LOCATING POTENTIAL HELICOPTER LANDING ZONES IN MOUNT TAHAN, MALAYSIA USING SPATIAL MODELLING

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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The increase in forest recreation, mountaineering activities, and wilderness exploration in Malaysia brings positive and negative impacts on society and the forest environment. Various incidents due to mountaineering activities in the forested setting have brought to a rise in the need for Search and Rescue (SAR) operations. Due to the limitation of accessibility to reach the wilderness, helicopter use has become a vital function in tropical forest rescue. Landing recovery offers the safest and high-security technique. One of the limitations that the rescue team faced was selecting a suitable area for safe ingress and egress by the helicopters by considering the circumstances and environmental impacts at the accident site. Despite the uniquely fair use of helicopters in conditions such as altitude, weather, and terrain, they can be extremely dangerous. Therefore, an effective method needs to be established to ease the safe evacuation process and reduce environmental impacts on sensitive mountainous area. This study aimed to establish an alternative method to determine potential helispot by using a spatial-based Topographic Position Index (TPI) to automate landform classification (LC). The system for automated geoscientific analyses (SAGA) software was used with an integration of a digital terrain model (DTM) at 5-meter resolution. A map of potential helispot was generated, and their coordinates were obtained within the GIS environment. Field verification showed landform accuracy of 66.7%, which were considered as acceptable and satisfactory. The analytical method and surveying techniques discussed in this study will support sustainable land management planning in a complex forested mountainous area within the region.

Keyword: Digital terrain model, landform classification, mountain rescue, helispot.

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

PENENTUAN KAWASAN PENDARATAN HELIKOPTER DI GUNUNG TAHAN DENGAN MENGGUNAKAN PERMODELAN RUANG

Oleh

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Peningkatan rekreasi perhutanan, aktiviti di kawasan pergunungan dan penerokaan hutan belantara memberi impak positif dan negatif kepada masyarakat, dan juga kepada persekitaran hutan. Teknik menyelamat menggunakan helikopter menawarkan kaedah yang paling selamat. Akan tetapi, teknik ini tidak dapat dilaksanakan disebabkan kekangan pemilihan kawasan yang selamat bagi tujuan akses helikopter, dengan mempertimbangkan faktor lokasi kawasan kemalangan dan juga impak terhadap persekitaran. Walaupun mempunyai kelebihan di kawasan altitud tinggi dengan ciri-ciri kepelbagaian cuaca, dan kontur, penggunaan helikopter dalam aktiviti menyelamat adalah amat berbahaya. Oleh yang demikian, kaedah yang berkesan perlu dirangka untuk memudahkan proses pemindahan mangsa, dan pada masa yang sama mengurangkan impak kepada kawasan pergunungan yang sangat sensitif. Kajian ini menerangkan kaedah alternatif penggunaan aplikasi geospatial dalam menentukan kawasan pendaratan helikopter dengan cara *Topographic Position Index* (TPI) bagi mengklasifikasikan bentuk muka bumi (LC) secara otomatik. Dalam kajian ini, LC dilakukan dengan bantuan perisian sistem maklumat geografi (GIS). Perisian *System for Automated Geoscientific Analyses* (SAGA) digunakan bagi menganalisa *Digital Terrain Model* (DTM) kawasan kajian dengan menggunakan data beresolusi 5 meter. Peta kawasan yang berpotensi sebagai lokasi pendaratan helikopter di jana, dan koordinat setiap kawasan berkenaan diperoleh dengan menggunakan aplikasi GIS. Data penilaian lapangan menunjukkan ketepatan dengan nilai 66.7%, di mana nilai ini boleh dianggap memuaskan. Kaedah analisis dan teknik tinjauan yang dibincangkan dalam kajian ini dapat digunakan untuk membantu proses perancangan pengurusan kawasan, terutamanya di kawasan hutan pergunungan yang kompleks dalam rantau ini.

Kata kunci: *Digital Terrain Model*, klasifikasi bentuk muka bumi, operasi penyelamatan gunung, kawasan pendaratan helikopter.

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I want to thank my family and close friends, including Mr. Muhammad Shafeeq Bin Mohd Sapian, for his moral support and comradeship to do Master study in a field that I passionate about, even though it is the opposite of my degree study in Mechatronic engineering.

