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DIGITAL TERRAIN MODEL APPLICATION IN TERRAIN SENSITIVITY ASSESSMENT OF MOUNTAINOUS FOREST IN CAMERON HIGHLANDS, MALAYSIA

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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July 2020

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Statistics has shown that Malaysia receives high frequency of landslide while Cameron Highlands (CH) is one of the landslide prone hotspots. Previous studies have been conducted on landslide assessment but most research focused on urbanised populated area and limited study was conducted in forested mountainous area of CH. Most of the Malaysian show insufficient knowledge and low awareness regard landslide issue even though landslide case is not rare in this country. Besides, Digital Terrain Model (DTM) developed by radiogrammetry technology tends to produce spatial data with high precision. However, application of DTM in terrain assessment of mountainous forest was said to be challenging due to its complex terrain structure. This study aimed to demonstrate method to map terrain morphological characteristics and establish a terrain sensitivity map in landslide prone area of CH. Moreover, this study also aimed to analyse the landslide density in forested and non forested area of CH and evaluate the accuracy of DTM application in terrain assessment of mountainous forest. DTM of CH was applied to generate the terrain parameters which are elevation, slope gradient, aspect, Length-slope Factor (LS Factor) and Topography Wetness Index (TWI). All parameters were integrated, and a terrain sensitivity map was simulated by using weighted overlay analysis. Field assessment was conducted to collect landslide coordinate as data for landslide density measurement and DTM accuracy assessment. Result shows that 35.28% of slopes which are scatterly distributed in CH are classified as high sensitive area with landslide density of 2.18unit/km. Ringlet Forest Reserve recorded the highest frequency of landslide occurrence in forested area with 9.09unit/km, and Kuala Terla area recorded 4.01unit/km in non-forested area. Map comparison with field verification suggested that the DTM based Terrain Sensitivity Map generated obtained accuracy of 79.25%. Results presented provide a significant contribution to the understanding of interactions between terrain characteristic and forest functions were critically discussed. Digital

terrain analysis approach presented in this study offer alternative techniques for the assessment of micro topography in forested area, which opens up opportunity for researchers and forest practitioners to assess forest stability and structure from the perspective of terrain parameters. In addition, the difference of landslide density in forested and non-forested area emphasized the impact of forest exploitation which can raise public concern about the importance of forest conservation. Information and analytical methods discussed in this study will be beneficial for further site assessment to support sustainable land management planning, especially in the complex mountainous forest of CH.

Keyword: Digital terrain model, terrain sensitivity, terrain parameters, landslide density, map accuracy.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENILAIAN SENSITIVITI TOPOGRAFI DI HUTAN BERGUNUNG CAMERON HIGHLANDS, MALAYSIA BERDASARKAN *MODEL TERRAIN DIGITAL*

Oleh

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Statistik menunjukkan bahawa Malaysia kerap mengalami tanah runtuh dan Cameron Highlands (CH) merupakan salah satu kawasan berpotensi tinggi mengalami kejadian tanah runtuh. Kajian tentang penilaian tanah runtuh yang terdahulu kebanyakannya hanya memberi tumpuan kepada kawasan bandar manakala kajian di kawasan pergunungan hutan CH adalah terhad. Sebilangan rakyat Malaysia menunjukkan kekurangan pengetahuan dan mempunyai kesedaraan yang rendah terhadap isu-isu tanah runtuh walaupun negara ini mempunyai kekerapan kejadian tanah runtuh yang tidak rendah. Selain itu, *Model Terrain Digital* (DTM) yang dijanakan oleh teknologi radiogrammetri berkemampuan untuk menghasilkan data spatial dengan ketepatan yang tinggi. Namun, applikasi DTM dalam penilaian topografi hutan bergunung boleh dikatakan amat mecabar kerana struktur muka buminya yang kompleks. Objektif kajian ini dijalankan adalah bagi menunjukkan kaedah pemetaan ciri-ciri morfologi dan menggambarkan kawasan yang berpotensi tinggi untuk kejadian tanah runtuh di CH. Di samping itu, penilaian kekerapan tanah runtuh di kawasan berhutan dan tidak berhutan serta penilaian ketepatan applikasi DTM dalam penilaian topografi di kawasan bergunung juga dijalankan. DTM yang menunjukkan topografi CH telah digunakan untuk mengenal pasti ciri-ciri kawasan seperti ketinggian, kecerunan, aspek, faktor panjang-cerun (*LS Factor*) dan indeks kelembapan tanah (*TWI*). Semua parameter telah diintegrasikan, dan peta topografi sensitif telah disimulasi dengan menggunakan analisis *weighted overlay*. Penilaian lapangan telah dilakukan bagi mengumpulkan koordinat tanah runtuh sebagai data bagi pengukuran kekerapan tanah runtuh dan penilaian ketepatan applikasi DTM. Keputusan kajian ini menunjukkan bahawa 35.28% daripada cerun di CH diklasifikasikan sebagai kawasan sensitif aras tinggi dengan kekerapan tanah runtuh sebanyak 2.18unit/km. Hutan Simpan Ringlet menunjukkan kekerapan kejadian tanah runtuh yang tertinggi dengan 9.09unit/km di kawasan berhutan, manakala kawasan Kuala Terla mencatatkan 4.01unit/km merupakan kekerapan tertinggi di kawasan tidak berhutan. Peta Topografi Sensitif yang dihasilkan berdasarkan DTM memperoleh ketepatan

sebanyak 79.25%. Keputusan kajian ini memberi sumbangan yang signifikan kepada pemahaman tentang interaksi antara ciri-ciri topografi dengan pembentukan tanah runtuh di CH. Interaksi antara ciri-ciri topografi dan fungsi hutan telah dibincangkan secara kritikal. Kaedah analisis topografi secara digital yang dibentangkan dalam kajian ini menawarkan teknik alternatif untuk penilaian topografi mikro di kawasan berhutan, yang membuka peluang kepada penyelidik dan pengamal dalam industri perhutanan untuk menilai kestabilan dan struktur hutan dari perspektif ciri-ciri topografi. Selain daripada itu, perbezaan kekerapan tanah runtuh di antara kawasan berhutan dan tidak berhutan menunjukkan kesan eksploitasi hutan yang boleh menimbulkan kesedaran masyarakat mengenai kepentingan pemuliharaan hutan. Kaedah maklumat dan analisis yang dibincangkan dalam kajian ini akan memberi manfaat kepada penilaian tapak selanjutnya untuk menyokong perancangan pengurusan tanah lestari, terutama di hutan pergunungan kompleks CH.

Kata Kunci: *Model terrain digital*, sensitiviti topografi, ciri-ciri topografi, kekerapan tanah runtuh, ketepatan peta.

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LIST OF ABBREVIATIONS

CH	Cameron Highlands
DOE	Department of Environment
DTM	Digital Terrain Model
ESA	Environmentally-Sensitive Areas
EWS	Early Warning System
FAO	Food and Agriculture Organization of United Nation
GDV	Gross Development Value
GIS	Geographic Information System
GLC	Global Landslide Catalog
GPS	Global Positioning System
HR	Hutan Rizab
HRR	Hutan Rizab Ringlet
HS	High Sensitivity
IFSAR	Interferometric Synthetic Aperture Radar Digital
IUCN	International Union for Conservation of Nature
JPA	Jabatan Perkhidmatan Awam
JPSM	Jabatan Perhutanan Semenanjung Malaysia
JUPEM	Jabatan Ukur dan Pemetaan Malaysia
KuLSIS	Kuala Lumpur Slope Information System
LIDAR	Light Detection and Ranging
LS Factor	Length-slope Factor
MS	Moderate Sensitivity
NASA	US National Aeronautics Space Administration
PWD	Public Work Department
QGIS	Quantum Geographical Information System
RUSLE	Revised Universal Soil Loss Equation
SAGA	System for Automated Geoscientific Analyses
SAR	Synthetic Aperture Radar
TSM	Terrain Sensitivity Map
TWI	Topography Wetness Index
UV	Ultraviolet
USLE	Universal Soil Loss Equation
VHS	Very High Sensitivity
3D	Three Dimensional

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Landslide is defined as collapse of land that causes displacement of soil and earth mass down to the lower slope (Froude, 2018). It is shifting of debris or rocks down to the lower hill due to the gravity effect (Cruden, 1991). Landslide can occur when an area was overexploited without proper management plan. In addition, landslide can occur in nature too due to external triggers such as vibration caused by earthquakes or rainfall (Zhang et al., 2014).

