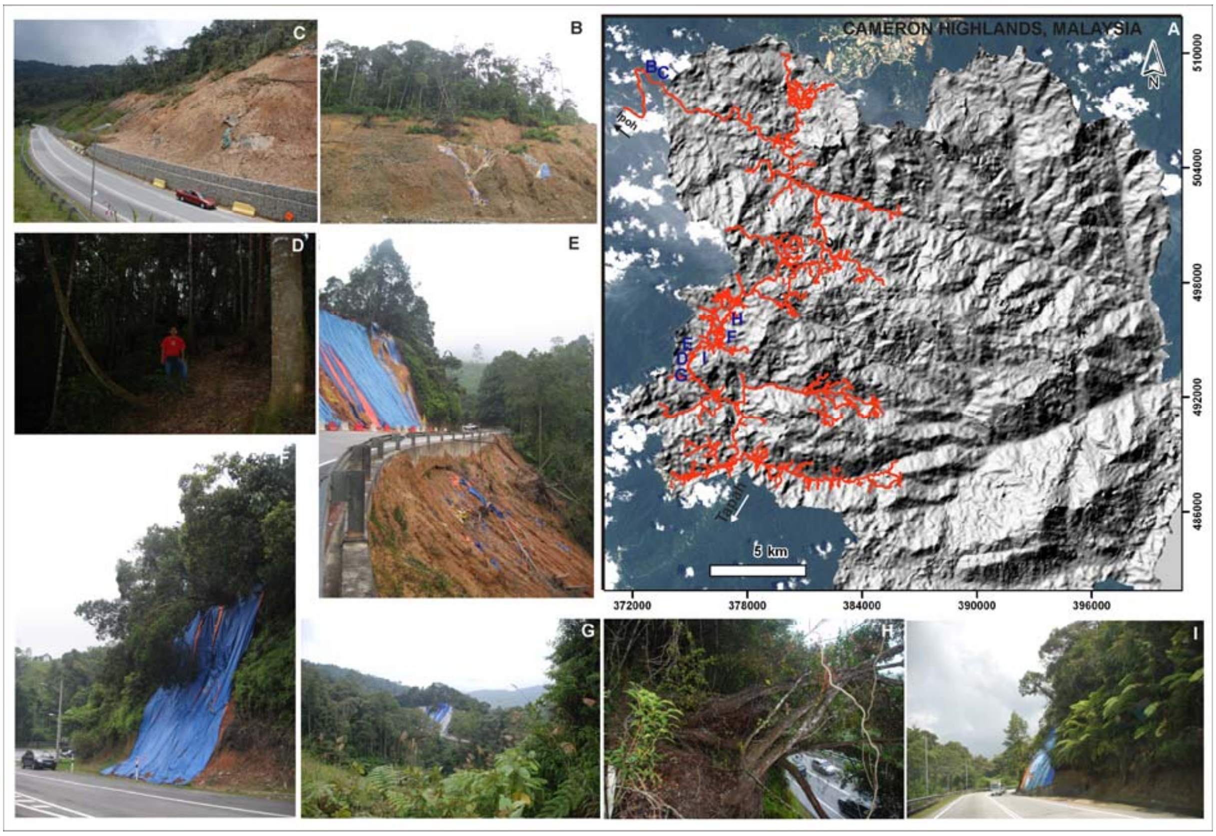

Figure 2: Location of the study area in the Cameron Highlands. A) Shaded relief derived from ASTER GDEM 30m overlaid on ALOS AVNIR-2. Red line indicates road network. B-I) field photos showing the specific study areas.