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I hope this research will inspire idea and discussion to make forest a better place.

Thank you.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Signature: _____

Name of Member of Supervisory Committee: Professor Dr. Mohd Hasmadi Ismail

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4WD	Four-wheel drive
ALS	Advanced Cardiovascular Life Support
APM	The Malaysia Civil Defence Force
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BPI	Bathymetric Position Index
CAA	Civil Aviation Authority
CASEVAC	Casualty Evacuation
D-value	D-value represents overall length of helicopter
DA	Density Altitude
DSM	Digital Surface Model
DTA	Digital Terrain Analysis
DTM	Digital Terrain Model
DWNP	The Department of Wildlife and National Parks Peninsular Malaysia
EMS	Emergency Medical Services
FAA	Federal Aviation Administration
FATO	Final Approach and Take-off Area
FRDM	The Fire and Rescue Department of Malaysia
GDM	New Geocentric Datum for Malaysia
GDTM	Global Digital Elevation Model
GIS	Geographic Information System
GPS	Global Positioning System
GR	Grid Reference
HEMS	Helicopter Emergency Medical Services

HFs	Human factors
HIGE	Hover-in-ground effect
HOGE	Hover-out-off-ground effect
ICAO	International Civil Aviation Organization
ICT	Information Communication Technology
IFR	Instrument Flight Rules
IFSAR	Interferometric Synthetic Aperture Radar
ISA	International Standard Atmosphere
JUPEM	The Department of Survey and Mapping of Malaysia
Lat	Latitude
LC	Landform Classification
LiDAR	Light Detection and Ranging
Long	Longitude
LP	Landing Point
MCO	Movement Control Order
MEDEVAC	Medical Evacuation
MERS	Malaysia Emergency Response Services
MET	Malaysian Meteorological Department
MIST	Minimum Impact Suppression Technique
MMEA	Malaysian Maritime Enforcement Agency
MOH	Ministry of Health
MPH	Miles Per Hour
MRSO	Malaysia Rectified Skew Orthomorphic
MUST	Multi Skill Team
N.B.	Nota Bene
NDVI	Normalized Difference Vegetation Index

NWCG	National Wildlife Coordinating Group
OGE	Out-of-Ground Effect
PASKUB	FRDM's Special Air Service
PDRM	Royal Malaysian Police
PEO	Professional Emergency Officer
PGOU	FRDM's Centre of Air Operation
RAM	Risk Analysis and Risk Management
RD	Main rotor diameter of helicopter
SA	Safety area
SAR	Search and Rescue
SPR	Soil Penetration Resistance
SRTM	Shuttle Radar Topographic Mission
STANAG	NATO Standardization Agreements
TLOF	Touchdown and lift-off area
TPI	Topographic Position Index
UAV	Unmanned Aerial Vehicle
VFR	Visual Flight Rules
VMC	Visual Meteorological Condition

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The interests of human being especially in mountaineering in Malaysia are increasing from time to time. Mountaineering looks fun, but it is a high-risk activity. Anything can happen inside the forest because there are many factors which may put anyone (be a professional or amateur hiker) in a real serious situation like weather, terrain, physical limitation as well as wild animals.

In any wilderness environments, we expect unexpected events, and we must prepare ourselves for the worst-case scenario. One of the important steps in risk-mitigating is Risk Analysis and Risk Management (RAM), focusing on laying out all potential risks and mitigating them. Regardless of the practice, it is absurd to eliminate accidents in the forests. A contiguous action plan should be carried out to deal with life taking cases.

Many rescuers believe that numerous injuries and fatalities in mountain territories are due to the lack of appropriate training, equipment, ignorance of local weather conditions and their physical conditioning among many participants. Consequently, the statistics of Search and Rescue (SAR) operations increases. (Ciesa, Grigolato, & Cavalli, 2014).

In rescue mission, delay means lower survival rate. Effective ways need to be identified and established to ease lifesaving and evacuation process. Search and rescue mission or emergency evacuation in the wilderness environment (remote forest) is not an easy task to perform. In the wilderness, many factors may constraint rescuer to perform their mission and the only way to ensure high chances of survival rate is by using the helicopter.