Malaysia is very common in landslide disasters. According to Kazmi et al. (2016), the highest rate of landslide incidents were 71 major cases recorded in the year of 1996 due to several factors such as geological condition and failure in development planning. Although landslide occurrence is getting decreased at the following year, there were still 193 landslide cases recorded between the year 1997 to 2008 that caused fatalities or economics loss in large scale. As reviewed by Gue and Tan (2006), 88% of landslide in Malaysia is caused by the construction and design error due to the insufficient understanding of slope condition. Slope stability and terrain parameters such as water drainage condition were not study in details before the building was raised. While, the reason that caused another 12% of landslide case is due to the lack of slope maintenance and natural flaw in geological aspect.

Malaysia's government show concern on landslide issue and thus introduced several monitoring systems to reduce landslide frequency. The systems were installed to assess the slope information regularly. In 2018, Public Works Department (PWD) had started mitigation work of landslide all along the public roads to enhance road safety. It involved risk assessment and hazard mapping to avoid landslide. An Early Warning System (EWS) was established by installing rain gauge devices at risky slope to provide alert messages whenever landslide can be triggered in high chance (Zakiah et al., 2019). Besides, a system named Kuala Lumpur Slope Information System (KuLSIS) that enable 360 degree of three dimensional (3D) views in Kuala Lumpur was launched in 2014. KuLSIS can be access by developers to obtain slope information such as rain distribution and geology settings in order to minimise the risk of construction (Wong, 2014). These techniques are developed by using technology of Geographic Information System (GIS). The image data is built by integration of map that represented different feature of earth surface such as street, buildings and vegetation.

Other than that, researchers contributed to prevent landslide by conducting landslide assessment in Malaysia. Previous research conducted regard landslide assessment in Malaysia presented in various aspects such as the correlation between rainfall intensity and landslide frequency along public road (Tay & Selaman, 2011); the effect of soil type and lithology factors towards landslide occurrence (Mohd et al., 2019); and influence of land use towards landslide occurrence (Kamilia et al., 2016). However, most of the landslide related studies were focused on explored areas such as public road, infrastructure and populated area. There are limited studies conducted on natural areas such as mountainous forest even though the hazard is persisted (Schuster & Highland, 2007; IUCN, 2016). According to University of Cincinnati (2018), society shows less interest in natural landslide as it happened in less populated areas. Therefore, most of the landslide related studies were targeted in urban areas to secure human lives and avoid economic loss. Forest conservation and study related to forest community does not raise the public concern.

In fact, forest plays their part in maintaining slope stability. According to Forbes and Broadhead (2011), vegetation cover in forest can effectively reduce the risk of landslide by expelling excessive water on soil surface to the atmosphere. Moreover, tree stand in forest can act as natural barrier whenever there is event of erosion and rock falls. In the view of ecology, forest act as environmental stabiliser to maintain the welfare of its surrounding. In Malaysia, forest exploitation activities had caused water pollution. From the year of 1986 to 2000, the coverage of polluted river in Malaysia raised from 46% to 72% due to the diminished size of forest in Malaysia (DOE, 2001). As reviewed by Mohamad and Zainudin (2011), rivers in Peninsular Malaysia were severely polluted due to the rapid development since 1970s. As 90% of water resources in Peninsular Malaysia is arose from mountain forest, thus unsustainable forest exploitation altered the hydrological cycle. Water pollution is only one of the impacts of forest exploitation. Series of adverse impact included species extinction, pollution, land degradation and disasters should be expected once forest resources are overexploited. Therefore, forest conservation is a national issue and it has its value to be studied. Well spoken by Haliza (2014), no country will be free from environmental disasters if natural resources were overexploited.

Moreover, landslides in mountainous area bring huge loss to society as well. According to Tongkul (2015), a large scale earthquake attack had occurred in Ranau, Sabah at June 2015. Intense shaking caused 18 climbers died on Mount Kinabalu and also triggered a landslide that cover 15km^2 of area. Besides, the incident caused huge damage to farmland, houses and numbers of bridges. Another landslide tragedy was happened in hillside area in 2008. According to The Star Online (2008), a huge landslide occurred in Taman Bukit Mewah at 3.30am which caused four people died and destroyed 14 bungalows. Around 2000 residents were required to evacuate and air-wing unit was initiated to transfer 13 people who are pregnant, stroke and heart attack. Leaking pipes are believed to be the main cause of the incident. Soil

underneath the buildings were loosen and unstable due to the continuously water immersion from leaking pipe over years (Tariq, 2013).

Landslide in mountainous area could be happening in our society. However, the remoteness of mountainous forest is one of the reasons that caused limited study of the area. According to Martin et al. (2007), tropical mountainous forest having elevation of 1100m to 3100m above sea level with minimum temperature <5°C. These conditions increase the risk of health issue and expose researchers to a danger environment. Researchers require high fitness and health to work under such environment. Moreover, mountainous forest does not have fine facilities such as road, accommodation, food and water supply compared to urban area. Research and data collection activities will be challenging to be carrying out in remote forest area. With the advance technology, assessment in forest can be done remotely. Digital Terrain Model (DTM) is a digitised data that enable user to extract information of earth surface without access to the area.

DTM is a spatial dataset that exhibit ground elevation as earth topography representation (Podobnikar, 2009). According to Balasubramanian (2017), DTM digitised ground elevation point and able to present surface of bare land in 3D views. It consists of topography information such as slope and aspect that enable user to execute analysis in various fields. In common, DTM are built based on data collected from satellite image, aerial photography, space-borne radar or topography map. Thus, it eases the works of data collection in low accessibility areas.

1.2 The Case in Cameron Highlands

Based on data from US National Aeronautics Space Administration (NASA), Cameron Highlands (CH) is one of the mountainous forest areas which are spotted to have landslide frequently (Sim et al., 2018).

CH is well known as crop producer in Malaysia. Based on The Star Online (2019), CH is the main producer of vegetables and flowers in Malaysia. The annual production of solely cabbage is 68,500 tonnes and cultivation area covered 27.70km^2 of land. As reported by Rendana et al. (2015), the total coverage of agriculture land in CH was 75.27km^2 in 2014; solely cabbage cultivation land had occupied 36.80%. The percentage shows the high demand of the agriculture product from CH. However, high demand of the agriculture goods brings adverse effect to the environment in CH.

Cultivation of agriculture products can contribute to risk of landslide indirectly. According to Chan (2018), land in CH had being exploited illegally without control for plantation establishment. As plantation establishment require series of terrain disturbance such as deforestation and land clearing, those activities

will increase the risk of slope instability and might trigger sensitive spot (Abhisbek, 2014). Furthermore, illegal exploitation of mountainous forest does not undergo environmental impact assessment by authority. Thus, unexpected slope failure might occur when the sensitive spot was triggered.

Construction and development event in CH contribute to landslide occurrence as well. According to Loh (2018), the development of housing and building involving hills had increased since 2014. In 2018, ruler of Pahang had called for termination of construction and agriculture expansion in CH to prevent landslide triggering (Kaur, 2018). However, it does not halt development in CH effectively. Based on bulletin from News Straits Times (2019a), MGB Berhad (Construction Services Unit) initiated a property development project in CH with about RM107 million of Gross Development Value (GDV). As mentioned by Haliza and Jabil (2017), development without detailed terrain survey might trigger slope failure and lead to fatal landslide. Thus, it raised the need of terrain assessment in CH to minimise the environmental hazard.

Several landslide cases in CH are shown in Table 1.2 The location of incident included plantations, housing areas and busy highways. Landslide in different kind of land use indicates the terrain instability in CH. Any human activities in CH might encourage landslide triggering. Therefore, detailed study related to landslide is needed in CH to minimise and effectively reduce the environmental hazard in CH (Chan, 2018).

Table 1.2 : Landslide cases in Cameron Highlands.

Date	Location and Incident	Source
19 Oct 2019	Landslide in Jalan Simpang Pulai.	News Straits Times, 2019b
25 May 2019	Landslide in Jalan Ringlet-Blue Valley and Jalan Ulu Merah.	Kaur, 2019
14 Oct 2018	Landslide in Kuala Terla – caused three people from Myanmar died in the incident.	Muhammad, 2018
25 Jan 2017	Landslide in Kampung Raja – caused a gardener from Bangladesh died in the incident.	Avineshwaran, 2017
28 Dec 2016	Landslide in Tanah Rata – caused damage to a bungalow and four vehicles.	The Star Online, 2016
09 Nov 2015	Landslide in Jalan Tapah-Ringlet – caused debris and trees fall on the road.	Loh, 2015
31 Dec 2014	Landslide in Jalan Brinchang-Tringkap – caused three deaths and one injury.	Loghun, 2014
06 Nov 2014	Landslide in Ringlet New Village – caused one death, four injuries and a child missing.	Malay Mail, 2014

06 Nov 2014	Landslide and flash flood in Ringlet and Kuala Terla – caused three deaths and five injuries.	The Sun Daily, 2014
07 Aug 2011	Landslide in Kampung Sungai Ruil – caused six deaths and two injuries.	Looi, 2011
01 May 1961	Landslide in Ringlet town – caused 16 deaths.	Fauziah, 2017

Landslide related study is not lacking in CH. Based on several studies in recent years, Gahgah et al. (2009) studied the landslide causal factors along the road between CH and Gua Musang; Lateh et al. (2010) studied the effect of rainfall towards land movement in CH; and Matori et al. (2011) studied the monsoonal effects on landslide hazard in CH. Whereas, terrain assessment in mountainous forest is still inadequate in CH. Based on Zaini et al. (2014), only 21% of CH was explored and urbanised while 79% remained forested. The huge forest area in CH will be a potential study site for terrain assessment. In general, research on natural area such as mountainous forest is very limited even though natural hazard in remote area is not rare (Schuster & Highland, 2007; IUCN, 2016). Thus, a study of terrain sensitivity focused on mountainous forest area in CH will provide beneficial information to assist further management and sustainable forest planning in the region.