The study area frequently experiences heavy rainfall characterized by a mountainous landscape and situated in a dense equatorial forest zone. The average mean daily temperature is 27° C while the mean daily maximum and minimum temperatures range between 31.4° C and 23.5° C, respectively. The mean daily humidity varies between 60.9% and 96.8%. The annual rainfall of the Cameron Highlands is very high (up to 3000mm per year). The two rainy seasons are the south-west monsoons from April to October and the north-east monsoons from October to February. The topograpy is characterized by rugged terrain with 66% of the slopes having gradients of more than 20^o. About 86% of the Cameron Highlands is forested area, 8% under agriculture, 4% occuiped by settlements, and the remainder used for other purposes. Wyatt-Smith (1995) classified the forest types over the Cameron Highlands into lowland evergreen rainforest (hill dipterocarp forest and upper dipterocarp forest), lower montane forest (montane oak forest), and upper montane forest (montane ericaceous forest).

3.0 METHODS

3.1 Space-based geodetic (SBG) measurement

A space-based geodetic measurement was conducted for establishing several control stations over the study area. Eight stations were observed using a static observation mode. These stations are required to register the 3D models (scanned point clouds) into a local coordinate system (e.g. rectified skew orthomorphic-RSO). This is an important component of GLS and thus, often affects the quality of GLS observation and period of data acquisition.

In this study, we utilized two set of Topcon HiPer Pro Wireless Long-Range Integrated GPS and receiver. Accuracy of the static observation can be up to 3 mm ± 5 ppm horizontal and 3 mm ± 5 ppm vertical. We also employed a real time kinematics observation for certain cases, which the accuracy can be up to 10 mm ± 1 ppm horizontal and 15 mm ± 1 ppm vertical. However, accuracy of SBG measurement in the tropics is not always the case and we experienced that the observed data are slightly less accurate than what the company offered. We used coordinates of known control stations (TBO and KTR) setup by the Department of Survey and Mapping Malaysia. A Topcon tool office software version 6.11 was used for determining the controls stations coordinates with standard GPS processing modules.

3.2 Geodetic laser scanning (GLS) measurement

We utilized a geodetic laser scanner for topographic mapping and modeling operations which was operated on a stationary position by mounting it on a tripod. This static terrestrial laser scanner implies simultaneous measurement of slant range by a laser range finder and the two associated angles by angular encoders in the horizontal and vertical rotations. Further detail on metadata for the geodetic laser scanning campaign is given in Table 1. The field campaign was carried out in July 2009, using a Topcon GLS-1000 which can be handled like a total station surveying scheme. The occupation and back-sight observation yield a better data acquisition inside the tropical rainforest areas. A traversing scheme makes this dual-axis tilt instrument suitable to be applied for complex scanning areas (e.g. short bended roads, high vegetation covering the side-roads and limited coverage of horizontal/vertical scanned views).

With regards to registration – the process of aligning data taken from different scan positions into the same global coordinate system, this technology offered tie points registration, georeferencing, and occupation/back-sight registration. Topcon GLS-1000 is capable of stand-alone operation without the disturbances of laptops, cables and heavy batteries. Among the main drawbacks of GLS are requirement of a line of sight which likely difficult for direct observation in the tropics and therefore need many scanning stations in order to complete an entire 3D model. While a higher resolution and accurate of scanned surface area required more scanning time or observation.

Table 1: Metadata for the geodetic laser scanning campaign.

Acquisition (month/year)	July 2009
Laser scanner system (technique)	Topcon GLS-1000 (pulsed-based)
Color digital imaging	2.0 megapixels digital camera
Maximum range at specified reflectivity	330m at 90 % and 150 mm at 18 %
Single point accuracy	4mm at 150 m
Dual axis compensators (accuracy)	6” for vertical and horizontal angles
Scan density (spot size)	6mm at 40 m
Scan density (maximum sample density)	1 mm at 100 m
Speed (pts/second)	3000
Laser Class	Invisible laser class 1
Field of view (V x H deg)	70 x 360 deg
Power supply	Internal battery (4 hours / 4 units)
Power supply (size and weight)	70 x 40 x 45 and 0.2 kg
Data storage	SD card
Software	ScanMaster Office

Four specific study areas were scanned with resolution of 30 cm. Each site consists of two SBG stations which were used to observe the location of target plate or holders using Total Stations or RTK measurement technique. The target plate was used if traversing scheme is applied whereas, several target holders were used where the scanning implies directly onto scanned areas. The combinations of the plates are needed when the scanned areas located on the densely vegetated areas. We used standard modules of laser data processing embedded in the ScanMaster Office software for downloading, viewing, filtering and 3D registration.