Condition of the patient and accessibility to the accident site are the two main indications determining helicopter use. With these indications, it was found that more fatality of patients happens by ground rescue than patients brought by an aircraft (Hannay et al., 2014; Samdal et al., 2018).

1.1.1 Search and Rescue Operation (SAR) and Emergency Medical Services (EMS)

A search and rescue operation (SAR) refers to an operation coordinated by emergency services to locate persons believed to be in distress and retrieve them, give first aid or other needs, and bring them to medical facilities. SAR has many names according to where the SAR is conducted, as in Figure 1.1, yet the first resort is to seek and provide immediate assistance to people in distress or imminent danger. This study is mainly about SAR operations in the mountainous area or mountain rescue (Heggie, 2008; ICAO, 2004).

Figure 1.1: Types of search and rescue operation according to its mission (Heggie, 2008; ICAO, 2004).

In Malaysia, the Fire and Rescue Department of Malaysia (FRDM) actively participates in mountain rescue. Any call for help from the public through 999 regarding mountain rescue will be handled by Malaysia Emergency Response Services (MERS) and will be channelled to FRDM (MAMPU, 2020).

During SAR responses, time is of the essence. The moment there is a call for an emergency, the clock starts ticking. The longer the delay, the greater the risk to involved parties. SAR operations generally consist of two parts: searching for distressed persons, then followed by their rescue. There are various techniques used for search operations, mainly using thermal imaging search techniques, using animal (dog) searching techniques, camera-equipped mini Unmanned Aerial Vehicle (UAV), hasty search, and helicopters (Ciesa et al., 2014; Phillips et al., 2014; Boucher, 2006).

The other term which is equally important to know is Emergency Medical Services (EMS), also known as ambulance services (including cars, motorcycles, boats, and aircraft) or paramedic services. It is a system responsible for providing first aid service and then transports the victim to the medical facility (Aboueljinane et al., 2013).

EMS systems may vary between nations and geographic areas. However, the operations typically consist of (1) Central operations and (2) External operations (Figure 1.2). It is further subdivided into seven classes; dispatching time, preparation time, travel time to patient, on-site time, travel time to the hospital, drop-off time, travel time to base or another rescue mission.

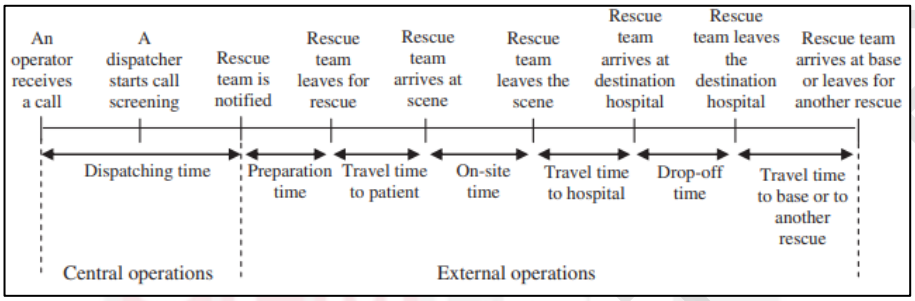

Figure 1.2: The typical EMS processes (Aboueljinane et al., 2013).

1.1.2 The use of Helicopter for Search and Rescue (SAR)

According to Tomazin et al. (2011) and Tomazin and Kovacs (2003), grievously ill and injured patients especially in the mountainous or wilderness regions (no road access) subject to SAR operation delay due to long evacuation response. The delay can compromise recovery or survival. In this geographical region, no land rescue method can work better than the use of helicopter rescue. With a helicopter's help, a rescue team may reach the accident scene and rapidly could be transported to the correct level of medical care (Shimanski, 2008b). The travel time to the patient, on-site time, and travel time to the hospital, as described in Figure 1.2 can be shortened dramatically and significantly reduce the rescuers' fatigue level.

The use of helicopters has many advantages over ground rescue, especially when fatalities are involved and when SAR operation was carried out in the mountainous area. The goal is to provide quick medical care and to transport injured person safely with a short delay. However, the benefit of using the helicopter to save the victim should outweigh the risk of using a helicopter in a mountainous area (Figure 1.3). Helicopter use is risky, and its operation is hampered by many environmental dangers including altitude, terrain and weather. SAR ground rescue should be considered instead of air rescue when the patient’s conditions are stable (Ciesa et al., 2014; Heggie, 2008; Johnson, 2004; Westcott & Cleary, 1950).

