PROCEDURAL EFFECTS ON CONTROLLING NATURAL DISASTERS (LANDSLIDES AND FLASH FLOODS) BASED ON ENVIRONMENTAL DEGRADATION FROM DEVELOPMENT IN MALAYSIA

ALYA BATRISYIA BINTI HIPENY

SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA
2022

ALYA BATRISYIA BINTI HIPENY 2022

PROCEDURAL EFFECTS ON CONTROLLING NATURAL DISASTERS (LANDSLIDES AND FLASH FLOODS) BASED ON ENVIRONMENTAL DEGRADATION FROM DEVELOPMENT IN MALAYSIA

By

ALYA BATRISYIA BINTI HIPENY

This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of the requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

June 2022

SCHOOL OF CIVIL ENGINEERINGACADEMIC SESSION 2021/2022

FINAL YEAR PROJECT EAA492/6 DISSERTATION ENDORSEMENT FORM

Title: Procedural Effects on Controlling Natural Disaster (Landslides and Flash Floods) Based on Environmental Degradation from Development in Malaysia

Name of Student: Alya Batrisyia binti Hipeny

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature:

Alya

Date : 9th August 2022

Approved by:

NOR AZAM RAMLI 14363

(Signature of Supervisor)

Name of Supervisor : Professor Dr Nor Azam Ramli

Date : 10082022

Approved by:

(Signature of Examiner)

Name of Examiner : Assoc. Prof. Dr. Noor Faizah Fitri Md Yusof

Date : 11th August 2022

ACKNOWLEDGEMENT

All praises and thanks to Allah for His blessings throughout my research work and complete it satisfactorily.

Words cannot express my gratitude to my research supervisor, Prof. Dr Azam bin Ramli, lecturer in the School of Civil Engineering, Universiti Sains Malaysia, for his guidance and constant supervision and for providing necessary information regarding this research. Additionally, this endeavour would not have been possible without his encouragement and generous support.

I want to extend my sincere thanks to my parents and family for their support, prayer, and belief in me, which have kept my spirits and motivation high during this process. I had like to mention my friends who provided both moral support and helped throughout the completion of this research.

Last but not least, I wanna thank me, I wanna thank me for believing in me, I wanna thank me for doing all this hardwork, I wanna thank for having no days off, I wanna thank me for never quitting, and to all those whom doubted me, I made it!

ABSTRAK

Dalam beberapa tahun kebelakangan ini, jumlah penduduk Malaysia yang semakin meningkat dan keadaan ekonomi yang semakin pesat telah menyebabkan pembinaan kondominium dan pemendapan dan merentasi kawasan berbukit. Bencana alam sentiasa berlaku di Malaysia dengan tanah runtuh dan banjir kilat sebagai masalah utama dan bencana alam yang kerap dihadapi oleh rakyat Malaysia. Masalah ini berlaku setiap tahun berikutan peningkatan bilangan pembangunan di Malaysia yang melibatkan pembersihan tanah dan pembinaan pesat terutamanya di kawasan berbukit. Dalam keadaan sedemikian, satu penyelidikan yang dijalankan ke atas kejadian tanah runtuh dan banjir kilat berlaku di Malaysia dari tahun 2020 hingga 2022. Penilaian dalam penyelidikan ini dilakukan dengan menggunakan kaedah matriks yang biasa digunakan dalam Penilaian Kesan Alam Sekitar (EIA). Keputusan yang diperoleh dengan menggunakan kaedah tersebut menunjukkan bahawa kedua-dua tanah runtuh dan banjir kilat lazimnya berlaku pada suku akhir tahun iaitu pada bulan Disember dan Januari untuk kedua-dua tanah runtuh dan bencana banjir kilat. Skor tertinggi bagi kejadian tanah runtuh direkodkan di Putrajaya dan Kuala Lumpur dengan 8.4 manakala 9.2, purata markah tertinggi direkodkan untuk banjir kilat berlaku di Selangor, Pahang, Kelantan, Kuala Lumpur, Melaka, Negeri Sembilan, Perak, dan Terengganu. Kedua-dua kejadian ini berlaku pada Disember 2021. Keadaan ini menunjukkan kedua-dua bencana in terjadi secara alami dan manusia mempengaruhi berlakunya bencana di Malaysia. Hujan lebat dan pembangunan pesat telah membawa kepada terjadinya masalah ini. Pematuhan garis panduan am daripada kontraktor, pemaju dan agensi boleh membantu dalam mengurangkan bilangan bencana ini pada masa hadapan. Oleh itu, perkara ini akan membantu mengelakkan hakisan tanah dan kegagalan cerun kerap berlaku di Malaysia.