3.3 Characterization of tropical landslides along high-risk road zones

We characterized the landslides by analyzing the local topographic roughness and slope-based filter which were presented by Glenn et al., (2006) and Kasai et al., (2010), respectively. The topographic roughness is measured by calculating the standard deviation of ground points within higher grid cell which associated to de-trended process of LIDAR point clouds. This pre-processing step is required to remove the trend in the height due to the instrument error and surface variability (Davenport et al., 2004). By taking into account the surface of most landslides is rougher than neighbouring unfailed slopes (McKean and Roering, 2004), the topograhic roughness map was used for analyzing landslide accumulation zones and further examining the mechanisms of landsliding. Slope angle filter can be used for calculting the slope unit features in local scales (Iwahashi et al., 2003) and also provides understanding on local hill-slope processes driving landslide movement (Kasai et al., 2010). Sidle and Ochiai (2006) described the slope angle as an important role for driving force of landsliding, particularly the shallow landslides which associated to slope steepness that mainly influenced by the soil strength.

4.0 RESULTS AND DISCUSSION

Table 2 shows the accuracy of local geodetic network represented in the form of standard deviation of each coordinates. These coordinates are later converted into a RSO coordinate system. The accuracy of target holders fluctuates within sub-millimeter level. A detail result of target holders coordinates are not presented here.

Table 2: Coordinates and standard deviations of each control stations used for GLS observation in the Cameron Highlands, Malaysia

Stations	Latitude (Std Dev)	Longitude (Std Dev)	Ellipsoid height (Std Dev)
TBO	4° 27’ 15.636”N	101° 25’ 56.111”	1382.496m
KTR	4° 32’ 49.823”N	101° 24’ 53.760”	1217.652m
Stn1A	4° 35’ 52.480”N (0.003m)	101° 20’ 50.450” (0.004m)	1382.608m (0.005m)
Stn1B	4° 35’ 55.832”N (0.002m)	101° 20’ 49.750” (0.004m)	1386.282m (0.005m)
Stn2A	4° 27’ 54.021”N (0.002m)	101° 21’ 58.988” (0.004m)	1342.624m (0.004m)
Stn2B	4° 27’ 51.751”N (0.002m)	101° 22’ 00.747” (0.003m)	1346.984m (0.003m)
Stn3A	4° 28’ 02.829”N (0.002m)	101° 22’ 55.157” (0.002m)	1395.997m (0.005m)
Stn3B	4° 28’ 28.782”N (0.003m)	101° 25’ 56.111” (0.005m)	1382.496m (0.006m)
Stn4A	4° 28’ 03.478”N (0.003m)	101° 22’ 04.625” (0.003m)	1397.791m (0.004m)
Stn4B	4° 28’ 29.863”N (0.003m)	101° 22’ 53.961” (0.003m)	1455.122m (0.005m)

Figure 3 presents the results of the GLS campaign which were delivered in the form of images (digital photographs) and point clouds of four specific study areas. Figure 3B clearly indicates the open landslide zone and bended trees caused by a retrogressive landslide. Figure 3D and 3F indicates the point cloud taken from one scanning location and need to be registered with other scanned site. Figure 3H shows the point cloud observed the back-tilted tree on the landslide crown. Figure 3A, C, E, G illustrate the images of the scanned areas.

As mentioned previously, a local topographic roughness map reveals the local changes of topographic roughness. Glenn et al., (2006) addressed that the higher value of surface roughness indicates the more local topography that fluctuates on the ground. The topographic roughness of four landslide zones ranging between 0.1 and 1.5 m. Figure 4 indicates the topographic roughness of landslide zone 1 was up to 1.5 m. The slope angles of the scanned areas ranges from 20^o and 90^o. A higher concentration of the roughness appeared on the slope of 20 to 60 degrees – with average slope at 41 degree as shown in Figure 4(A). During the heavy rainfall, a concave slope presumably captures more water or displaced materials. If this situation lasts for a longer period, these area could lead to sudden-failures and generate a landsliding along the cut slope zones.