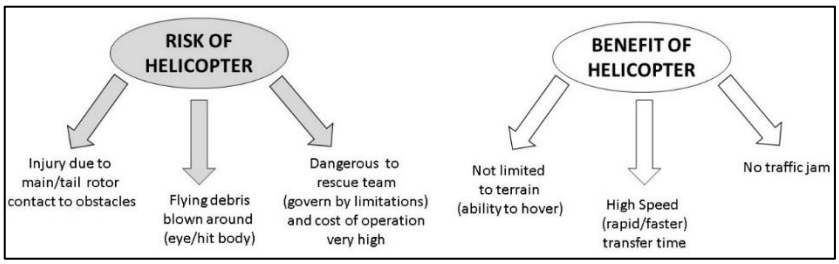

Figure 1.3: Risk versus benefit of launching a helicopter (Ciesa et al., 2014; Heggie, 2008; Johnson, 2004; Westcott & Cleary, 1950).

According to Hamsad (2019), air access is the best way to reach a patient if a delay is harmful. However, choosing to reach the patient via helicopter or ground (operational priority) is determined by the FRDM's Centre for Air Operation (PGOU). Refer to Appendix I for the FRDM aircraft operation flow chart.

Regardless of the helicopter model, there are various limitations, such as weight and balance, allowable payload, operating weight, and climb performance which are not discussed in this thesis. Federal Aviation Administration (2000) offers good reading on these limitations. There are many accidents involving rescue helicopters in the United States as reported by Shimanski (2017). Although there is a lack of reported accidents of mountain helicopter rescue in Malaysia, the possibility of the incident still exists. Fortunately, the risk of helicopter accidents can be improved via a landing at a secure helispot during a SAR operation.

1.1.3 Helicopter Evacuation Techniques and Sustainable Recreation

According to Hamsad (2019) and Hassan and Farizul (2019), the best mode of helicopter evacuation is by the landing recovery method as in Figure 1.4 (The types of helicopter evacuations are as described in Appendix II). According to their experience, landing evacuation does not 100% relying on the machineries, and SAR missions can be performed without depending on the helicopter's performance and fear on the helicopter limitations. Doherty et al. (2013) agreed that the difficulty to detect a landing point may resulted in a severe and dangerous helicopter rescue techniques (refer Appendix II). Figure 1.5 below shows the benefits of having a landing point.

Figure 1.4: Helicopter landing recovery (Lau, 2020).

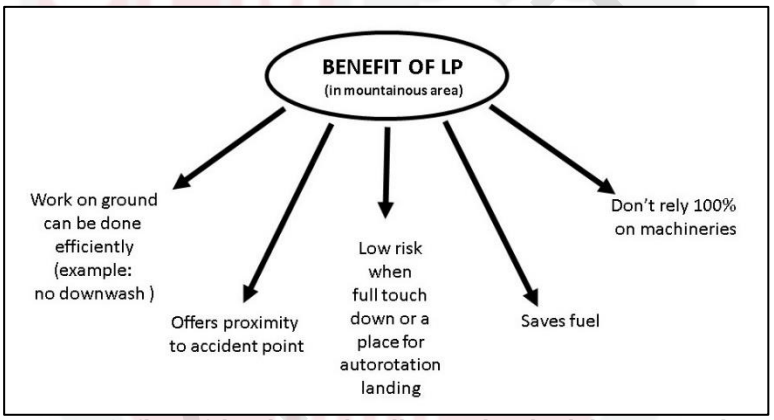

Figure 1.5: Benefits of having a landing point (LP) in mountainous area (Ramlee, 2020; Shimanski, 2008a).

During helicopter SAR operations, landing techniques generally offers the safest option than the other techniques whereas the other techniques which require helicopter hovering poses high overall risk (Appendix II) (Doherty et al., 2013).

1.2 Problem Statement

Mountain helicopter SAR operations regularly face teams with unique difficulties in which even small errors can end up in terrible situations. Potential risk factors can be reduced significantly with implementing a helispot, especially in the mountainous area or as a specific area for autorotation landing in engine failure situation (Baker et al., 2006; Pietsch et al., 2016; Shimanski, 2008b, 2017). Foo et al. (2010) agreed that a potential solution to mitigate the risk of crashes due to bad weather and darkness is building and designating secure landing sites such as helispots.