1.3 Problem Statement

Malaysia is one of the top 10 countries all around the world with highest frequency of landslide. According to Sim et al. (2018), Malaysia is ranked at 10th place in the list of Global Landslide Catalog (GLC) based on number of landslide cases reported from the year of 2007 to 2016.

At present, most of the landslide cases reported in Malaysia was focused on populated or urban area. There is limited study and less attention was given to the landslide in remote forest areas as presume that landslide in remote area does not cause effect to the society. According to Haliza and Jabil (2017), 94% of landslide cases reported in Malaysia were due to construction error and flaw in construction design; while only 6% of landslides reported were occurred naturally. The distinctness of both percentages are due to that landslides happened in remote area is less likely being reported or further investigated (Petley, 2009). However, safety in remote areas such as mountainous forest is equally important as it will cause tragedy as well. For example, a deadly landslide triggered by earthquake had occurred in Mount Rinjani, Indonesia and trapped 40 Malaysia tourists (Teh, 2019). Besides, a landslide occurred in Vajont, Italy caused huge part of mountain material crashed into a lake and triggered a tsunami that cost 2,000 human lives in 1963 (University of Cincinnati, 2018). These hidden threats might occur in Malaysia as well. Thus, a detailed terrain assessment on mountainous forest will be crucial to avoid the repetition of these tragedies.

In social aspect, public have low accessibility regard landslide knowledge as well as prevention method in Malaysia. As refer to a survey conducted in Penang Island, Malaysia, most of the government and non government officer in charge of landslide cases do not have sufficient knowledge, awareness, skill and experience to handle the situation (Habibah & Vijaya, 2012). This is due to the education in Malaysia covered only the environmental hazard information in certain university course such as Geography and Science (Jamilah et al., 2014). However, knowledge is important when dealing with natural disaster (Karnawati & Pramumijoyo, 2008). Research related to landslide should be encouraged and make available to public (Jamilah et al., 2014). As mentioned by Izumi et al. (2019), impact of natural disaster is not often can be prevented entirely; however, cooperation between different parties can reduce the damage and severity effectively. Thus, this study demonstrated an efficient method of terrain assessment that can be conducted by any relevant agencies or individual for landslide prevention.

Other than that, low awareness which is an extensive issue of low accessibility of hazard knowledge had raised among certain group of Malaysian community. According to Khairiah and Habibah (2012), resident in vulnerable area especially highland area has low awareness toward landslide issue compared to respondent that reside in flat land area. Among the respondent, around 27.4% agreed that environmental issue are too far in the future to be worry about; and 38.3% of respondent agreed that it is difficult to contribute to activity that are environmentally friendly. The author further stated that level of awareness does not affect by the education level. The statement proved that the Malaysian show low interest on the environmental issue. As reviewed by Khaled et al. (2016), Malaysia's resident possess of limited environmental knowledge and awareness. Most of the Malaysian agreed that natural environment could be forgone for the sake of development. Therefore, this study provided the comparison of landslide density between forested and non-forested area to reveal the contribution of forest exploitation towards the frequency of landslide.

In technology aspect, types of spatial data available in Malaysia having the issue of low accuracy and low practicability which is very difficult to be use in terrain assessment. In conventional way, terrain data can be acquired through traditional surveying techniques. Traditional technique makes measurement based on instrument such as theodolites and computerized total stations while coordinate of location was recorded by Global Positioning System (GPS) (Kavitha et al., 2018). Data accuracy of this technique is relatively high. However, it is time consuming, area limiting and require high labour cost.

Terrain survey can also be done with remote sensing techniques. Terrain characteristic can be described through data produce via Light Detection and Ranging (LIDAR) technology. Sensor from platform such as satellite or airplane will detect electromagnetic energy reflected from ground to measure the physical properties such as elevation (Moore, 1979). The technology is currently applied by most of the countries in the world for terrain and

hydrological assessment. Anyhow, LIDAR technology is high priced; therefore, it is not affordable by public (Izni et al., 2015). Due to this reason, LIDAR technology is very difficult to be widely applied without the financial support from government or relevant agencies. Moreover, Malaysia's government does not provide free LIDAR data for public like other countries and most of the data are confidential (Singh, 2016). Thus, study or analysis done by LIDAR data is very rare in Malaysia due to its low accessibility.

Besides, photogrammetry technology is also a remote sensing technique to acquire terrain information. According to Li et al. (2005), photogrammetry requires stereo pair of camera to capture same scene of landscape from different angle. The images produced were overlay to produce 3D image. Photogrammetry produce relatively high resolution image with low cost and high speed. However, it is not practical in tropical area. Operation of photogrammetry is highly dependent on the existence of sun radiation. Thus, the accuracy of image data will be relatively low when the areas are covered by dense cloud. As cloud covering is a common phenomenon in tropical country, therefore, photogrammetry techniques is not suitable to be apply in Malaysia (Ahamad, 2017).

Other than the previously mentioned techniques, DTM which have been introduced since 1970's is also an option for terrain surveying. DTM developed by radargrammetry utilise microwave to collect terrain information which the accuracy does not effect by cloud density and haze intensity (Ahamad, 2017). In addition, public user can access to DTM of Malaysia from Jabatan Ukur dan Pemetaan Malaysia (JUPEM) with low cost (JUPEM, 2019). However, the application of DTM was said to be challenging in hybrid geographic features and area with dense canopy such as tropical rainforest (Li, 2013; Hodgson & Bresnahan, 2004). Thus, the accuracy of DTM in application of terrain sensitivity assessment in tropical mountainous forest remains unresolved.

In short, the aim of this study is to conduct terrain assessment of mountainous forest area which is often neglected by public and also to evaluate the accuracy of DTM application of terrain assessment in tropical mountainous forest. Besides, the landslide density of forested and non-forested area was emphasised in this study as well to highlight the impact of forest exploitation. This study also displayed an efficient research framework to assist researcher, forest manager or any relevant parties for further evaluation of the forest resources.

1.4 Objectives

(a) To characterise terrain parameters of mountainous forest in Cameron Highlands using DTM.

(b) To establish a terrain sensitivity map of mountainous forest in Cameron Highlands.

(c) To analyse the landslide density of forested and non-forested area in Cameron Highlands.

(d) To evaluate the accuracy of DTM application in terrain sensitivity assessment of mountainous forest in Cameron Highlands.

1.5 Significant of Study

Main contribution of this study is the terrain sensitivity map generated that layout the high landslide susceptibility slope in CH. With the aid of terrain sensitivity map, local authority and relevant agencies could make use of the information by involving it in mitigation planning. High sensitive spots will be protected and strictly prohibited from visitors. It will assist in future decision making by select the suitable spot for development purpose.

Besides, the outcome of this study will raise awareness of local people or public regard the needs of environmental conservation. As reviewed by Khaled et al. (2016), only 12 to 22% of Malaysian youngsters possess the mindset of environmental conservation. While, high percentages of Malaysian possess insufficient environmental knowledge and awareness. In addition, knowledge of environmental hazard not only lacking in public but also insufficient among the officer in government and non government sector (Habibah & Vijaya, 2012). Thus, this study reveals the environmental complexity and level of terrain sensitivity in mountainous forest of CH that can be a reference to the public. Relevant parties and our society can comprehend the contribution of development towards landslide occurrence and can have better understanding regard the terrain sensitivity.

Moreover, the outcome can benefit the ecotourism sector to enhance the visitor's safety. Activities such as jungle trekking and rock climbing will be avoided in high sensitive area. Early execution can be done whenever there are sudden changes of weather during activities. As reported by Tourism Pahang (2019), the tourist number of CH had increased 109.12% from the year 2010 (715,575 tourists) to 2018 (1,496,372 tourists). The statistic shows the vigorous growth of tourism sector in CH. Thus, outcome of terrain sensitivity study does not only benefit the safety of local resident but also the safety of domestic and international visitors. Indirectly, the reputation and international profile of Malaysia can be maintained when legislation and law relevant to well being of visitors are established in CH.