ABSTRACT

In recent years, Malaysia's growing population and accelerating economic conditions have resulted in the construction of high-rise condominiums and the expansion of settlements and lifelines across hilly areas. Natural disasters are always happening in Malaysia, with landslides and flash floods as the main problems and common natural disasters. This problem occurs annually due to rising numbers of development in Malaysia involving land clearance and rapid construction, especially in hilly areas. Under such circumstances, research was conducted on landslide and flash flood incidences in Malaysia from 2020 until 2022. The assessment in this research was done using the matrix method commonly used in Environmental Impact Assessment (EIA). The results gained by using those method shows that both landslides and flash flood naturally happen in the last quarter of a year, which are in December and January for both landslides and flash flood disaster. The highest score for landslide incidences was in Putrajaya and Kuala Lumpur with 8.4; in contrast, 9.2, the highest average score recorded for flash floods, happened in Selangor, Pahang, Kelantan, Kuala Lumpur, Melaka, Negeri Sembilan, Perak, and Terengganu. Both of these incidences occurred in December 2021. This situation shows that both natural and man-made affect the occurrence of the tragedy in Malaysia. Heavy rainfall and rapid development lead to this problem. Compliance with general guidelines from contractors, developers and agencies may reduce the number of these disasters in the future. Hence, it will help to prevent soil erosion and slope failure that frequently occurs in Malaysia.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Several natural disasters always happen in Malaysia. Malaysia has experienced 51 natural disaster events based on the 2019 Malaysia Disaster Management Reference Handbook. The most common natural disaster experienced by Malaysia is flash floods and landslides. Malaysia is located in South-East Asia in a tropical region. This region has been an area with heavy rains for almost a year. Malaysia is a region that is rich in tropical forests and jungles. Besides natural disasters that are always happening in Malaysia, man-made disasters are frequently experienced, such as transportation accidents, public places failures, and technological disasters.

Malaysia is mainly located away from the Pacific Rim of fire and relatively away from any severe destruction caused by natural disasters such as earthquakes, typhoons, and volcanic eruptions. Nevertheless, Malaysia has been subjected to several natural catastrophes such as monsoon floods, landslides, and haze episodes.

Floods are one of the most frequent disasters that occur in Malaysia. The latest flash floods occurred from December 2021 until January 2022, affecting several states in Malaysia. There were 55 fatalities recorded during the disaster, resulting in significant damage to roads and infrastructure in the affected area. Some landslides frequently occur in Malaysia. According to the 2019 Malaysia Disaster Management Reference Handbook, approximately 28 significant landslides occur in Malaysia from 1993 to 2011. Several causes have been recorded that have been the main factors of landslides in

Malaysia: rainfall, stormwater activities, poor slope management, and improper site management during land and earth clearing phases of construction.

1.2 Background Study

Doswell III (2015) defined flood events as the rise in water during or within a few hours of the rainfall that produces the increase. Flash floods occur within small catchments, where the response time of the drainage basin is short. Flash floods are always associated with heavy rainfall produced by thunderstorms. A single thunderstorm can produce enough rain to cause a flash flood. Flash floods cause high monetary losses that are often related to development. The severity caused by these problems has been mainly focused on in Malaysia, but it has yet to be overcome.

While a landslide is defined as the movement of a mass of rock, debris or earth down a slope, every landslide occurs because of several different causes. Commonly construction activities are significant problems that lead to this disaster (USGS,2016). Construction and development projects do several works that frequently lead to disasters such as earth and land clearing, uncontrolled construction development, and excessive cutting of slopes and hills. These activities will cause steeper hilly that will then cause soil movement and leads to landslides in that area. For example, landslides in Ampang last March 2022 claimed four lives during the disaster. The developed hilly regions, especially in Ampang, have shown the risks of landslides and the cut slope. Still, no retaining walls are provided in the area, even though it would risk several design failures. The high-risk areas that need slope monitoring are Bukit Antarabangsa, Cameron Highlands, and Ipoh.

The mitigation measures and actions are always the centres of any assessment regarding the disaster. It is used to reduce any unacceptable impacts for the projects to suit the local environment sustainably and present the predictions and options to decision-makers. It conveys the assessment outcomes and proposed mitigation actions and provides information for decision-making before implementing the project in the early stage. The assessment includes many contributors with different impacts, mitigation measures, and plans.