All safety measures should be treated seriously. Even though helicopters are uniquely valuable, they are incredibly dangerous. Safety and security must be the highest priority in any SAR mission because many rescuers have lost their lives during SAR missions. With rotors revolving at over 150 M.P.H., the hazard to the SAR team is real. Although no accidents involving rescue mission were reported in Malaysia, this situation could not be taken for granted (Shimanski, 2008b, 2017).

It is better to construct at least one helispot for mountain rescue than suddenly make one in the case of emergency. For example, on 17th February 2013, there was a hiker who died because of breathing problem at Mount Tahan (Bernama, 2013). The body cannot be carried out using manpower because most of the hikers are exhausted, and the only choice they had at that time was to evacuate the body using a helicopter. The evacuation was done with the help of a winchman (a man lowered from the helicopter using a winch). But, to lower down the winchman and ensure his safety, the forested surrounding had to be cleared. Chopping of trees was done without following the minimal impact code of practice (sustainable recreation), and the forest canopy was opened drastically (Figure 1.6). The picture was taken in the year 2013, two weeks after the incident by the author as an ordinary hiker (not a researcher).

Figure 1.6: Excessive canopy opening during mountain rescue in Mount Tahan.

A properly selected helispot would avoid unnecessary destruction or negative impact on the forest environment. In recreation ecology, planning and management, the term impact indicates any undesirable visitor-related biophysical change of the wilderness resource. Adverse impacts on wilderness are an unavoidable consequence of recreation. Indeed, even the most well-thought visitors would unintentionally disturb wildlife and leave footprints (Leung & Marion, 2000). These impacts will alter the microclimate of the trail and cause changes in environmental stability. Usually, if the trail involves highly concentrated use, impacts are often pronounced (Man, 2001). According to Park (2014), once the site is destroyed, naturally, it will take some time to recover as a lot of damage, including habitat loss and species destruction, will occur at the site.

Recreational activities can cause an impact on all resource elements in a wilderness ecosystem. By entering an area (in our context, helispot), we may change the ecology of a complex and frequently hard-to-understand system (Romer, 1998). There are many obvious (direct) and indirect recreation impact (Leung & Marion, 2000). Therefore, to ensure the mountainous area's well-being over an indefinite time (sustainability), a good trail assessment must be carried out. This assessment ensures sustainability and ensures the safety of the landing aircraft and all people involved in SAR operations.

One of the limitations that rescue team faced are constraints in selecting suitable area for helispot (helicopter landing point), by considering the risks and environmental impacts at the rescue site. Helispot development may contribute to the substantial impacts on soil and vegetation, including soil compaction, erosion, muddiness, loss of vegetative groundcover, and species composition changes (Leung & Marion, 2000). Finding a helispot in a mountainous area is difficult to establish, but implementing a well-studied helispot could be an alternative to reduce the impact on the environment and ensure the sustainability of the mountainous area.

According to Doherty et al. (2013), the difficulties in finding a helispot in mountain rescue might lead to a more dangerous rescue operations. In Malaysia, due to the rugged mountainous terrain and limited landing point, many SAR missions were carried out by hoist. Table 1.6 listed the SAR cases in the mountainous area involving helicopter rescue in Malaysia from year-2016 to the year-2020, as been reported by Hamsad (2019).

Table 1.1: SAR cases at mountainous area involving helicopter.

Date	Location	SAR method	Complications
16 Mac 2020	Kor Campsite, Mount Tahan, Pahang	Winching	Thick forest/ No available landing point
31 Aug 2019	Mount Yong Belar, Pahang	Winching	Thick forest/ No available landing point
22 Apr 2019	Mount Korbu, Perak	Winching	No available landing point and operation delayed one day due to bad weather
18 Aug 2018	Yong Forest Reserve, Pahang	Cannot perform	Heli Departed Back (unserviceable)
15 Aug 2018	Camp 5, Mount Mulu, Sarawak	Land	Available landing point
21-24 July 2018	Mount Yong Yap, Kelantan	Winching	Thick forest/ No available landing point
30 May 2018	Camp 3, Mount Mulu, Sarawak	Winching	Thick forest/ No available landing point