Lastly, this study will benefit to various parties included researchers, stakeholders and management authority by providing informative reference. Terrain assessment framework provided in this study is feasible and user friendly to any parties. It overviewed the landslide and mitigation plan in Malaysia; types of spatial data available for assessment purpose; terrain characteristic of mountainous forest in CH; and provides better understanding on DTM application as well.

REFERENCES

Abdul, L. T. S., Muhammad, R. M., Khamaruzaman, W. Y., & Ahmad, M. H. (2017). Geostatistical based susceptibility mapping of soil erosion and optimization of its causative factors: A conceptual framework. *Journal of Engineering Science and Technology, 12*(11), 2880-2895.

Abdullah, A. F., Aimrun, W., Nasidi, N. M., Hazari, S. A. F., Sidek, M., & Zalilah, S. (2019). Modeling erosion and landslides induced by farming activities at hilly areas, Cameron Highlands, Malaysia. *Jurnal Teknologi, 81*(6), 195-204.

Abdulwahid, W. M., & Pradhan, B. (2016). Landslide vulnerability and risk assessment for multi-hazard scenarios using airborne laser scanning data (LiDAR). *Landslides, 14*(3), 1057-1076.

Abhisbek, S. S. R. (2014). A review on effects of deforestation on landslide: Hill areas. *International Journal for Scientific Research and Development, 2*(7), 37-46.

Acharya, T. D., Yang, I. T., & Lee, D. H. (2017). GIS-based landslide susceptibility mapping Bhotang, Nepal using frequency ration and statistical index methods. *Journal of Korean Society of Surveying, Geodesy, Photogrammetry and Cartography, 35*(5), 357-364.

Ahamad, S. Z. (2017). Application of IFSAR technology in topographic mapping: JUPEM's experience. *Proceedings of International Cartographic Association, 1*, 125-128. https://doi.org/10.5194/ica-proc-1-125-2018.

Ahmed. F., & Rao, K. S. (2019). Application of DEM and GIS in terrain analysis: A case study of Tuirini River Basin, NE India. *International Journal of Geology and Earth Sciences, 5*(1), 1-20.

Aminuddin, B. Y., Wan, A. W. Y., Cheah, U. B., Ghulam, M. H., Zulkefli, M., Salama, R. B. (2001). Impact of intensive highland agriculture on the ecosystem. *Journal of Tropical Agriculture and Food Science, 29*(1), 69-72.

Anbalagan, R. (1992). Landslide hazard evaluation and zonation mapping in mountainous terrain. *Engineering Geology, 32*, 269-277.

Anderson, S. P., Blum, A., Lee, J., & Cowie, R. (2009). Weathering, water, and slope aspect. *Eos, Transactions American Geophysical Union, 90*(52), 1-2.

Anisimov, V., Malykh, K., Anisimov, A., & Edigarian, A. (2016). The functional models of system of the automated design of the railroads on the basis of use of three-dimensional terrain models. *Procedia Engineering, 165*, 1873-1879.

Annis, A., Nardi, F., Morrison, R. R., & Castelli, F. (2019). Investigating hydrogeomorphic floodplain mapping performance with varying DTM resolution and stream order. *Hydrological Sciences Journal, 64*(5), 525-538.

Avineshwaran, T. (2017, January 25). Bangladeshi killed in Camerons landslide. *The Star Online*. https://bit.ly/2QBaOpV.

Azita, A. Z., Masami, S., Noor, J. N. J. (2014). Landform classification for site evaluation and forest planning: Intergration between scientific approach and traditional concept. *Sains Malaysiana, 43*(3).

Azita, A. Z., Muhammad-Shafeeq, S., Thinaraj, B., & Paul, L. (2019). Terrain characterisation of mountainous forest area in Cameron Highland. *The Malaysian Forester, 82*(2), 445-454.

Azlini, R., Sharifah, N. S. I., Suriyani, A., Sarva, M. P., & Emilia, Z. A. (2018a). Land use change in highland area and its impact on river water quality: a review of case studies in Malaysia. *Ecological Processes, 7*(19). https://doi.org/10.1186/s13717-018-0126-8.

Azlini, R., Sharifah, N. S. I., Suriyani, A., Sarva, M. P., & Emilia, Z. A. (2018b). Heavy metals contamination and potential health risk in highland river watershed (Malaysia). *Malaysian Journal of Medicine and Health Sciences. 14*(2), 45-55.

Balasubramanian, A. (2017). Digital elevation model (DEM) in GIS. *ResearchGate*. https://bit.ly/304hnVb.

Ballerin, C (2017). *Topographic wetness index: Urban flooding awareness act action support*. Illinois State Water Survey.

Beaven, P. J., & Lawrance, C. J. (1973). *The application of terrain evaluation to road engineering*. [Paper presentation]. Conference on Road Engineering in Asia and Australasia 1973, Kuala Lumpur, Malaysia.

Benavidez, R., Jackson, B., Maxwell, D., & Norton, K. (2018). A review of the (Revised) Universal Soil Loss Equation ((R)USLE): With a view to increasing its global applicability and improving soil loss estimates. *Hydrology and Earth System Sciences, 22*, 6059-6086.

Beven, K. J., & Kirkby, M. J. (1979). A physically based variable contributing area model of basin hydrology. *Hydrological Science Journal, 24*, 43-69.

Bolgiani, P., Fernandez-Gonzalez, S., Valero, F., Merino, A., Garcia-Ortega, E., Sanchez, J, L., & Martin, M. L. (2018). Numerical simulation of a heavy precipitation event in the vicinity of Madrid-Barajas International Airport: Sensitivity to initial conditions, domain resolution, and microphysics parameterizations. *Atmosphere, 9*, 1-24. http://doi:10.3390/atmos9090329.

Bunning, S., Mcdonaugh, J., & Rioux, J. (2011). *Manual for local level assessment of land degradation and sustaibable land management*. Food and Agriculture Organization of the United Nations.

Butler, R. (2012). Types of Rainforests. *Mongabay*. https://bit.ly/2QEftYg.

Caskey, B. J., & Frey, J. W. (2009). *Biological-community composition in small streams and its relations to habitat, nutrient, and land use in agriculturally dominated landscapes in Indiana and Ohio, 2004, and implications for assessing nutrient conditions in Midwest streams*. United States Geological Survey.

Cervantes, M. S., Hernando, A., Garcia-Abril, A., Valbuena, R., Saornil, J. V., & Manzanera, J. A. (2020). Simulation of overflow thresholds in urban basins: Case study in Tuxtla Gutierrez, Mexico [Abstract]. *River Research and Applications*. http://rb.gy/acxnnd.

Chan, J. (2018, October 23). Study needed to stop Cameron Highlands landslides, says minister. *Malay Mail*. https://bit.ly/36F363E.

Chaudhari, A. R. V., Lal, B. D., Dutta, C. S., Umrikar, B., & Halder, E. S. (2018). Weighted overlay analysis for delineation of ground water potential zone: A case study of Pirangut River basin. *International Journal of Remote Sensing and Geoscience, 7*(1), 1-7.

Ciesla, W. M. (1995). *Climate changes, forests and forest management: An overview*. Food and Agriculture Organization of United Nation.

Cislaghi, A., Sangalli, G. B., Sali, G., & Bischetti, G. B. (2019). Planning forest management to reduce landslide risk along a railway line: A case study in Valle Camonica [Abstract]. http://shorturl.at/amEFL.

Colby, J. D., & Dobson, J. G. (2010). Flood modeling in the coastal plains and mountains: Analysis of terrain resolution. *Natural Hazard Review, 11*(1), 19-25.

Crockett, K. J., & Shelford, R. C. (1982). *Terrain sensitivity classification methodology* (T/17). Alberta Energy and Natural Resources. http://rb.gy/j1rf9p.

Cruden, D. M. (1991). A simple definition of a landslide. *Bulletin of the International Association of Engineering Geology, 43*(1), 27-29.

Dai, F. C., & Lee, C. F. (2002). Landslide characteristics and slope instability modeling using GIS, Lantau Island, Hong Kong. *Geomorphology, 42*(3), 213-228.

DeGraff, J. V., & Romesburg, H. C. (1980). Regional landslide-susceptibility assessment for wildland management. In C. R. Coats., & J. Vitek (Eds.), *Regional landslide-susceptibility assessment for wildland management: A matrix approach* (pp. 401-414). Allen and Unwin.

Department of Environment (DOE). (2001). *Environmental quality report 1987-2001*. Ministry of Science, Technology and the Environment.

