SUSTAINABLE RECREATION PLANNING WITH SPATIAL ANALYSIS FOR TRAIL AND CAMPSITE CHARACTERIZATION IN CAMERON HIGHLANDS, MALAYSIA

By

MUHAMMAD SHAFEEQ BIN MOHD SAPIAN

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

October 2022

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Outdoor activities and the provision of recreational trails provide numerous benefits to health, human well-being, and education through nature appreciation and understanding. They can also increase environmental awareness, local economic development, connect major areas, and diversify the tourism market. However, trail development and design must adhere to the principles of sustainable recreation while understanding the perceptions of trail users. In the case of Cameron Highland, the forested area is facing a challenge to assess the resource condition as the complex mountain ecosystem limits researchers accessibility for ground monitoring. This study aims to demonstrate the use of geospatial technology methods using terrain analysis to assess and map the trail and campsite characteristics in the complex mountainous area of Cameron Highlands. Spatial assessment was carried out on Mount Irau which is located in the Batu Gangan Forest Reserve. The method used in this study comprises digital terrain assessment, field monitoring and verification. Terrain characteristics such as Slope, Topographic Wetness Index (TWI), Slope Length Factor (LS), and landform classification (LC) are automatically obtained by using a Digital Terrain Model with a resolution of 10 meters through the SAGA GIS platform. This study suggested that the hiking trail of Mount Irau is dominated by ridge landform type with a mean elevation value of 1572.46±171.48. The study found out that the trail slope of Mount Irau is erosive with a mean value of 19.16±9.53°, thus an alternative route has been proposed. Interestingly, the plain landform covers only 3.26% or 2.03km^2 of the entire study area, where two potential camping sites have been identified. Results obtained from the study which were presented in the Geographical Information System (GIS) theme can be used for long-term project planning and produce effective management of recreational resources in the area.

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Keyword: Digital terrain model, GIS, landform classification, campsite, trail, sustainable recreation

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

PERANCANGAN REKREASI MAMPAN MENGGUNAKAN ANALISA RERUANG BAGI PENCIRIAN DENAI DAN TAPAK PERKHEMAHAN DI CAMERON HIGHLANDS, MALAYSIA

Oleh

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Aktiviti rekreasi luar melalui penyediaan denai rekreasi memberi manfaat kepada kesihatan, kesejahteraan manusia, dan pendidikan melalui penghargaan dan pemahaman terhadap alam semulajadi. Ia nya juga dapat meningkatkan kesedaran terhadap alam sekitar, pembangunan ekonomi tempatan, menghubungkan tarikan utama di kawasan tertentu dan mempelbagaikan pasaran pelancongan. Walau bagaimanapun, pembangunan dan reka bentuk denai mesti mematuhi prinsip rekreasi mampan di samping memahami persepsi pengguna denai. Kawasan berhutan di Cameron Highland menghadapi cabaran dalam penilaian sumber dimana keadaan hutan pergunungan yang kompleks membataskan pemerhatian lapangan. Kajian ini bertujuan untuk mendemostrasikan penggunaan kaedah teknologi geospatial di dalam analisis rupa bumi dan pemetaan untuk mengenal pasti pencirian denai dan tapak perkhemahan di kawasan pergunungan Cameron Highland yang kompleks bagi menyokong perancangan kawasan rekreasi mampan. Penilaian spatial telah dijalankan di Gunung Irau yang terletak di dalam Hutan Simpan Batu Gangan. Kaedah yang digunakan dalam kajian ini mengemukakan pendekatan analisis yang melibatkan Sistem Maklumat Geografi (GIS), pemantauan lapangan dan pengesahan keputusan. Ciri-ciri rupa bumi seperti Cerun, Indeks Kelembapan Topografi (TWI), *Slope Length Factor* (LS), dan klasifikasikan bentuk muka bumi (LC) diperolehi melalui *Digital Terrain Model* dengan resolusi 10 meter menggunakan platform SAGA GIS. Keputusan kajian menyarankan bahawa denai utama pendakian didominasi oleh permatang dengan nilai purata 1572.46±171.48. Nilai purata kecerunan di Gunung Irau adalah 19.16±9.53°, dengan potensi hakisan yang tinggi. Satu laluan alternatif telah dicadangkan untuk mengurangkan impak pendaki di laluan utama. Keputusan kajian mencadangkan bahawa kawasan berprofil rata hanya meliputi 3.26% atau 2.03km^2 dari keseluruhan kawasan kajian, dimana terdapat dua tapak perkhemahan berpotensi telah dikenal pasti. Maklumat yang diperolehi melalui Sistem Maklumat Geografi (GIS) boleh digunakan untuk perancangan dan pengurusan jangka panjang sumber rekreasi yang lebih efektif.