27 Mac 2018	Camp 5, Mount Mulu, Sarawak	Land	Available landing point
13 Nov 2016	Mount Inai, Perak	Winching	Thick forest/ No available landing point
28 Oct – 1 Nov 2016	Mulu National Park, Sarawak	Land	Available landing point
21 Oct 2016	Mount Baling, Kedah	Winching	High ridge/ no flat areas
1 Sept 2016	Mount Rajah, Kuala Kubu Baru	Winching	High ridge/thick forest
10 Aug 2016	Ulu Tembeling National Park, Pahang	Winching	Thick forest/ No available landing point
23-24 Apr 2016	Mount Rajah, Kuala Kubu Baru	Winching	High ridge/thick forest
11 Jan 2016	Mount Bintang, Sedim, Kedah	Winching	Thick forest/ No available landing point

Table 1.1 depicts that most of the rescue mission involved the winching method, which was determined due to the unavailability of a landing point near the rescue site. Therefore, construction of a helispot somewhere in the middle or far from the trailhead should be implemented, preferably at a place where it consumes time to evacuate or rescue people using manual manpower or land transportation.

1.3 Objectives

1. To characterize landform classes in Mount Tahan using TPI-based geospatial approach.
2. To determine potential helispots based on helispot criteria and landform suitability.
3. To evaluate the accuracy of DTM application in landform classification of Mount Tahan.

1.4 Significant of Study

Analysis of contemporary research of the helispot selection and surveys reveal that the potential of emerging technology such as the spatial data and computer modelling, especially using GIS, aid in the remote survey of the potential landing sites. As proposed by Foo et al. (2010) and Doherty et al. (2013), the use of GIS is capable of selecting potential helispot locations in support of Helicopter Emergency Medical Services (HEMS) flights or in emergent rescue situations. Also, agreed by Keith (2017), military helicopter crews conduct helispot surveys

using GIS using remote-sensing geospatial data before conducting disaster relief flight missions. Also, according to Doherty et al. (2013), the utilization of GIScience can be applied by the park/forest management to abruptly reduce the ecological impacts by finding suitable landing areas.

The purposes and needs for helispot in the mountainous area for mountain rescue are undeniable and it is mainly due to the rapid advancement of outdoor activities participation. Any helispot allocation should consider its impact on the recreational resources. Therefore, to ensure the well-being of the mountainous area over an indefinite time (sustainability) an effective trail assessment need to be carried out. This assessment not only to ensure sustainability but to ensure the safety of all people involved in SAR operations. Hence, effective method needs to be established to ease the evacuation process as well as to reduce environmental impacts to the sensitive mountainous area.

As proposed by Foo et al. (2010), the use of GIS to select potential helispot will support the helicopter emergency medical services or Mountain rescue and this research is conducted to demonstrate it. This research shall benefit society, forest management and rescue agency during SAR response operations and providing a guideline for helispot detection during SAR missions.

The advance tools within GIS also provide multiple techniques and technologies for better analysis and presentation of natural resources to achieve sustainable management. The integration of Digital Terrain Model (DTM) and other forest cover information may produce a set of databases that offers a significant reduction in cost, working times, labour usage and lead to the selection of the most suitable helicopter landing point in the area compared to traditional method such as ground survey. To overcome delays and inaccuracies, a geographic information system (GIS) is used in modern studies.

This study establishes a method to determine the potential helispot by using a geospatial technique based on automated landform classification (LC). Again, this study is not about constructing the helispot but to give an idea on how to find a potential helispot by using the geospatial application to automate LC. The method presented would not just time-saving but is also cost-effective in terms of operation and labour usage compared to the traditional survey technique. Moreover, this study may take a broader perspective on their practicality by doing ground-truth evaluation.

Lastly, this study will benefit various parties, including researcher, stakeholder, management authority and search and rescue (SAR) agencies, by providing an informative reference. This study will provide a better understanding of the DTM application. The landform classification technique and guidelines used in this study is feasible and user friendly to any party. This study will highlight several potential areas for helispot landing and would be an effective guideline for the forest manager and rescue team in an emergency. Also, the outcomes will

provide a set of information for land practitioners for sustainable management planning particularly in the study site.

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