1.3 Problem Statement

Flash floods and landslides frequently happen in Malaysia, especially in the high rainfall intensity season. Several risks and causes of landslides and flash floods repeatedly occur in Malaysia. The assessment needs to be done to measure the best possible options included in the report with detailed mitigation measures before implementing a project. Hence, the evaluation helps to detect and provides relevant mitigation measures to reduce the impacts of the disaster.

1.4 Objectives

This study is carried out to achieve the following main objectives:

1. To observe the effects of environmental degradation from development in Malaysia, particularly for landslides and flash floods disaster.

2. To measure the affected area of landslides and flash floods because of environmental degradation in Malaysia.

1.5 Scope of Research

Assessing flash floods and landslides disasters in Malaysia is based on environmental degradation from development. This research was conducted only using the data collection for flash floods and landslides in Malaysia from September 2020 to June 2022. The scope of work focuses on the causes of the frequent flash floods and landslides problem in Malaysia. The method used for this assessment is using matrix method to measure the affected area by landslides and flash floods because of environmental degradation in Malaysia.

1.6 Thesis Outline

Chapter 1: Introduction – General description of the study that includes problem statement, objectives and scope of work to be carried out.

Chapter 2: Literature Review – This chapter's content discusses previous research on environmental degradation for both landslides and flash floods in Malaysia.

Chapter 3: Methodology – Explaining the steps taken in proceeding with the research. This chapter includes an introduction, study areas and a description of the matrix method.

Chapter 4: Results and Discussion – The study's results collected and discussed in this chapter include the procedural causal effect on the environment and mitigation measures on environmental impacts.

Chapter 5: Conclusion and Recommendation – This chapter concludes this study's findings and provides suggestions to mitigate the environmental impacts.

CHAPTER 2

LITERATURE REVIEW

2.1 Landslides

Landslides are one of the significant natural hazards that commonly happen in Malaysia and most countries worldwide. Landslides taking account of extensive property damage in terms of direct and indirect costs put a lot of load on both people and governments in the respective countries. Landslides, defined as the movement of mass rock, debris or earth down a slope (Cruden, 1991), can be triggered by a variety of external stimuli, such as intense rainfall, earthquake shaking, water level change, storm waves or rapid stream erosion that cause a rapid increase in shear stress or decrease in shear strength of slope-forming materials. Keller (1999) explained that landslides are “mass wasting, a comprehensive term for any type of downslope movement of Earth materials”. In addition, as development expands into unstable hillslope areas under the pressures of increasing population and urbanisation, human activities such as deforestation or excavation of slopes for road cuts and building sites, etc., have become essential triggers for landslide occurrence (Dai et al., 2002).

Landslides are always associated with an elevated region that can also occur in areas of generally low relief. Commonly in low-relief areas, landslides occur as cut-and-fill failures, especially in roadway and building excavations, river bluff failures, lateral spreading landslides, the collapse of mine-waste piles, especially coal, and a wide variety of slope failures associated with quarries and open-pit mines (USGS, 2004).

Various landslides can be identified by movement mode and materials, as shown in Table 2.1.

Table 2.1: Types of Landslides (Source: Varnes (1978))

Type of movement		**Type of material**		
		Bedrock	**Engineering Soils**	
			Predominantly coarse	**Predominantly fine**
Falls		Rock Fall	Debris fall	Earthfall
Topples		Rock topple	Debris topple	Earth topple
Slides	Rotational	Rockslide	Debris slide	Earth slide
	Translational			
Lateral spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flow (deep creep)	Debris flow (Soil creep)	Earth flow (Soil creep)
Complex	Combination of two or more principal types of movement			

Cameron highland is one of the familiar places frequently affected by natural disasters such as a landslide. Especially in October 2018, Cameron Highlands was hit by a landslide disaster that affected three fatalities of non- Malaysia citizens in that case. The case occurred because of the construction of a shared house constructed in an illegal area below a steep slope. According to (Leh and Mokhtar, 2021), issues such as unlawful land exploration, the presence of illegal immigrants and weak enforcement are synonymous with Cameron Highlands, not a year or two but meant to be ingrained long ago. The recent landslide incident in 2018 should be carefully investigated, particularly to answer general questions about how the victim was able to build a house in an illegal location in a run-down area.