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Kata kunci: *Digital terrain model*, Sistem Maklumat Geografi (GIS), klasifikasi bentuk muka bumi, tapak perkhemahan, denai gunung, rekreasi mampan

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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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LIST OF ABBREVIATIONS

4WD	Four-wheel drive
API	Application Programming Interface
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BPI	Bathymetric Position Index
CC	Carrying Capacity
CH	Cameron Highlands
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
FR	Forest Reserve
FRDM	The Fire and Rescue Department of Malaysia
GDM	New Geocentric Datum for Malaysia
GIS	Geographic Information System
GPS	Global Positioning System
GR	Grid Reference
HFs	Human factors
JPSM	Jabatan Perhutanan Semenanjung Malaysia
JUPEM	The Department of Survey and Mapping of Malaysia
Lat	Latitude
LC	Landform Classification

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LG	Landform Grade
LIDAR	Light Detection and Ranging
Long	Longitude
LOTR	Lord of The Ring
LP	Landing Point
LS	Length-Slope
MCO	Movement Control Order
MRSO	Malaysia Rectified Skew Orthomorphic
NA	Not Available
NDVI	Normalized Difference Vegetation Index
NWCG	National Wildlife Coordinating Group
RAM	Risk Analysis and Risk Management
RS	Running Slope
SA	Safety area
SAGA	System for Automated Geoscientific Analysis
SAR	Search and Rescue
SPR	Soil Penetration Resistance
SR	Slope Ratio
SRTM	Shuttle Radar Topographic Mission
T1	Trail 1
TG	Trail Grade
TIN	Triangulated Irregular Network
TPI	Topographic Position Index
TSA	Trail Slope Alignment
TWI	Topographic Wetness Index

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UAV	Unmanned Aerial Vehicle
UC	Uncommon

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Outdoor and recreation activities in mountain areas have a significant influence on sustainable tourism development. According to Markovic and Petrovic (2013) studies have found that the presence of recreational activities in mountain areas attracts tourists who seek to experience nature in a variety of ways. Furthermore, these activities can provide a source of income to local communities and are a way to preserve local culture, which helps to promote sustainable tourism development.

The purpose and value of outdoor and nature-based recreation is an increasingly important topic of discussion in the modern world. According to a study by Rice et al. (2020), outdoor recreation has a significant impact on the environment, providing a range of ecosystem services. These services help to maintain human wellbeing, as well as providing important ecological functions such as preserving biodiversity, protecting clean air and water, and reducing soil erosion.

The study found that outdoor recreation is a key factor in promoting human health, particularly physical and mental health. It also provides a range of cognitive and educational benefits, such as developing problem solving and communication skills and improving knowledge of the natural environment. Furthermore, it can also lead to increased social interaction and community cohesion, which can help to reduce social isolation and promote better mental health. The study also identified the economic benefits of outdoor recreation, including the creation of jobs, increased tourism, and improved economic growth.

According to Winter et al. (2020) it is important to examine the differences between outdoor and nature-based recreation and ecotourism. Outdoor recreation involves activities that take place outdoors, such as camping and fishing, while nature-based recreation involves activities that take place in natural settings, such as hiking and bird watching. Ecotourism, on the other hand, is defined as "responsible travel to natural areas that conserves the environment and improves the well-being of local people" (Lovelock et al., 2016). Thus, ecotourism involves activities that are both nature-based and recreation-based, but with an emphasis on conservation and sustainability. The primary differences between outdoor and nature-based recreation and ecotourism is that the former seeks to provide leisure activities in a natural environment, while the latter seeks to promote conservation and sustainability.

The use of outdoor and recreation activities to promote sustainable tourism development can also be beneficial for the environment, as these activities can help to protect natural

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resources, preserve wildlife, and reduce pollution. In addition, there has been a lot of interest in employing sustainable trail construction, campsite management, and visitor management strategies in mountain areas, which will allow local economies to thrive while simultaneously preserving the cultural and ecological basis on which tourism depends (Dragovich, 2017).

Upadhayaya (2018) further argues that the Great Himalaya Trail is an example of how sustainable management of trekking trails can be achieved through careful planning and implementation of a range of management strategies, including the promotion of local tourism businesses, the development of local infrastructure, and the adoption of sustainable practices such as the use of renewable energy and waste management systems.