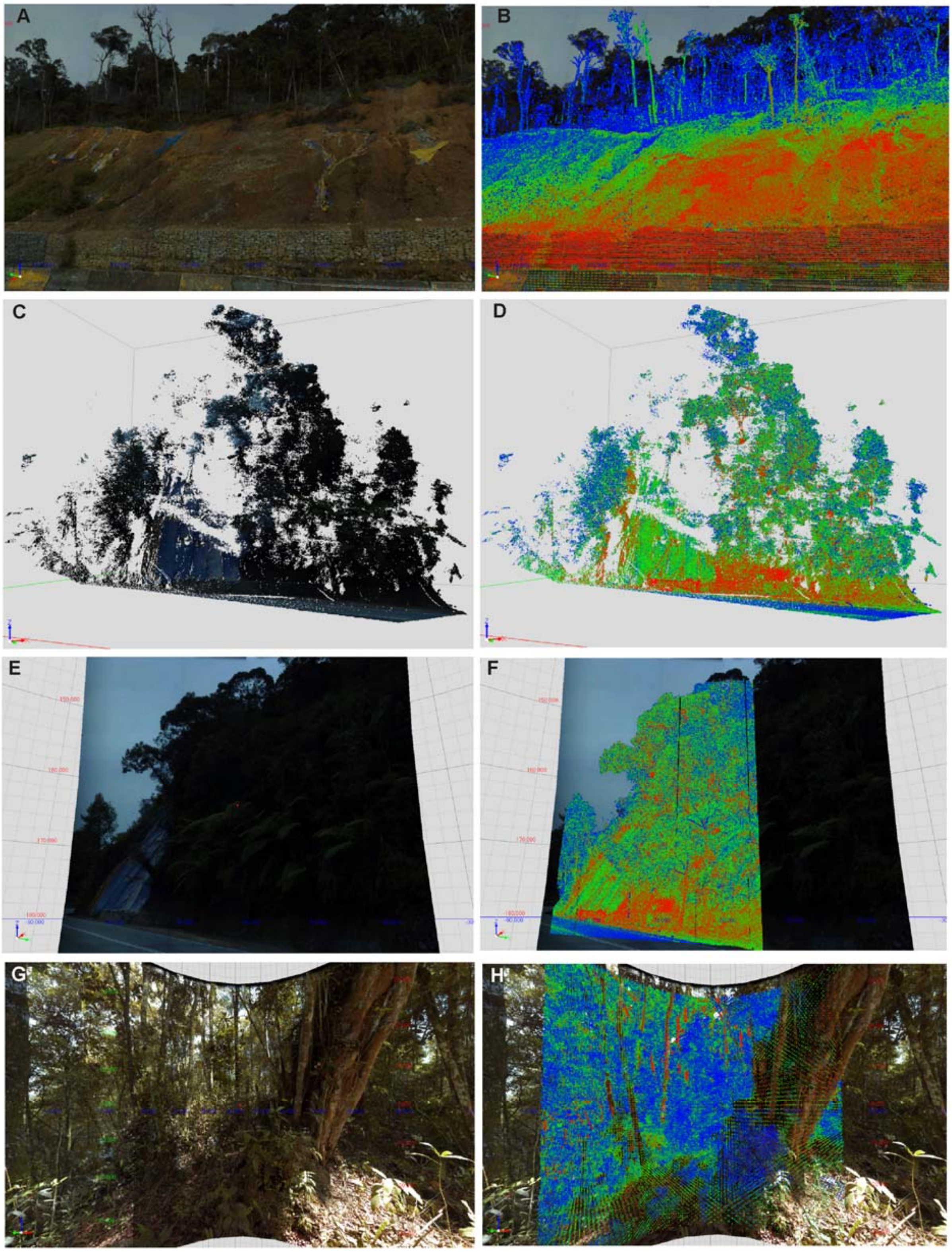

Figure 3: GLS data representing images - digital photographs (I) and 3D point clouds (II)

A) retrogressive landslide B) slope failures along road-cut zone, C) land sliding at zone 3, D) irregular trees located at landslide crown – zone 4.