2.2 Flash flood

Flash floods are one of the most devastating natural disasters, mostly corresponding to heavy rainfall and a short response time. A flash flood is correlated with a quick increase and fall in water levels, causing damage to stream banks, infrastructure, buildings, bridges, and different artificial channelisation /diversion structures. Erosion, sediment movement and abrasion, and devastation of neighbouring habitats are also effects of flash flood events. These negative consequences are linked to the extinction of aquatic flora and animals and the disruption of human health and lives. In addition to environmental stresses, flash floods negatively affect economic growth and social development due to their rising frequency and devastation. The climate in Malaysia is experiencing rainfall with an average of approximately 2,500 mm a year in Peninsular Malaysia, 3,000 mm a year in Sabah and 3,500 mm a year in Sarawak (Tahir, 2009; Khalid & Shafiai, 2015; Tan et al., 2015).

Malaysia has three types of flooding: riverbank overflow, high tides, and flash floods (Zakaria et al., 2017). The most recent significant floods in Malaysia occurred between 15 December 2014 and 3 January 2015, evacuating over 200,000 people and relocating 21 individuals to relief centres. This flood caused severe damage to Peninsular Malaysia's East Coast and northern regions. The entire cost of these flood disasters in terms of property loss was estimated to be $560 million, making it one of the most expensive flood events in Malaysian history.

The river's water catchment flow is obstructed during the tide and cannot be entirely drained. Because of the rapid increase in river discharge, rainfall might create flooding in these circumstances. Flooding caused by human activity is most common in urban areas. This is owing to the rapid increase in urban imperviousness brought on by urbanisation and forestry operations. Due to the lack of flora and the usage of asphalt, cement, and concrete to cover the lands, urban landscapes often have low water permeability surfaces. Water infiltration and interception were disrupted in these circumstances, causing the essential process of managing surface runoff when it rains to be disrupted (Azlan et al., 2022). The vulnerability or inefficiencies of the urban irrigation system is also one of the factors causing a flood that makes channel systems such as rivers and drains too shallow and clogged due to the deposition of solid waste or soil, enhancing the problem of flash floods as well in Malaysia. The shallow channel system reduces the traction capacity of the input in the form of runoff or through flow (Adi et al., 2022).

One of the most significant impacts of flash floods in Malaysia was in Cameron Highlands. It occurred in 2016; Ringlet had a flash flood when the water of the nearby rivers rose over the cliffs due to heavy rain. The river water then entered the residents' houses in that area, drowning most of them in a blink. After this incident occurred, according to Leh and Mokhtar (2021), to slow down the effects of flash flooding, residents of Pekan Ringlet expressed hope that authorities could expand and deepen Sungai Ringlet as soon as possible. Because the water level of the Sungai Ringlet has risen sharply due to the narrow stream and cannot cope with the overflowing water of the Sungai Bertam, especially during heavy rains, therefore, it can be concluded that the Ringlet disaster was not only due to land exploration for commercial activities, but also influenced by the natural factor that the river could not function fully because it was shallow and could not cope with the sudden eruption could overflow of water. For this reason, efforts should be made immediately to deepen and expand Sungai Ringlet to avoid the same event.

2.3 Mud Flood

"Mud flood refers to floods carrying up to half sediment by floodplains. Mud floods are also called processes including sufficient water to behave hydraulically. According to (Committee on Methodologies for Predicting Mudflow Areas, 1982, p.15 ad 16)". Based on Jeffrey (2019), mud floods can carry heavy loads of sediment, including coarse debris; However, mudflows have no static shear resistance. Consequently, the coarse debris in mudflows settles as the velocity-dependent strength decreases in response to a deceleration in fluid velocity.

In 2014, a mud flood hit Cameron Highlands and affected more than 20 houses in Ringlet town, Ringlet new village, Kampung Ulu Merah Ringlet and Bertam Valley submerged in a knee height of flood water on 5th and 6th November 2014. This incident caused three fatalities during this disaster happening because of downpours. Based on Tan and Loh (2017), when soil erosion was measured in river sediment (tonnes per hectare per year, t/ha/y), it was clear that vegetable farming produced the most deposition compared to tea plantations and forests. Because of the intensive agriculture and agricultural activities in the Cameron Highlands and the rainy season with torrential rains and running water, erosion and runoff are relatively high, making the riverbank even shallower. There was a combination of flash flooding and mudslides.

A mud flood hit Cameron Highlands as it happened during rain. The rainwater led the earth into a situation that caused mud floods because fewer trees were needed to help protect the soil. It is one of the tourist areas that has always been affected by both landslides and mud floods in Malaysia that even affected a thousand residents and the traffic in that area. The floods, landslides and mudslides have been associated with land development factors in Cameron Highlands for agricultural purposes and the development of tourism spots and various commercial activities to meet the demand of tourists, thereby exploring the land to the maximum to the extent that it violates the limits of its capacity to absorb. Worse still is the greed of some parties conducting illegal land exploration for farming activities around Ringlet in connection with flash floods, landslides and mudslides.