Dieu, T. B., Himan, S., Shirzadi, A., Chapi, K., Alizadeh, M., Chen, W., Mohammadi, A., Baharin, B. A., Panahi, M., Hong, H. Y., & Tian, Y. Y. (2018). Landslide detection and susceptibility mapping by AIRSAR data using support vector machine and index of entropy models in Cameron Highlands, Malaysia. *Remote Sensing, 10*(10). https://doi.org/10.3390/rs10101527.

Dobson, M. (1995). *Tree roots systems*. Arboricultural Advisory and Information Service.

Dou, J., Dieu, T. B., Yunus, A. P., Jia, K., Song, X., Revhaug, I., Huan, X., & Zhu, Z. F. (2015). Optimization of causative factors for landslide susceptibility evaluation using remote sensing and GIS data in parts of Niigata, Japan. *Plos One, 10*(7), 1-29.

Douass, S. (2020). Flood zones detection using runoff model built on hexagonal shape based cellular automata. *International Journal of Engineering Trends and Technology, 68*(6), 68-74.

Doyle, F. J. (1978). Digital terrain models: An overview. *Photogrammetric Engineering and Remote Sensing, 44*(12), 1481-1485.

Earle, S. (2015). Factors that control slope stability. *BCCAMPUS*. https://bit.ly/35zI5Gl.

Eden, J. T., Alimuddin, I., & Azikin, B. (2020). Modeling vulnerability density of landslide using IFSAR DEM in Manuju and Bungaya District Gowa Regency, South Sulawesi. *Earth and Environmental Science*. http://doi:10.1088/1755-1315/500/1/012048.

Evans, M. (2011). Rainforests. *Earth Times*. https://bit.ly/2FAoQBN.

Fauziah, I. (2017, October 26). It should not have happened. *New Straits Times*. https://bit.ly/36OULut.

Ferdaus, B. A. (2017). *Landslide susceptibility in Cameron Highlands*. [Powerpoint Slide]. https://bit.ly/35sl9ss.

Food and Agriculture Organization of the United Nations (FAO). (2010). *Global forest resources assessment 2010: Main report*. Author. https://bit.ly/37KgdRg .

Forbes, K., & Broadhead, J. (2011). *Forests and landslides: The role of trees and forests in the prevention of landslides and rehabilitation of landslide-affeected areas in Asia*. Food and Agriculture Organization of the United Nations.

Forest Practices Code of British Columbia. (1999). *Mapping and assessing terrain stability guidebook*. https://bit.ly/2FuruJh.

Froude, M. J., & Petley, D. N. (2018). Global fatal landslide occurrence from 2004 to 2016. *Natural Hazards and Earth System Sciences, 18*, 2161-2181.

Gahgah, M. M., Akhir, J. M., Rafek, A. G. M., & Abdullah, I. (2009). GIS based assessment on landslide hazard zonation: Case study of Cameron Highlands-Gua Musang road Kelantan, Malaysia. *Sains Malaysiana, 38*(6), 827-833.

Gariano, S. L., & Guzzetti, F. (2016). Landslides in a changing climate. *Earth-Science Reviews, 162*, 227-252.

Gasim, M., Sahid, I., Toriman, E., Pereira, J. J., Mokhtar, M., & Abdullah, M. P. (2009). Integrated water resource management and pollution sources in Cameron Highlands, Pahang, Malaysia. *American-Eurasian Journal of Agriculture and Environmental Science, 5*(6), 725–732.

Gessler, P. E., Moore, I. D., McKenzie, N. J., & Ryan P. J. (1995). Soil-landscape modeling and spatial prediction of soil attributes. *International Journal of Geographical Information Science, 9*, 421-432.

GIS Geography (2018). *Choropleth Maps - A guide to data classification*. https://bit.ly/36GWdiq.

Goudie, A. S. (2004). *Encyclopaedia of Geomorphology*. Routledge.

Gray, L. (2011). World's forests absorb almost 40 per cent of man made CO_2. *The Telegraph*. https://bit.ly/302QXDc.

Gue, S. S., & Tan, Y. C. (2006). *Landslides: Abuses of the prescriptive method* [Paper presentation]. International Conference on Slope 2006, Kuala Lumper, Malaysia. http://shorturl.at/cgklG.

Gutierrez-Martin, A., Herrada, M. A., Yenes, J. I., & Castedo, R. (2019). Development and validation of the terrain stability model for assessing landslide instability during heavy rain infiltration. *Natural Hazards and Earth System Sciences, 19*, 721-736. https://doi.org/10.5194/nhess-19-721-2019.

Habibah, L., & Vijaya, G. (2012). The level of landslide awareness among officers in Penang, Malaysia. *International Journal of Scientific and Engineering Research, 3*(5). 1-7.

Haliza, A. R. (2014). An overview of environmental disaster in Malaysia and preparedness strategies. *Iranian Journal of Public Health, 43*(3), 17-24.

Haliza, A. R., & Jabil, M. (2017). Landslide disaster in Malaysia: An overview. *Health and Environment Journal, 8*(1). 58-71.

Hancox, G. T., & Wright, K. (2005). *Analysis of landsliding caused by the February 2004 rainstorms in the Wanganui-Manawatu hill country, southern North Island, New Zealand* (2005/11). Institute of Geological and Nuclear Sciences Limited.

Herrero-Huerta, M., Felip-Garcia, B., Belmar-Lizara, S., Hernandez-Lopez, D., Rodriguez-Gonzalvez, P., & Gonzalez-Aguilera, D. (2016). Dense canopy height model from a low-cost photogrammetry platform and LiDAR data. *Trees*. http://doi:10.1007/s00468-016-1366-9.

Hickey, R. (2000). Slope angle and slope length solutions for GIS. *Journal of Cartography, 29*(1), 1-8.

Hill, J. L., & Hill, R, A. (2001). Why are tropical rainforests so species rich? Classifying, reviewing and evaluating theories. *Progress in Physical Geography, 25*(3), 326-354.

Himan, S., & Mazlan, H. (2015). Landslide susceptibility mapping using GIS-based statistical models and remote sensing data in tropical environment. *Scientific Report, 5*, 1-15.

Hodgson, M. E., & Bresnahan, P. (2004). Accuracy of airborne Lidar-derived elevation. *Photogrammetric Engineering and Remote Sensing, 70*(3), 331-339.

Hsieh, Y. C., Chan, Y. C., & Hu, J. C. (2016). Digital elevation model differencing and error estimation from multiple sources: A case study from the Meiyuan Shan landslide in Taiwan, *Remote Sensing, 8*(3). https://doi.org/10.3390/rs8030199.

Hutchinson, M. F., & Gallant, J. C. (2000). Digital elevation models and representation of terrain shape. In J. P. Wilson., & J. C. Gallant (Eds), *Terrain analysis: Principle and Applications*. John Wiley and Sons.

Ikelegbe, O. (2012). Forest exploitation and the challenge of conservation in Nigeria. *Journal of Agriculture, Forestry and Fisheries, 13*(1-2), 28-32.

International Union for Conservation of Nature (IUCN). (2016). *Reducing risks from landslides and flash floods*. https://bit.ly/2QBaibn.

Izni, Z., Badronnisa, Y., Alireza, H., Helmi, Z. M. S., & Thamer, A. M. (2015). Object-based classification of QuickBird image and low point density LIDAR for tropical trees and shrubs mapping. *European Journal of Remote Sensing, 48*, 423-446.

Izumi, T., Matsuura, S., Mohd, Y. A. F., Razak, K. A., Moriguchi, S., Kure, S., Jamal, M. H., Motoyama, E., & Supar, L. M. (2019). *Disaster risk report: Understanding landslide and flood risks for science-based disaster risk reduction in the state of Selangor*. Sedar Malaysia-Japan.

Jabatan Ukur dan Pemetan Malaysia (JUPEM). (2019). *How to get the JUPEM digital data?* [FAQ]. https://www.jupem.gov.my/soalan-lazim.

Jakovljevic, G., Govedarica, M., Alvarez-Taboada, F., & Pajic, V. (2019). Accuracy assessment of deep learning based classification of LIDAR and UAV points clouds for DTM creation and flood risk mapping. *Geosciences, 9*(7). https://doi.org/10.3390/geosciences9070323.

Jamilah, A., Habilah, L., & Saifudin, S. (2014). Landslide hazards: Household vulnerability, resilience and coping in Malaysia. *Journal of Education and Human Development, 3*(3), 149-155. http://dx.doi.org/10.15640/jehd.v3n3a12.

Jerkins, E. (2014). Summary of weather in the Cameron Highlands- 2nd edition. *Regional Environmental Awareness Cameron Highlands*. http://reach.org.my/2014/?p=709.

Kalimuthu, H., Tan, W. N., Lim, S. L., Mohammad, F. A. F. (2015). Assessing frequency ratio method for landslide susceptibility mapping in Cameron Highlands, Malaysia. *2015 Institute of Electrical and Electronics Engineers Student Conference on Research and Development,* 93-99. https://doi.org/10.1109/SCORED.2015.7449440.