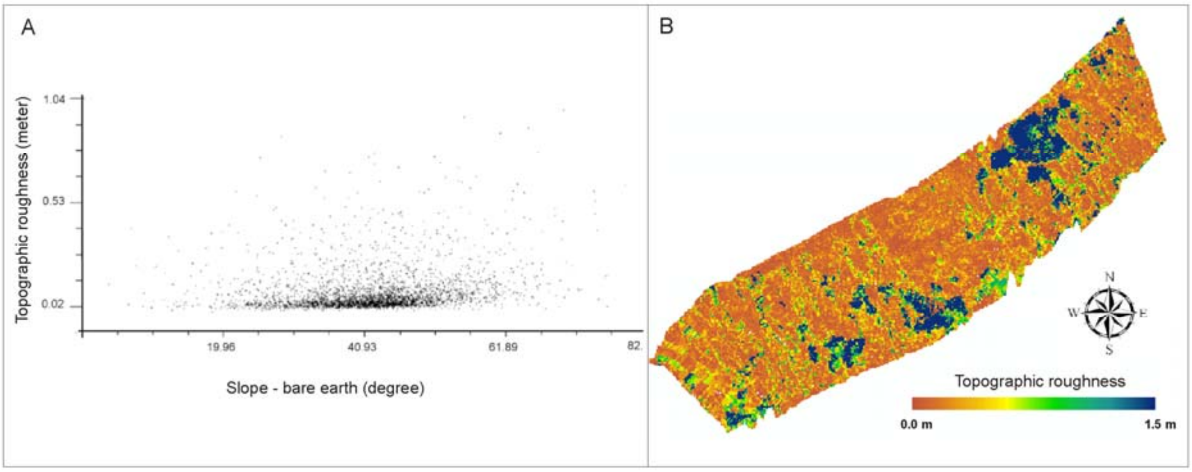

Figure 4: Local topographic roughness analysis of landslide zone 1. A) Scatter plot of topographic roughness and slope of the bare earth, B) Topographic roughness map.

We observed that active landslide components have high topographic variability and undergoes high degrees of deformation. Also, the landslide surfaces are rougher than the neighboring surfaces as appeared on side scarps, tension cracks, and hummocky topography. A future work is to carefully analyze the GLS data on the irregular vegetation such as tilted or fallen trees caused by landslide processes. Figure 5 shows a group of chaotic trees or refer to drunken trees phenomena was selected from one of the scanned area and clearly indicates that they were subjected to series of landsliding that occurred on that particular area. A dense and accurate point cloud of stem bending yields a better physical representation and thus, makes it possible to act as an indicator and relate the spatial of tree anomalies towards landslide activity. Furthermore, a second GLS campaign has been scheduled and the results will be used to analyze the morphological deformation. The continuous observation could lead to a better understanding of spatiotemporal of tropical landslides. In the near future, the utilization of the mobile terrestrial laser scanning for characterizing and monitoring landslides along the roads is much needed. Use of higher density of point clouds of airborne laser scanning acquired using a handheld laser scanner could be a better option for mapping landslides over a larger forested terrain (Razak et al., 2011).

5.0 CONCLUSION

In this study, we presented an application of geodetic laser scanning (GLS) technique for mapping and characterizing landslides located along the high risk road zones in the Cameron Highlands, Malaysia. Although the development of GLS tended to lag behind that of airborne laser scanning, it has a large potential to be utilized for large scale landslide investigation in the tropics. We concluded that GLS is of great interest to supersede the capability of traditional surveying techniques such as Total Stations and RTK-GPS in providing highly accurate and reliable topographic data in equatorial regions. As recommended in the National Slope Master Plan 2009-2023, this technique can be an important tool to support for emergency response in the context of disaster management in the tropics, particularly over highlands areas in Malaysia.