2.4 Water Column Phenomenon (Kepala Air)

The water column phenomenon is a vertical expanse stretching between the body of water's surface and the bottom. This phenomenon commonly causes flash floods in the area. This phenomenon is partly due to climate change, such as intense rainfall, and partly to anthropogenic activities such as construction, forest clearing, agriculture, and developments predominantly in forest reserves.

2.5 Soil Erosion

The interaction of several factors, including rainfall, slope, vegetation, soil properties, and mechanical practices, causes soil erosion. Soil erosion caused by water is a significant issue in tropical countries such as Malaysia, particularly in areas devoid of vegetative cover. The amount of erosion is determined by the rain's ability to cause erosion and the soil's ability to withstand the rain (Hudson, cited in Mohd Fozi, 2000).

Soil erosion has been a significant source of pollution in many of this country's rivers.

Increased human activity, such as developing new lands for housing and urban areas, agricultural lands, construction activities, mining, logging, and highway and road construction, has contributed to serious problems in some areas. Severe erosions can cause costly damage to reservoirs, harm to fish habitat, damage to irrigation channels, which can lead to rising flood levels, and biological damage to lakes. Furthermore, eroded land produces more runoff and lower dry-season flows, implying that pollution will be more severe during low flows due to less dilution.

Water is vital in influencing and intricately linking soil erosion and tropical landslides. Excessive cultivation on steep slopes and heavy rains contribute to increased soil erosion and landslides in the tropics. The relationship between erosion and landslides is also affected by slope angle, shape, and soil depth, providing essential info into their prediction in critical landscapes. The degree of slope steepness and rainfall erosivity are crucial factors influencing soil erosion, among others. Erosivity, one of the properties of rainfall, can be quantified as the potential of rain. (Mohd Fozi, 2000)

2.6 Environmental Degradation from Development in Malaysia

Environmental degradation from development in Malaysia, particularly landslides and flash floods, contributed a tragic consequence to the country. Many landslides have been recorded in Cameron Highlands due to land clearing and development. Many developments have been constructed in hilly areas with multiple ranges of slopes. The story within areas surrounding the hillside is known to cause environmental problems such as soil erosion and landslips (Syabiha et al., 2021).

In the previous study by Abd Majid (2020), there were 21,000 landslide-prone areas across the country, of which 16,000 or 76% are in Peninsular Malaysia, while around 3,000 are in Sabah and 2,000 are in Sarawak. The landslide statistics recorded in Malaysia show the dominance of preliminary engineering design. Based on Table 2.2, there are 49 cases of slope failures, and 29 instances contributed to design weakness. The addition of faulty design, incompetence, casualness and insufficient raw input data often leads to these regular landslide events.

Most of the significant causes of landslides are generally related to slope instability caused by development activities. The increase of casualties increases the number of fatalities with an increase in the number of landslides. The development peculiarly in hilly areas is caused by the development of highways or housing areas development of housing, and human activities keep growing, failures from landslides affecting the soil failure increase significantly. Malaysia needs to overcome the challenges of drastic development; strategic and appropriate low-lying area development is severe and scarce to meet the development demand, particularly in urban areas of Malaysia. (Abd Majib et al., 2020).

Table 2.2: Reported cases of Landslide in Malaysia

Causes of landslides	Number of Cases	Percentage (%)
Design errors	29	60
Construction errors	4	8
Design and Construction errors	10	20
Geological features	3	6
Maintenance	3	6
Total	49	100

2.7 Development in Hilly Areas

Hill lands are susceptible to natural systems that include living such as forests, fauna, and other ecosystems and a non-living physical system such as climate, hydrology and soils. Any environmental change to such systems can disrupt nature's balance, which can have negative consequences not only for natural systems but also for human society. The development of hill land and its adverse on the environment, both within and outside the hills, are well documented. One of the massive landslides in Malaysia was the collapse of 14-storey block A of the Highland Tower in Ulu Klang, Selangor, in 1993, with 48 fatalities recorded. The leading cause of these Highland Tower collapse is because of inadequate drainage. Another cause recorded is the design deficiencies found after this tragedy. Several factors are responsible for this collapse: soil movement, and a proper drainage system that causes surface off, cut and fill slopes. Inadequate design with a safety factor designed less than 1.0 slope gradient is also suspected to be so steep with lack of maintenance in drainage system along with a leakage from pipe culvert carrying the diverted flow of East stream. (MPAJ, 1994)