Kamilia, S., Simon, N., & Rodeano, R. (2016). Regional assessment on the influence of land use related factor on landslide occurrences in Kundasang, Sabah. *AIP Conference Proceedings, 1784*(1), 1-5. https://doi.org/10.1063/1.4966853.

Karnawati, D., & Pramumijoyo, S. (2008). Strategy for promoting education for natural disaster reduction in Indonesia and ASEAN region. In B. Rouhban & R. Shaw (Eds.), *The first world landslide forum* (pp. 1-4). United Nation University.

Kaur, M. (2018, October 26). Halt projects to stop landslides. *The Star Online*. https://bit.ly/2T869gN.

Kaur, M. (2019, May 25). Rain causes two landslides at Cameron Highlands. *The Star Online*. https://bit.ly/2Nc6WJR.

Kavitha, M. N. C., Viswanath, R., Kavibharathi, P., Aakash, K., & Balajimanikandan, M. (2018). A comparative stdy of conventional surveying techniques with total station and GPS. *International Journal of Civil Engineering and Technology, 9*(1), 440-446.

Kazmi, D., Qasim, S., Harahap, I. S. H., Baharom, S., Imram, M., & Moin, S. (2016). A study on the contributing factors of major landslides in Malaysia. *Civil Engineering Journal, 2*(12), 669-678.

Kemp, K. K. (2016). *Encyclopedia of geographic information science: Terrain analysis.* Sage Publication.

Kennie, T. J. M., & Petrie, G. (1990). Digital terrain modeling. In T. J. M. Kennie., & G. Petrie. (Eds.), *Engineering Surveying Technology* (pp. 394-396). Taylor and Francis.

Khairiah, S. M., & Habibah, L. (2012). Towards community-based landslide preparedness in Malaysia. *Journal of Environmental Science, Technology and Food Technology, 1*(2), 1-9.

Khaled, A. F., Mohd, K. A., & Romlah, R. (2016). A theoretical and empirical discussion of environmental awareness issue in Malaysia: Establishing a viable research framework. *International Journal of Sciences: Basic and Applied Research, 30*(4), 318-334.

Khamsin, I., Zulkarnain, M., Razak, K. A., & Rizal, S. (2014). Detection of tropical landslides using airborne LiDAR data and multi imagery: A case study in Genting Highland, Pahang. *Earth and Environmental Science, 18*, 1-6. http://rb.gy/ngtmpf.

Kim, H., Kang, Y., & Kim, J. (2017). Evaluation of wind resource potential in mountainous region considering morphometric terrain characteristics. *Wind Engineering, 41*(2), 114-123.

Korner, C., & Ohsawa, M. (2005). Mountain Systems. In B. Fitzharris & K. Shrestha (Eds), *Ecosystems and human well-being: Current state and trends* (pp. 683-713). Millennium Ecosystem Assessment.

Kumaran, S., & Ainuddin, A. N. (2006). Forest, water and climate of Cameron Highlands. In N. W. Chan (Ed), *Cameron Highlands: Issues and challenges in sustainable development*. School of Humanities, Universiti Sains Malaysia.

Larsen, M. C., & Simon, A. (1993). A rainfall intensity-duration threshold for landslides in a humid-tropical environment, Puerto Rico. *Geografiska Annaler: Series A, Physical Geography, 75*(1-2), 13-23.

Lateh, H., Jefriza., Muhiyuddin, W. M., Taib, B., & Khan, Y. A. (2010). Monitoring of hill-slope movement due to rainfall at Gunung Pass of Cameron Highlands district of Peninsular Malaysia. *International Journal of Earth Sciences and Engineering, 3*(1), 6-12.

Li, A., Dhakal, S., Glenn, N. F., Spaete, L. P., Shinneman, D. J., Pilliod, D. S., Arkle, R. S., & Mcllroy, S. K. (2017). LIDAR aboveground vegetation biomass estimates in shrublands: Prediction, uncertainties and application to coarser scales. *Remote Sensing, 9*, 1-19. http://doi:10.3390/rs9090903.

Li, Y. (2013). Filtering airborne LIDAR data by an improved morphological method based on multi-gradient analysis. *International Society of Photogrammetry and Remote Sensing,* 191-194.

Li, Z., Zhu, Q., & Gold, C. (2005). *Digital Terrain Modeling*. CRC Press.

Liu, J., Li, Z., & Xu, M. (2019). Analysis of terrain height effects on the asymmetric precipitation patterns during the landfall of Typhoon Meranti (2010). *Atmospheric and Climate Sciences, 9*(3), 331-345.

Loghun, K. (2014, December 31). Pregnant mum and toddler killed in Cameron Highlands landslide. *Malay mail*. https://bit.ly/35zUdHb.

Loh, I. (2015, November 09). Small landslide causes Cameron Highlands traffic jam. *The Star Online*. https://bit.ly/36Kz4vy.

Loh, I. (2018, November 24). Rep blames developers for Cameron Highlands landslides. *The Star Online*. https://bit.ly/2QZQBcd.

Longenecker, H. E., Graeden, E., Kluskiewicz, D., Zuzak, C., Rozelle, J., & Aziz, A. J. (2019). A rapid flood risk assessment method for response operations and nonsubject-matter-expert community planning. *Journal of Flood Risk Management*. http://doi:10.1111/jfr3.12579.

Looi, S. (2011, August 09). Landslide in Cameron Highlands kills seven. *The Star Online*. https://bit.ly/37Tha9I.

Mahalingam, R., Michael, J. O., & Matt, S. O. (2016). Evaluation of landslide susceptibility mapping techniques using lidar-derived conditioning factors (Oregon case study). *Geomatics, Natural Hazards and Risk, 7*(6), 1884-1907.

Malay Mail. (2014, November 06). One dead, 4 injured after heavy rain causes landslides in Cameron Highlands. https://bit.ly/2FzTcEz.

Mallet, C., & David, N. (2016). Digital terrain models derived from airborne LiDAR data. In N. Baghdadi., & M. Zribi (Eds), *Optical remote sensing of land surface* (pp. 299-319). Elsevier.

Mancini, F., & Salvini, R. (2019). Applications of photogrammetry for environmental research. *International Journal of Geo-Information, 8*, 1-3. http://doi:10.3390/ijgi8120542.

Martin, P. H., Sherman, R. E., & Fahey, T. J. (2007). Tropical montane forest exotones: Climate gradients, natural disturbance, and vegetation zonation in the Cordillera Central, Dominican Republic. *Journal of Biogeography, 34*, 1792-1806.

Matori, A. N., & Basith, A. (2012). Evaluation of landslide causative factorstowards efficient landslide susceptibility modeling in the Cameron Highlands, Malaysia. *Monitoring, Simulation, Prevention and Remediation of Dense and Debris Flow IV, 4*, 207-217.

Matori, A. N., Basith, A., & Harahap, I. (2011). Study of regional monsoonal effects on landslide hazard zonation in Cameron Highlands, Malaysia. *Arabian Journal of Geosciences, 5*(5), 1-16.

Mercer, N. Z., Griffiths, S. C., Wollershei, M. J., Miller, T. R., Zhang, Q. (2019). *Method and apparatus for enhancing 3D model resolution*. (United States Patent No. US010325349B2). United States and Trademark Office. http://shorturl.at/mtIUV.

Mestre, L. S. (2012). *Designing effective library tutorials: A guide for accommodating multiple learning styles*. Chandos Publishing.

Mezaal, M. R., & Pradhan, B. (2018). An improved algorithm for identifying shallow and deep-seated landslides in dense tropical forest from airborne laser scanning data. *Catena, 167*, 147-159.

Michalak, R., Moravcik, M., Pekkarinen, A., Rasi, R., Schwarz, M., & Tomter, S. (2018). *Forest resources assessment (FRA) 2020 regional workshop for North America, Europe, the Caucasus and Central Asia*. United Nations Economic Commision for Europe (UNECE); Food and Agriculture Organization of the United Nations (FAO); Forest Europe. http://shorturl.at/iyHKZ.

Mohamad, S. Y. C. N., & Zainudin, O. (2011). Impact of land development on water quality and water quality in Peninsular Malaysia. *Malaysian Journal of Environmental Management, 12*(2), 113-120.

Mohamed, K., Yoshino, K., & Setiawan, Y. (2012) Assessment and mapping of soil erosion risk by water in Tunisia using time series MODIS data. *Paddy and Water Environment*, 10(1), 59-73.