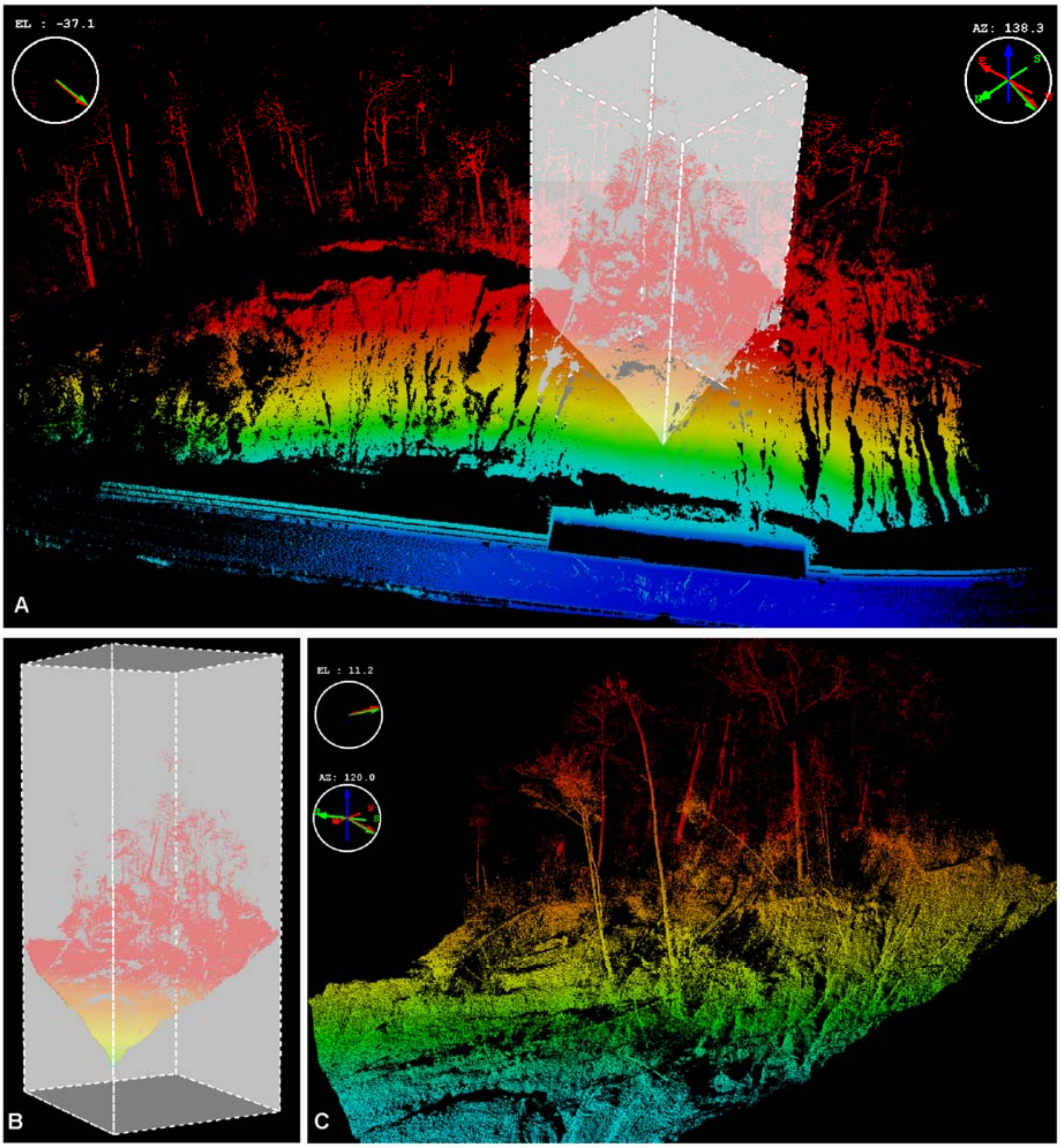

Figure 5: Irregular tree analysis over landslide zone 1: A) B area of interest of the disrupted trees caused by landslide, C) 360000 point cloud showing the tree irregularity on the sliding surface of the tropical landslide in Cameron Highlands (Malaysia).