In the Malaysian context, even though most of the recreational activities consist of visiting national park sites, and hiking during the weekend, interest in hiking and camping has been rapidly growing (Jusoff and Skidmore, 2009). Hiking and camping are becoming increasingly popular in Malaysia, and for good reason. With its lush forests, stunning mountain ranges, and diverse wildlife, Malaysia is a great place to explore and experience the outdoors. The existence of campsites in the forest is essential for hikers who are looking to spend more than one day on the trail. Not only do these campsites provide a place for hikers to rest and recharge, but they also serve as a meeting point for hikers who are climbing and resting along the way.

When choosing a campsite in a mountain area in Malaysia, there are a number of factors to consider. The first factor to consider is the terrain and the type of vegetation present. It is important to look for flat, dry ground and to avoid dense, overgrown areas of vegetation. Second, the campsite should be located in an area that is considered safe and secure. This includes being located away from any hazardous areas, such as those with a large concentration of wild animals. Finally, gentle winds are important, as they can help keep the campsite cool and comfortable. Taking these factors into consideration can help to ensure that the camping experience in a mountain area in Malaysia is safe, secure, and enjoyable. (Lye, 2002).

Although hiking and camping have grown in popularity and provide benefits to the society, mountain climbing is not without hazards. This is due to the fact that this activity exposes hikers to a variety of natural obstacles. Hikers mental and physical preparedness, as well as rapid weather changes and unpredictable environmental circumstances, are among the challenges (Gatterer et al., 2019).

On the other hand, camping activities can induce significant and often localised resource impacts that can affect soil (compaction and erosion, ground exposure, changes to the hydrology of site), vegetation (loss of ground vegetation and seedlings, trampling, change in species composition, spread of invasive plants), wildlife (habitat alteration, disturbance to wildlife), and water (increased turbidity, contamination with human faecal matter) with severity of such impacts varying on the use level (Pickering et al., 2010).

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Nevertheless, no prior research has particularly attempted to examine the campsite choices and characteristics at mountainous areas. Only a few studies thus far about the terrain analysis and campsite location characteristic in the Asian tropics (Mallikage et al., 2021). If this risk management is not managed appropriately, it might lead to occurrences that are dangerous to hikers. Getting lost, stuck, and falling are all common occurrences in the Malaysian climbing scene. It will have an indirect negative impact on the hikers physical and emotional wellbeing. (Azita et al., 2019).

Last but not least, accidents when climbing are expensive for both the relevant agencies and the hikers themselves such as the hiker's personal medical bills and rehabilitation expenses. In the case of an incident while ascending the mountain, local authorities must additionally cover the cost of SAR efforts. Logistics expenses, specialised rescue allowances, and equipment support are a few of them (Heggie, 2009).

1.2 Study Site

For this research, Cameron Highlands region is situated in the Main Range of Peninsular Malaysia. The average elevation of the catchment area is approximately 1829 m above sea level. The area is covered by 71,218 hacter of forests (Tan et al., 2015). The Cameron Highlands lies between 4°19’ and 4°37’ N and between 101°21’ and 101°30’ E, in the mountainous region of Pahang state, Malaysia; the districts bordered by Lipis district to the south-east, Kelantan to the north, and Perak to the west. Daily temperatures are no higher than 25°C and rarely fall below 12°C year-round; the average annual rainfall is 2660 mm, with the highest rainfall in May and October.

The justification of the study site’s selection has been added. The identification of campsites is critical for logistic mobilization and rescue transportation, and this research received positive support from the JPSM (Cameron Highland Forestry Department). Mount Irau is purposely chosen with relations to the significant challenging SAR cases as listed in Table 1.1. The evacuation process was carried out using helicopter winching technique whereby campsite is crucial for this process. Recreation impacts in high elevation ecosystems at Mount Irau can be particularly problematic, because this mountain ecosystems are often unique and sensitive.

This study area highlights a study that associated with the sustainable trail of the area that recognized as Mount Irau (2110 m) at Cameron Highland, Pahang. Vast forests, critical habitat for numerous plant and wildlife species, and the headwaters of several major rivers are contained within the region. According to Razali et al. (2018), the Cameron Highlands has been classified as environmentally sensitive area because of its rich variety of flora and fauna and its role as main water catchment for the Jelai and Pahang Rivers (Sg. Jelai and Sg. Pahang). Below is the topographic map of Cameron Highland.