Most of the time in Malaysia, large-scale landslides were discovered after the developed areas, and extensive and ongoing damage to built infrastructures had occurred. It is unfortunate and frequently too late when large-scale landslides are found after the affected areas have been developed and have suffered extensive damages/disasters. Unnecessary disasters and significant economic losses could have been avoided if large-scale landslide geohazards had been identified and assessed before construction. As a result, when interfering with deep-seated large-scale landslides, infrastructure development should be avoided (Haliza and Jabil, 2017)

2.8 Matrix Method

Leopold (1971) developed the Matrix technique of effect analysis. Matrices are approaches that include a list of project operations and a checklist of environmental qualities that may be impacted. The Leopold matrix can also be used to define impacts associated with multiple spatial limits, such as at the site and in the region, and to identify beneficial and detrimental consequences for various project periods, such as construction, operation, and post-operation phases. The first phase of the Environmental Assessment is to identify the impacts. An impact is an interaction between an activity and an environmental parameter, resulting in the EIA matrix when stacked in rows and columns.

The matrix method provides a framework of interactions between different actions/activities of a project with potential environmental impact. The activities linked to the project need to impact people, the environment, and the existing social and ecological conditions possibly affected by the project.

CHAPTER 3
METHODOLOGY

3.1 Introduction

This chapter explains the method used to carry out the study and provides information on the effects of controlling natural disasters, particularly landslides and flash floods. For this study, recorded landslide and flash flood events are collected from technical papers, national reports, newspapers and other literature to gather information on historical records of landslides and flash floods in Malaysia. This information was gathered peculiarly from September 2020 to June 2022 in Malaysia. Figure 3.1 shows the flow chart of this research study and the steps involved to achieve all of the study's objectives.