6.0 REFERENCES

Armesto, J., Ordonez, C., Alejano, L., Arias, P., 2009. Terrestrial laser scanning used to determine the geometry of a granite boulder for stability analysis purposes. Geomorphology 106(3–4):271–277. doi:10.1016/j.geomorph.2008.11.005.

Bitelli, G., Dubbini, M., Zanutta, A., 2004. Terrestrial laser scanning and digital photogrammetry techniques to monitor landslide bodies. In: Proceedings of the XXth ISPRS congress, Istanbul, Turkey, Commission V, WG V/2.

Brand, E.W., 1989. Occurrence and significance of landslides in Southeast Asia. In: Brabb and Harrod (Eds), Landslides: extent and economic significance, Balkema, Rotterdam, pp. 303-324.

Buckley, S.J., J.A. Howell, H.D. Enge, T.H. Kurz, 2008. Journal of Geol. Soc., 165, 625-638.

CRED, 2010. EM-DAT The International Disaster Database. http://www.emdat.be/.

Davenport, I.J., Holden, N., Gurney, R.J., 2004. Characterizing errors in airborne laser altimetry data to extract soil roughness. IEEE Trans. Geosci. Remote Sens. 42, 2130–141

Gibson, A., Forster, A. F., Poulton, C., Rowlands, K., Jones, L., Hobbs, P., Whitworth, M., 2003. An integrated method for terrestrial laser-scanning subtle landslide features and their geomorphological setting. In Aplin, P. and Mather, P.M. (eds.) Proceedings of the Remote Sensing and Photogrammetry Society 2003: Scales and Dynamics in Observing the Environment, Nottingham, 10-12 September 2003.

Glenn N.F, Streutker D.R, Chadwick J, Glenn D.J, Thackray G.D, Dorsch S.J., 2006. Analysis of Lidar-Derived Topographic Information For Characterizing And Differentiating Landslide Morphology And Activity. Geomorphology 73, 131-148.

Heritage, G.L. and A.R.G. Large, 2009. Laser scanning for the Environmental Sciences, Wiley-Blackwell, 278 pp.

Hobbs, P., Humphreys, B., Rees, J., Tragheim, D., Jones, L., Gibson, A., Rowlands, K., Hunter, G., Airey, R., 2002. Monitoring the role of landslides in 'soft cliff' coastal recession. In: Mcinnes, R. And Jakeways, J. (Eds.) Instability - Planning And Management. Thomas Telford, London, 589-600.

Hsaio, K. Lui, J. Yu, M., Tseng, Y., 2004. Change detection of landslide terrains using ground based lidar data. Proceedings of the 20th ISPRS Congress, 12 - 23 July 2004, Istanbul, Turkey Commission VII, WG VII/5.

Iwahashi, J., Watanabe, S., Furuya, T., 2003. Mean slope-angle frequency distribution and size frequency distribution of landslide masses in Higashikubiki area, Japan. Geomorphology 50, 349-364.

Jaboyedoff, M., Oppikofer, T., Locat, A., Locat, J., Turmel, D., Robitaille, D., Demers, D., Locat, P., 2009. Use of ground-based LIDAR for the analysis of retrogressive landslides in sensitive clay and of rotational landslides in river banks. Can Geotech J 46, 1379–1390. doi:10.1139/T09-073.

Jaboyedoff, M., Oppikofer, T., Abellan, A., Derron, M-H., Loye, A., Metzger, R., Pedrazzini, A., 2010. Use of LIDAR in landslide investigations: a review. Natural Hazards, 23p, DOI 10.1007/s11069-010-9634-2.