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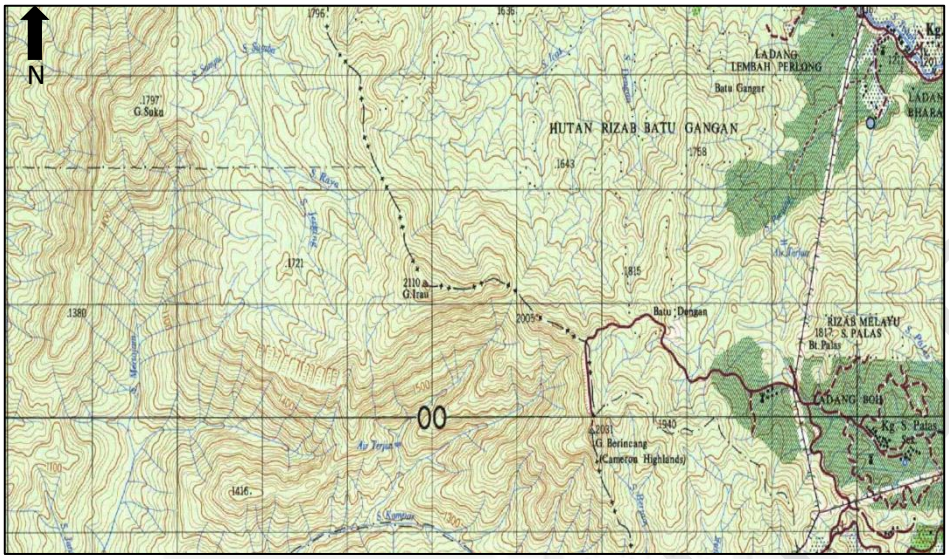

Figure 1.1: Topography Map of Mount Irau

1.3 Problem Statement

Gunung Irau is a popular hiking ground for visitors and it is alleged that the Pahang Forestry Department is aware that physical damage occurred along the trail to the Mini Irau summit. However, they do not know how frequent and extensive the damage has occurred. It was expected that many trekkers are not aware that hiking activities contribute a direct impact to soil and vegetation which cause great harm to the whole trail system especially in recreational resources. Hikers can access this mountain without any blockade or useful information of trail impact that can affect the condition of the mountain trail.

In the past few years, mountaineering activity has traditionally involved camping, trekking and hiking activities. These activities can lead to the impact on the trail. According to Tomczyk et al. (2016), recreation-based activities can damage the ecosystems, and take time for the recovery process. The tropical rainforest is characterized as having vegetation all year round, tree branching with soft and delicate leaves, easily compacted soils, very sensitive to changes and damages. Mountain fragility environments, as has been discussed by Catalan et al. (2017), are scattered into several elements such as; climatic extremes, low biological activity, slope steepness, and the basic conservatism of the dominant life forms, all constituting to the rate of restoration to original conditions after disturbance. Therefore, trail deterioration will also affect the overall mountain environment.

Therefore, the study will focus on identifying a properly selected alternative trail and campsite that would avoid unnecessary destruction or negative impact on the forest environment. In recreation ecology, planning and management, the term impact indicates

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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 and Marion, 2000). These impacts will alter the microclimate of the trail and cause changes in environmental stability. 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 the mountain trail, 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 and 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 hiker and all people involved in SAR operations.

Chen et al. (2017) have reported that the use of proper rescue equipment is essential for successful rescue operations in mountainous areas, especially in tropical countries, where the terrain and environmental conditions are more challenging. When emergency situations arise in mountainous areas such as the Mount Irau in tropical countries, it is crucial for the rescuer team to continue taking immediate action for sustainability of the trail. By having a plan in place, rescuers are able to ensure the safety of hikers who are unfamiliar with the trails, provide help and resources in an effective and organized manner, and better protect the environment. With proper trail maintenance and a comprehensive plan, rescuer teams ensure the preservation of the trail for further use, ensuring safety and avoiding further accidents. Finding a campsite in a mountainous area is difficult to establish, but implementing a well-studied campsite could be an alternative to reduce the impact on the environment and ensure the sustainability of the mountainous area.