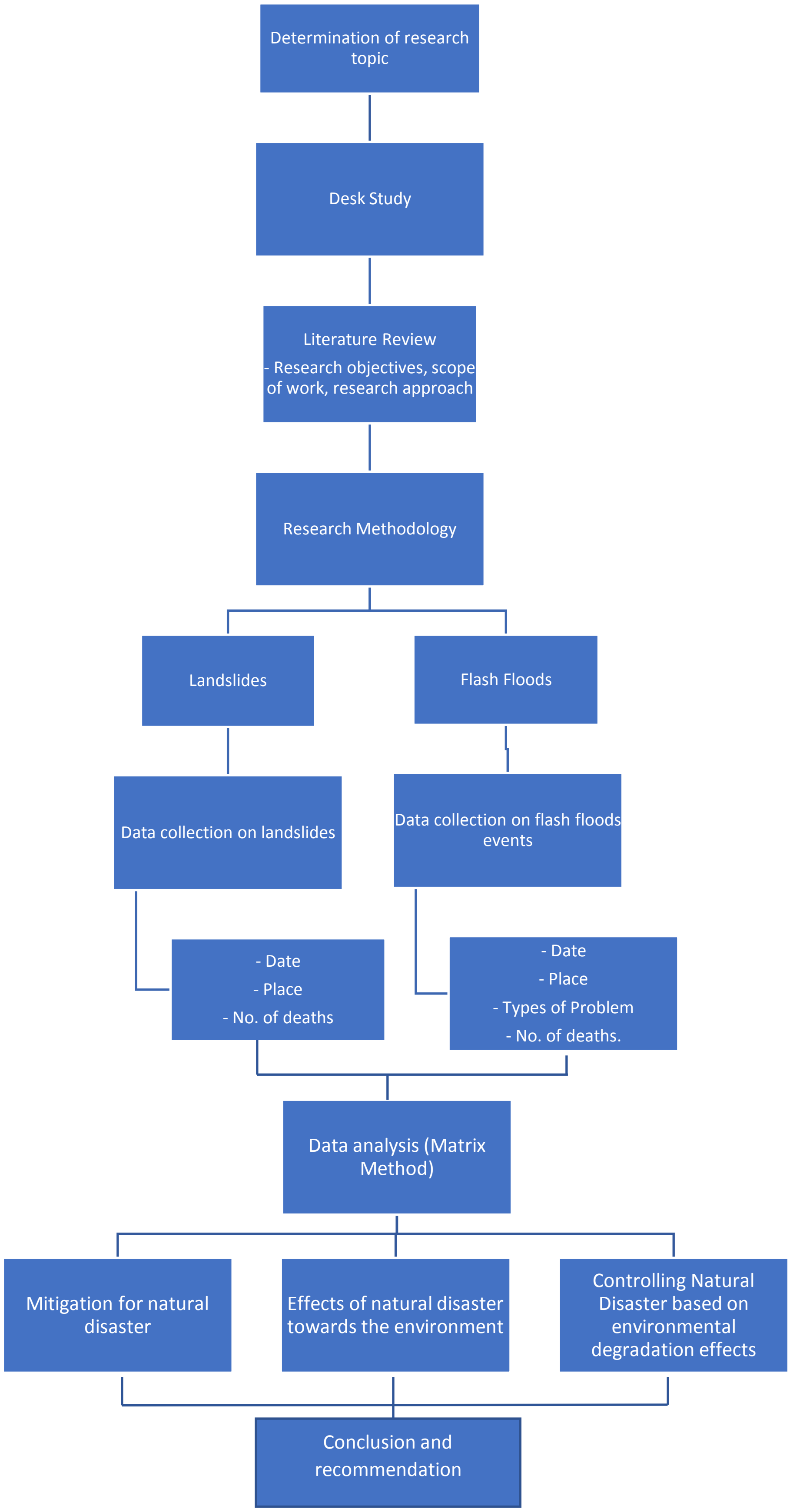

Figure 3.1: Flow chart of the study and research

3.2 Study areas

Malaysia is located at latitude 2’ N to 7’ N and longitude 99.5’ E to 120’ E in Southeast Asia. This country is divided into two major parts, Peninsular Malaysia and Borneo Island, covering 330,200 km^2. The South China Sea separates Malaysia. This research focused on landslide and flash flood tragedies from 2020 until 2022. This study uses secondary data from the press, newspapers, and research papers on Malaysia's respective disasters. Figure 3.2 shows the location of the study area of this research.

Figure 3.2: Map of the study area

3.3 Matrix method

The methodology was adopted for the study in several stages derived based on Environmental Impact Assessment (EIA) matrix. This method began with understanding the process of degradation of the environment, significant stressor elements of the risk for environmental degradation, and the effects on the source, particularly for landslides and flash floods. This analysing data will give a stressor-source interaction matrix.

This interaction matrix is then used to identify the interactions between various stressors that lead to the after-effect of the source of the risk of environmental degradation on landslides and flash floods in Malaysia. The matrix comprises the stressor causing the after effect towards the source of the risk in Malaysia's environmental degradation for development.

There are assigned subjective significance scores to each activity based on the subject of knowledge and practical experience of working and researching in the study area. These scores gave rise to assessing the impact of significance and the magnitude of effects required in completing the assessment. The criteria for each activity associated with stressor with an impact on source were measured based on baseline data. However, these measures had to be converted into magnitude scores ranging from 1 to 10 using criteria explicitly set for each activity, as outlined in Table 3.1. The intensity or extensiveness of the interaction can be measured on a scale of one to ten, with ten indicating the immense magnitude and one showing the small magnitude. The assignment of these numerical values should be based on evaluating the facts. The significance of the interaction is also related to the consequences of the interaction. The importance of interaction can be measured on a scale of one to ten, with ten indicating an important connection and one indicating low importance. Usually, the assignment of numerical significance is based on a subjective assessment or the expertise of a panel of experts.

Table 3.1: Significance Level and Criteria for Matrix Method

Category of Impact	Significance level	Assigned Score
MINOR	Very low	1
	Moderately low	2
	Low	3
MEDIUM	Low medium	4
	Medium	5
	High medium	6
MAJOR	high	7
	Moderately high	8
	Very high	9
	Extremely high	10

The methodology used is a version of a universal matrix of risk analysis (UMRA) which is one of the methods of risk analysis proposed to enhance the transparency and sensitivity of the evaluation process. Table 3.2 shows the established matrix to give a detailed description of the environmental degradation because of development that can cause both impacts on people and the environment. The table shows activities and elements in connection with the particularly sensitive environment, especially toward the source of the risk. The designated stressors for this research are selected based on the field of this study which is landslides and flash floods. This method has been used in landslides and flash floods because of environmental degradation in Malaysia.

Table 3.2: Stressor – Source Of Risk Assessment

Stressor – Source of Risk	Population	Climate conditions	Atmosphere	Water conditions	soil	Flora and fauna and their biotopes	Landscape, structure and use of terrain, scenic aspects of the landscapes	The protected areas and their protective zones	The territorial system of ecological stability	The urban environment and land use
Landslides										
Flash floods										

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Landslides

According to Cruden (1991), a landslide is the rapid displacement of rock, leftover soil, or sediments adjacent to a slope, with the centre of gravity of the moving mass moving outward and downward. According to Hutchinson (1995), a landslide is a characteristically fast movement of soil and rock on a downward slope that involves a defined boundary slip of the surface that is the moving mass. There are five different ways that a slope might move: fall, topple, slide, spread, and flow. The geologic materials (bedrock, leftover soil, earth, and mixtures) affect these patterns (Cruden & Varnes 1996).