JKR, 2009. National slope master plan 2009-2023. Jabatan Kerja Raya Raya Malaysia, Cawangan Kejuruteraan Cerun, Kuala Lumpur, Malaysia.

Kasai, M., Ikeda, M., Asahina, T., Fujisawa, K., 2009. LiDAR-derived DEM evaluation of deep-seated landslides in a steep and rocky region of Japan. Geomorphology 113, 57-69.

Mckean, J., Roering, J., 2004. Objective Landslide Detection And Surface Morphology Mapping Using High-Resolution Airborne Laser Altimetry. Geomorphology 57, 331-351.

Mikos, M., Vidmar, A., Brilly, M., 2005. Using a laser measurement system for monitoring morphological changes on the Strug rock fall, Slovenia. Natural Hazards and Earth System Sciences 5, 143 - 153.

Montgomery, C. W., 1997. Fundamentals of geology (3rd edition). Dubuque: Brown.

Othman, M.A., Hassan, N.R.N., Aziz, H.M.A., 1991. A statistical approach to cut slope instability problems in Peninsular Malaysia. In: Bell (Eds), Landslides, Belkema, Rotterdam, pp. 1379-1385.

Pradhan, B., Lee, S., 2009. Regional landslide susceptibility analysis using back-propagation neural network at Cameron Highlands, Malaysia. Landslides 7(1), 13-30.

Razak, K. A., Straatsma, M. W., van Westen, C. J., Malet, J. P., de Jong, S. M., 2011. Airborne laser scanning of forested landslides characterization: Terrain model quality and visualization. Geomorphology 126, 186-200.

Rosser, N. J., Petley, D. N., Lim, M., Dunning, S. A., Allison, R. J., 2005. Terrestrial laser scanning for monitoring the process of hard rock coastal cliff erosion. Quarterly Journal of Engineering Geology and Hydrogeology, 38, 363 – 375.

Rowlands, K.A., Jones, L.D., Whitworth, M., 2003. Landslide laser scanning: a new look at an old problem. Quarterly Journal of Engineering Geology and Hydrogeology 36 (2), 155 – 157.

Ruiz, A., Kornus, W., Talaya, J., Colomer, J., 2004. Terrain modelling in an extremely steep mountain: a combination of airborne and terrestrial LIDAR. Proceedings of the XXth ISPRS Congress Geo-Imagery Bridging Continents, 12-23 July 2004 Istanbul, Turkey. Commission III, WG III/3.

Sidle, R.C., Ochiai, H., 2006. Landslides: processes, prediction, and land use. Water Resources Monograph 18, American Geophysical Union, Washington, DC, 312p.

Wyatt-Smith, J., 1995. Manual of Malayan silvivulture for inland forest (Malayan forest record 23; Vol. 1). Forest Research Institute Malaysia, pp. III-7/1-III-7/58.

ACKNOWLEDGEMENT

The authors are grateful to the Malaysian Government for financing the first author's fellowship at the ITC-University of Twente and Faculty of Geosciences of Utrecht University, Netherlands. We acknowledged the Topcon Instruments (Malaysia) Sdn Bhd for lending us the Topcon GLS-1000 and the Topcon South Asia Pte Ltd (Singapore) for extending the license period of Topcon ScanMaster software during the compilation of the paper. Many thanks to Mr. Yap Marcus, Topcon Instruments (Malaysia) for assisting us during the early field campaign in the Cameron Highlands, Malaysia.

CONTACTS

Khamarrul Azahari RAZAK
Department of Earth Systems Analysis
Faculty of Geo-Information Science and Earth Observation
University of Twente
P. O. Box 6, 7500 AA Enschede,
NETHERLANDS
Tel. +31(0)534874416 (Office)
Tel. +31(0)617619879 (Mobile)
Fax + 31(0)534874336
Email: razak@itc.nl; khamarrul@ic.utm.my
Website: http://itc.academia.edu/khamarrul