Table 1.1: SAR Cases at Mountainous Area

Year	Month	Location	Incident / Cases	No of Victims	Result
2023	Jan	Bukit Tabur	Falling in high cliffs	1	Injured
	Jan	Bukit Botani	Lost during trekking	1	Found Safely
	Dec	G. Pulai	Lost during trekking	1	Found Safely
	Sept	G. Panti	Lost during trekking	3	Found Safely
2022	Mar	G.Keriang	Lost during trekking	3	Found Safely
2021	Dec	G.Lambak	Lost during trekking	4	Found Safely
2020	Aug	G. Santubong	Lost during trekking	7	Found Safely
2019	May	G. Tampin	Lost during trekking	6	Found Safely
2018	Dec	Bukit Bendera	Lost during trekking	9	Found Safely

Table 1.1 : Continued

Year	Month	Location	Incident / Cases	No of Victims	Result
2017	Oct	G. Irau	Lost during trekking	1	Found Safely
	May	G. Irau	Falling in high cliffs	1	Found Safely
	April	G. Panti	Lost during trekking	4	Found Safely
	Feb	G. Irau	Lost during trekking	5	Found Safely
2016	Feb	Bukit Tabur	Falling in high cliffs	1	Injured
	Jan	Kota Damansara Forest Hill	Missed from the trail route	6	Found Safely
		G. Jerai	Fell 15m to the valley	1	Died
2015	Dis	G. Tok Wan	Lost during trekking	2	Found Safely
	Sep	Bukit Saga	Lost during trekking	2	Found Safely
	Jun	Bukit Hartamas	Lost during trekking	1	Not Found Yet
	Mei	G. Kinabalu	Earthquake	18	Died
	Mac	G. Angsi	Heath problem (difficulty breathing)	1	Died
	Feb	G. Gerah	Missed from the trail route	1	Found Safely
	Jan	G. Angsi	Singaporean Hiker- Missed from the trail route	4	Found Safely
2014	Nov	G. Gajah Terom	Missed from the trail route	1	Died
	Mac	G. Bubu	Missed from the trail route	4	2 Died
2013	Dec	Bukit Tabur	Slipping from the trail	1	Died
		G. Stong	Slipping down the waterfall	1	Died
	Oct	G. Angsi	Stranded: No basic hiking equipment	70	Found Safely

[Adli et al. (2018), www.bomba.gov.my]

Table 1.1 revealed 160 mountaineering incidents and accidents throughout 2013 - 2023. Characteristics of incidents revealed lost during trekking (49 cases), fallen (4 cases), missing from trail (20 cases), slipping from trail (2 cases), earthquake (18 cases), health problem - difficulty of breathing (1 case), and stranded (70 cases).

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1.4 Research Objective

This research aims at how spatial modelling techniques can effectively plan recreational resources from a various perspective. The information offered in GIS themes can be utilized for long-term project planning, trail planning and monitoring, and ecosystem evaluation, resulting in effective recreational resource management in the area. The study findings and data will lead to proper forest use for recreational reasons that is consistent with conservation efforts. The specific objectives of this study are:

1. To identify the terrain characteristics in Mount Irau, Cameron Highlands, using Digital Terrain Modelling.
2. To analyse trails and campsite characterization using Topographic Position Index (TPI) analysis in Mount Irau, Cameron Highlands.
3. To propose an alternative trail and potential campsites based on TPI for sustainable recreation planning.

Based on point number 1, the Digital Terrain Modelling (DTM) has been used in a variety of ways to examine various aspects of a mountain. This is especially true for Mount Irau, which is located in Pahang, Malaysia. According to a study by Azita et al. (2019), the elevation, slope, and aspect of the mountain were examined using Digital Terrain Modelling. This model was then used to calculate the elevation, slope, and aspect of the mountain.

These results are important for understanding the characteristics of Mount Irau, as well as for planning future development projects in the area. With the help of Digital Terrain Modelling, the terrain characteristics and other land features can be accurately depicted and understood without the need for costly and time-consuming field data collection. This helps in the identification of terrain characteristics in Mount Irau in a safe, quick and cost-effective manner.

Referring to point number 2, studies have suggested that TPI values can be used to classify trails and campsites into three different categories: low, medium, and high (Mokarram et al., 2015). Low TPI values indicate flat terrain, which is ideal for trails and campsites, as it can provide a smoother, less challenging experience for hikers. Medium TPI values correspond to terrain that is slightly hilly, and is well-suited for more experienced hikers, as well as for camping sites that can provide a more scenic view. High TPI values represent terrain that is steep and rugged, and is best suited for experienced hikers who are looking for a more challenging experience.