Mohamedou, C., Korhonen, L., Erikainen, K., & Tokola, T. (2019). Using LIDAR-modified topographic wetness index, terrain attributes with leaf area index to improve a single-tree growth model in south-eastern Finland. *Forestry: An International Journal of Forest Research, 92*(3), 253-263. https://doi.org/10.1093/forestry/cpz010.

Mohammad, E. B., Mohamad, O. A., Teh, S. Y., & Maznah, W. O. W. (2019). Identification of critical erosion prone areas in Temengor Reservoir Basin using Universal Soil Loss Equation (USLE) and Geographic Information System (GIS). *Institute of Physics Conference Series: Earth and Environmental Science, 380*(1). https://doi.org/10.1088/1755-1315/380/1/012011.

Mohd, S. S., Amir, N., Noorbaya, M. S., Roslan, Z. A., Nirwani, D. M., & Abdul, H. Y. (2019). Landslide occurrences in Malaysia based on soil series and lithology factors. *International Journal of Advanced Science and Technology, 28*(18), 1-26.

Moore, G. K. (1979). What is a picture worth? A history of remote sensing. *Sciences Hydrologiques, 24*(4), 477-485.

Moore, I. D., Grayson, R. B., & Ladson, A. R. (1991). Digital Terrain Modelling: A Review of Hydrological, Geomorphological, and Biological Applications. *Hydrological Processes, 5*, 3-30.

Morrocco, S. M., Ballantyne, C. K., Gordon, J. E. & Thompson, D. B. A. (2016). Assessment of terrain sensitivity on high plateau: A novel approach based on vegetation and substrate characteristics in the Scottish Highlands [Abstract]. *Plant Ecology and Diversity, 9*(2). https://doi.org/10.1080/17550874.2015.1092610.

Moses, A. N. (2017). GIS-based determination of RUSLE'S 'LS' factor for River Nzoia Basin in Kenya. *International Journal of Innovative Research and Advanced Studies, 4*(11), 441-444.

Muhammad, A. I. (2018, October 14). Third victim in Cameron Highlands landslide found. *New Straits Times*. https://bit.ly/2FAHdGO.

Muhammad, B. G., Ismail, S., Ekhwan, T., Joy, J. P., Mazlin, M., & Pauzi, M. A. (2009). Integrated water resource management and pollution sources in Cameron Highlands, Pahang, Malaysia. *American-Eurasian Journal of Agriculture and Environmental Science, 5*(6), 725–732.

Muhammad, I. M. H., Solemon, B., Omar, R., Roslan, R., Warishah, A. W., Intan, N. Z., & B., Vigneswaran, G. (2019). Landslide susceptibility assessment for Cameron Highlands using analytical hierarchy process. *International Journal of Engineering and Advanced Technology, 9*(1), 3494-3499.

Mutasem, S. A., Ngah, U. K., Lea, T. T., Nor, A. M. I., & Mohammad, S. A. (2013). Determination of important topographic factors for landslide mapping analysis using MLP network. *The Scientific World Journal,* 1-12.

Naranjo, L. (2019). *Connecting rainfall and landslides*. https://go.nasa.gov/307BGkE.

News Straits Times. (2019a, August 05). *MGB plans RM 107m GDV development in Cameron Highlands*. https://bit.ly/2ux2WNv.

News Straits Times. (2019b, October 19). *Landslide damages Cameron Highlands road; congestion expected*. https://bit.ly/2t2q3PI.

Nhu, V., Ayub, M., Himan, S., Baharin, B. A., Nadhir, A., Ataollah, S., Marten, G., Kress, V. R., Karimzadeh, S., Kamran, K. V., Chan, W., & Hoang, N. (2020). Landslide detection and susceptibility modeling on Cameron Highlands (Malaysia): A comparison between random forest, logistic regression and logistic model tree algorithms. *Forests, 11*, 1-28.

Noor, F. Y., Tukimat, L., Wan, M. R. I., Zulfahmi, A. R., Muzzneena, A. M., & Mohd, A. W. Y. (2019). Prediction of soil erosion in Pansoon sub-basin, Malaysia using RUSLE integrated in geographical information system. *Sains Malaysiana, 48*(11), 2565-2574.

Nordiana, A. A., Wahid, O., Mohamad, S., & Zulkifli, H. (2019). Topographic information from interferometric synthetis aperture rada (IFSAR) for oil palm plantation design, suitability and Management. *Journal of Environmental Science and Engineering, 8*, 159-172. http://doi:10.17265/2162-5298/2019.03.003.

Norudin, M., Kartini, M. R., Zuraida, M., & Zalinawati, A. (2015). Agro tourism potential in Malaysia. *International Academic Research Journal of Business and Technology, 1*(2), 37-44.

Pacifici, K., Reich, B. J., Miller, D. A. W., & Pease, B. (2019). Resolving misaligned spatial data with integrated species distribution models. *Ecology, 100*(6), 1-15.

Pawluszek, K. (2018). Landslide features identification and morphology investigation using high-resolution DEM derivatives. *Natural Hazards, 96*, 311-330. https://doi.org/10.1007/s11069-018-3543-1.

Petley, D. N. (2009). On the impact of urban landslides. *Geological Society, London, Engineering Geology Special Publications, 22*, 83-99.

Petschko, H., Bell, R., & Glade, T. (2014). Relative age estimation at landslide mapping on LiDAR Derivatives: Revealing the Applicability of land cover data in statistical susceptibility modeling. In K. Sassa., P. Canuti., & Yin, Y (Eds.), Landslide Science for a Safer Geoenvironment (Vol 2, pp. 337-343). Springer International Publishing.

Phan, V. H., Lindenbergh, R., & Menenti, M. (2016). Assessing orographic variability in glacial thickness changes at the Tibetan Plateau using ICESat laser Altimetry. *Remote sensing, 9*(2), 160. https://doi.org/10.3390/rs9020160.

Philips, O. L., & Gentry, A. H. (1994). Increasing turnover through time in tropical forests. *Science, 263*(5149), 954-958.

Podobnikar, T. (2009). Methods for visual quality assessment of a digital terrain model. *Surveys and Perspectivies Intergrating Environment and Society, 2*(2), 1-10.

Pourghasemi, H. R., Jirandeh, A. G., Pradhan, B., Chong, X., & Gokceoglu, C. (2013). Landslide susceptibility mapping using support vector machine and GIS at the Golestan Province, Iran. *Journal of Earth System Science, 122*(2), 349-369.

Pradhan, S. P., & Siddique, T. (2020). Stability assessment of landslide-prone road cut rock slopes in Himalayan terrain: A finite element method based approach. *Geotechnical Engineering, 12*(1), 59-73. https://doi.org/10.1016/j.jrmge.2018.12.018.

Raj, A. R., George, J., Raghavendra, S., Kumar, S., & Agrawal, S. (2018). Effect of DEM resolution on LS Factor computation. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42*(5), 315-321.

Rendana, M., Rahim, A. B. S., Idris, W. M. R., Lihan, T., & Rahman, Z.A. (2015). CA-Markov for predicting land use changes in tropical catchment area: a case study in Cameron Highlands, Malaysia. *Journal of Applied Science, 15*(4), 689-695.

Riad, N. (2013). Development of digital elevation models for hydrologic modeling purposes for large river basins in Surianame. *Journal of Surianame, 4*, 339-346.

Roback, K., Clark, M. K., Joshua, A. W., Zekkos, D., Li, G., Gallen, S. F., Chamlagain, D., & Godt, J. W. (2018). The size, distribution, and mobility of landslides caused by the 2015 M_w 7.8 Gorkha earthquake, Nepal. *Geomorphology, 301*, 121-138.

Rotaru, A., Oajdea, D., & Raileanu, P. (2007). Analysis of the landslide movements. *International Journal of Geology, 3*(1), 70-79.

Sabah Environment Protection Department (2012). *Environmental impact assessment (EIA): Guidelines for construction on hill slopes*. Environment Protection Department.

Saifuddin, M., & Normaniza, O. (2016). Rooting characteristics of some tropical plants for slope protection. *Journal of Tropical Forest Science, 28*(4), 469-478.

Schuster, R. L., & Highland, L. M. (2007). Overview of the effects of mass wasting on the natural environment. *Geological Society of America, Environment and Engineering Geoscience, 8*, 25-44.

Schwab, J. W., & Geertsema, M. (2009). Terrain stability mapping on British Columbia forest lands: An historical perspective. *Natural Hazards, 53*(1), 63-75.

Sharir, K., Roslee, R., Lee, K. E., & Simon, N. (2017). Landslide factors and susceptibility mapping on natural and artificial slopes in Kundasang, Sabah. *Sains Malaysiana, 46*(9), 1531-1540.

Shroder, J. F. (2014). *Natural resources in Afghanistan: Geographic and geologic perspectives on centuries of conflict.* Elsevier.

Sim, L. L., Chan, A., & Trisha, N. (2018, December 04). *The Star Online*. https://bit.ly/36FCRKv.