The Topographic Position Index (TPI) analysis carried out in Mount Irau, Cameron Highlands demonstrated that the highest TPI values were observed for the trails in this mountainous area. This indicates that the highest landforms in the area are the trails,

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which are more pronounced than the campsites. This helps us to better understand where the most visible trails and campsites are located in the area, helping us to better characterize and plan them accordingly.

Overall, incorporating a Topographic Position Index (TPI) into recreation planning can be an effective pathway towards sustainable outdoor recreation. This system helps to assess the conservation value of an area, which would then facilitate the development of eco-friendly trails and campsites. With the changes that have been made to this index, land managers can better assess the landscape and design trails and campsites in an environmentally safe manner. In addition to that, using the TPI to study ecological and topographic features helps land managers better understand the relationship between the environment and recreational activities. Ultimately, using the Topographic Position Index (TPI) to determine potential trails and campsites is an incredibly useful tool in sustainable outdoor recreation planning.

1.5 Significance of Study

This research is significant to explores how spatial modelling techniques can contribute to a unique perspective for recreational planning. The use of GIS mapping terrain analysis and mapping is possible to document the trail characteristics and select suitable locations for campsites using minimal data resources.

The purposes and needs for campsite in the mountainous area for trail checkpoint, resting area or area for mountain rescue are undeniable and it is mainly due to the rapid advancement of outdoor activities participation. Any campsite 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.

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 vegetation 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 campsite location 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 campsite and alternative trail by using a geospatial technique based on automated landform classification (LC) and terrain analysis. Again, this study is not about constructing the campsite and trail but to give an idea on how to find a potential campsite by using the geospatial application to

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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 campsite 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.

1.6 Limitation and Delimitation

Recreation planning is essential for developing sustainable trails and campsites, and one of the most important tools for doing this is the Topographic Position Index (TPI). This section will discuss specifically the effect of TPI analysis on the characterization of trails and campsites, examine the limitations and delimitations of TPI analysis for trails and campsites, and assess the utility of TPI analysis for characterizing trails and campsites in Mount Irau, Cameron Highlands.

Cetin and Sevik (2016) explain that TPI can provide beneficial insights into the environmental conditions of a given area, such as the amount of sunlight received, the slope of the terrain and the presence of vegetation. By understanding these conditions, planners can make more informed decisions about which areas are best suited for recreation and which types of activities are suitable for each area. Additionally, TPI can be used to identify potential conflict areas between different types of recreational activities, such as mountain biking and hiking on the same trail. Furthermore, TPI can help identify areas of potential risk for accidents or injury, allowing for more effective risk management. In conclusion, the use of TPI for sustainable recreation planning provides a wealth of information that can be used to create more effective and efficient recreation plans.

Topographic Position Index (TPI) analysis is a useful tool for the characterization of trails and campsites in Mount Irau, Cameron Highlands. TPI is a spatially continuous measure of topographic relief based on elevation data, which can be used to identify topographic features, surface roughness, and landform variability (Cuirong et al., 2016). TPI analysis can be used to identify the best locations for trails and campsites in the mountain. The TPI analysis helps to identify the most suitable areas for trail and campsite construction by combining elevation data, landforms, and terrain features (Gioia et al., 2020). It also provides a better understanding of the terrain and allows for the creation of trails and campsites which are safe and accessible for visitors. Furthermore, the TPI analysis allows for the identification of areas that are most suitable for camping and

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offers a better way of visualizing and understanding the terrain of Mount Irau (De Reu et al., 2013).

TPI analysis can also be used to identify potential risks and hazards associated with different areas of the mountain, such as steep slopes and unstable terrain, which can help to ensure the safety of hikers and campers. In conclusion, TPI analysis is a useful tool for the characterization of trails and campsites in Mount Irau, Cameron Highlands. It is an effective way of identifying the most suitable areas for trail and campsite construction, and also provides a better understanding of the terrain, allowing for the creation of trails and campsites which are safe and accessible for visitors.

The integration of Topographic Position Index into a recreation plan can provide a reliable tool for parks and recreation departments to identify potential trail and campsite locations for sustainable management and use. By utilizing this tool, management plans can more easily identify specific terrain features that can be helpful in making informed decisions about trail and camp locations. This further enables park departments to properly manage public lands for maximum use, while maintaining an emphasis on sustainable practices.

1.7 Summary

In this chapter, the researcher has presented an overview about the sustainability, trail characteristic, campsite guideline for recreational activities. It involved the discussion about the background, problem statement, objective, significance, limitation or delimitation and the definition of terms. The next chapter will describe the literature review which describe the literature review which provides further explanation about this study.

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