Simon, N., Roslee, R., & Goh, T. L. (2017). Temporal landslide susceptibility assessment using landslide density technique. *Geological Behaviour, 1*(2), 10-13.

Singh, I. (2016, October 14). *Malaysia: What the geospatial industry needs from the government?*. *Geospatial World*. https://bit.ly/2Fzct91.

Sitorus, S. R. P., & Pravitasari, A. E. (2017). Land degradation and landslide in Indonesia. *Sumatra Journal of Disaster, Geography and Geography Function, 1*(2), 61-71.

Su, M. B., Chen, F. M., & Chen, I, H. (2008). Applying digital photogrammetry to spatial distribution of debris variation. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 37*, 1659-1664.

Taghizadeh-Mehrjardi, R., Bawa, A., Kumar, S., Zeraatpisheh, M., Amirian-Chakan, A., & Akbarzadeh, A. (2019). Soil erosion spatial prediction using digital soil mapping and RUSLE methods for Big Sioux River Watershed. *Soil System 3*(43), 1-15.

Tariq, Q. (2013). Engineer tells court the 2008 Bkt Antarabangsa landslide likely caused by water pipe leaks. *The Star Online*. https://bit.ly/2N7RjDa.

Tarolli, P., Tarboton, D. G. (2006). A new method for determination of most likely landslide initiation points and the evaluation of digital terrain model scale in terrain stability mapping. (2006). *Hydrology and Earth System Sciences, 10*(5), 663-677.

Tas, E. (2016). *Flood risk potential assessment in Akarcay Sinanpasa Subbasin using GIS Techniques* [Paper presentation]. 3rd International Conference of Geography, Environment and GIS, for students and young researches, Targoviste, Romania. https://doi.org/10.13140/RG.2.2.12594.50884.

Tay, J. E., & Selaman, O. S. (2011). A study on the rainfall and landslides along Sarawak road using the antecedent rainfall analysis. *Unimas e-Journal of Civil Engineering, 2*(1), 1-6.

Teh, A. Y. (2019, March 17). Malaysians among 40 tourists trapped in deadly Lombok landslide. *New Straits Times*. https://bit.ly/2QYZFhH.

The Star Online. (2008, December 07). *Ampang's hill of death*. https://bit.ly/30aj7vV.

The Star Online. (2016, December 28). *Sunday's landslides, floods at Tanah Rata due to 'abnormal rainfall'*. https://bit.ly/3a4lZzc.

The Star Online. (2019, June 22). *Cameron Highlands growers given six months to reduce pesticide use before stricter enforcement*. https://bit.ly/39QCsqF.

The Sun Daily. (2014, November 06). *Two more dead in landslide and flash flood in Cameron Highlands*. https://bit.ly/2QUOJkU.

The Sun Daily. (2016, April 12). *33 landslide-prone slopes in Cameron Highlands identified*. https://bit.ly/2R4WWTV.

Tongkul, F. (2015). The 2015 Ranau earthquake: Cause and impact. *Sabah Society Journal, 32*, 1-28.

Tourism Pahang (2019). *Statistics of tourist arrival: Januari – Disember 2018*. https://bit.ly/2YGIndV.

Trochta, J., Krucek, M., Vrska, T., & Kral, K. (2017). 3D Forest: An application for descriptions of three-dimensional forest structures using terrestrial LiDAR. *Plos One, 12*(5). https://doi.org/10.1371/journal.pone.0176871.

Tse-ring, K., Sharma, E., Chettri, N., & Shrestha, A. (2010). *Climate change vulnerability of mountain ecosystems in the Eastern Himalayas*. International Centre for Integrated Mountain Development.

Tse, k. T., Werrasuriya, A. U., Hu, G. (2020). Integrating topography-modified wind flows into structural and environmental wind engineering applications. *Journal of Wind Engineering and Industrial Aerodynamics, 204*. https://doi.org/10.1016/j.jweia.2020.104270.

Tukimat, L., Nur, F. K., Muzzeena, A. M., Zulfahmi, A. R., & Wan, M. R. I. (2018). Potensi hakisan tanih di lembangan Sungai Bilut, Raub, Pahang menggunakan integrasi RUSLE dan GIS. *Sains Malaysiana*, *47*(10), 2241-2249.

University of Cincinnati (2018, November 06). Nobody wins in a landslide. *Science Daily*. https://bit.ly/2Ta6q30.

Usman, B. A., & Adefalu, L. L. (2010). An appraisal of Nigerian national policy on forestry, wildlife and protected areas. *Environmental Issues, 3*(1), 50-63.

Wang, Q., Li W., Chen, W., & Bai, H. (2015). GIS-based assessment of landslide susceptibility using certainty factor and index of entropy models for the Qianyang country of Baoji city, China. *Journal of Earth System Science, 124*(7), 1399-1415.

Wawer, R., & Nowocien, E. (2003). Application of SINMAP terrain stability model to Grodarz stream watershed. *Electronic Journal of Polish Agricultural Universities, 6*(1).

Weebers, A. C. M., & Hanizah, I. (2016). Decisions made on the development of the hill station of Cameron Highlands from 1884 till present day. *Journal of Surveying, Construction and Property,* 7(1), 1-11.

Wilson, J. P., & Deng, Y. (2008). Terrain analysis. In K. K. Kemp (Ed), *Encyclopedia of geographic information science*. Sage Publications.

Wong, P. M. (2014, June 28). Making new projects safe. *The Star Online*. https://bit.ly/35FLKSK.

World Bank. (2005). *Transect walk*. https://bit.ly/2FzZ80j.

Wu, C. Y., Qiao, J. P., & Wang, M. (2006). Landslides and slope aspect in the Three Gorges Reservoir area based on GIS and information value model. *Wuhan University Journal of Natural Sciences*, *11*(4), 773-779.

Yanalak, M., Musaoglu, N., Ipbuker, C., Sertel, E., & Kaya, S. (2012). DEM accuracy of high resolution satellite images. In S. Mirsa., O. Gervasi., B. Murgante, E. Stankova, V. Korkhov, C. Torre, A. M. A. C. Rocha, D. Taniar, B. O. Apduhan, & E. Tarantino (Eds.), *Computational Science and Its Applications – ICCSA 2012* (pp. 471-480). Springer.

Zaini, H., Che, Y. A., Ahmad, S., & Khalik, A. W. (2014). Quantifying soil erosion and deposition rates in tea plantation area, Cameron Highlands, Malaysia using 137Cs. *The Malaysian Journal of Analytical Sciences, 18*(1), 94-106.

Zainuddin, M. Y., Nur, A. A., Haslinda, N., Nik, N. N. D., & Azlan, A. A. (2016). Engineering geological of an active slope in KM46 Simpang Pulai, Perak. *Malaysian Journal of Civil Engineering, 28*(1), 35-41.

Zakaria, A., Ooi, J. B., Thomas, R. L., & Craig, A. L. (2019). Malaysia. *Encyclopedia Britannica*. https://bit.ly/2N9JhKb.

Zakiah, K., Lim, R., Chung, C., & Liew, J. X. (2019, November 20). 26,000 new hotspots on watch list. *The Star Online*. https://bit.ly/2s8SnPU.

Zhang, S., Zhang, L. M., & Glade, T. (2014). Charateristics of earthquake and rain-induced landslides near the epicenter of Wenchuan earthquake. *Engineering Geology, 175*, 57-73.

BIODATA OF STUDENT

Paul Lau Hua Ming was born on 5th July 1994 in Sibu, Sarawak. He had his secondary education in SMK Methodist, Sibu from the year 2007 to 2014. Besides, he also served as Vice President of Prefect Organisation of the school from 2013 to 2014.

Then, he pursued his Bachelor of Science Degree major in Plant Resources Science and Technology in Universiti Malaysia Sarawak (UNIMAS), Kota Samarahan from the year 2015 to 2018. During his study, he managed to maintain as a dean list holder for every semester and eventually graduated as a first class holder.

After his bachelor study, he joined WTK Holding Berhad and positioned as a management trainee in the company from August to December 2018. He was trained to study about the diseases of oil palm and management of plantation.

Lastly, he pursued his Master of Science Degree major in Forest Management and Ecosystem Sciences in Universiti Putra Malaysia (UPM), Serdang from 2019 to 2020.

LIST OF PUBLICATIONS

Azita, A. Z., Muhammad-Shafeeq, S., Thinaraj, B., & Paul, L. (2019). Terrain characterization of mountainous forest area in Cameron Highland. *The Malaysian Forester, 82*(2), 445-454.

Paul, L. H. M., & Azita, A. Z. (2020). Mapping potential landslide using digital terrain model: Application in Ringlet Forest Reserve. *The Malaysian Forester, 83*(1), 28-37.