4.1.1 Experience of Landslides in Malaysia

Table 4.1 shows annual landslides in Malaysia, providing several interpretations and perspectives related to physical, ecological, infrastructure and social connections.

Table 4.1: Landslides Incidences in Malaysia Sep 2020 – Mar 2022

DATE OF INCIDENT	PLACE	NO. OF DEATH	EFFECTS
15 Sep 2020	Batu 10 & 16 Jalan Tapah-Cameron Highlands, Batu 20 Jalan Tapah-Ringlet	-	- Affecting 2725 pupils, 190 teachers and 132 pre-schools, closure of 6 schools. - Heavy traffic
9 Nov 2020	The Banjaran Hotsprings Retreat, Tambung Perak.	2	-
3 Jan 2021	Hulu Chukai, Kemaman	-	Fourteen stall operators were ordered to stop operations after landslides occurred behind their premises.
4 Jan 2021	Gua Musang, Kelantan	-	One (1) Bangladesh worker is missing, feared buried alive.
5 Jan 2021	Kuantan, Pahang	-	Damage to two houses is believed to be triggered by soil movement caused by non-stop heavy rainfall.
11 Jan 2021	Johor Bahru, Johor	-	42 people, 12 houses need to evacuate their places

12 Jan 2021	Padawan, Sarawak	-	Affect a family after part of their house was buried under rubble in a landslide.
15 Jan 2021	Bau and Lundu, Sarawak	-	Power Failure
20 Jan 2021	Tamparuli-Ranau, Sabah	-	Severed damage on a parking area
17 Feb 2021	Pasir Mas, Kelantan	-	97 people, 15 families affected Eight houses and one shop premise were severely damaged.
17 July 2021	Kuching, Sarawak	1	One fatality recorded
18 Aug 2021	Gunung Jerai, Kedah	6	Six fatalities were recorded because of water column (Kepala air)
15 Sep 2021	Jalan Penampang-Tambunan, Kota Kinabalu, Sabah Forest Hill, Penampang, Sabah	2	2 fatalities recorded
16 Sept 2021	Sungai Palas, Cameron Highland, Pahang	1	One fatality recorded
17 Sep 2021	Jalan Kemensah Heights, Kuala Lumpur	-	Three bungalows and 16 townhouses with 32 families were affected.

1 Oct 2021	Tanjung Bungah,Georgetown, Penang	-	-
22 Nov 2021	Tanah Rata, Pahang	-	One people affected
2 Dec 2021	FT 185, KM 27.10 Jalan Simpang Pulai-Blue Valley, Ipoh, Perak	2	Two fatalities recorded
15 Dec 2021	Kampung Air Sejuk, Kuaka Terengganu, Terengganu	1	1 fatality recorded
18 Dec 2021	Kampung Sungai Merab Hulu, Putrajaya	-	-
19 Dec 2021	Jalan Pelimbayan Indah, Kampung Sungai Penchala, Kuala Lumpur	-	284 people and 94 houses were affected, with 24 of them damaged
26 Dec 2021	International Islamic University Malaysia, Gombak, Kuala Lumpur	-	128 people evacuate the building
10 Mar 2022	Taman Bukit Permai 2, Ampang, Kuala Lumpur	5	15 houses and ten vehicles affected - Triggered by soil movement.

The matrix method is usually used in Environmental Impact Assessment (EIA); the average score is based on the minor, medium and significant impact categories. Figure 4.1 shows the average score based on the latest landslide incidences in Malaysia from September 2020 until March 2022. There are ten aspects of stressor that was considered in doing this matrix method which are population, climate conditions, atmosphere, water conditions, soil, flora and fauna and their biotopes, landscape, structure and use of terrain, scenic aspects of landscapes, the protected areas and their protective zones, the territorial system of ecological stability and the urban environment and land use. The average value for each landslide disaster was calculated based on these aspects. The highest scores for the latest incidences happen in Putrajaya and Kuala Lumpur, with 8.4. The incidents affected a lot of people and ecological conditions. Most landslide incidences in this period are commonly due to slope failure. In Malaysia, these slope failures seem triggered mainly by heavy or non-stop rainfall that occurs more than 70 mm or over one day of an extended period of heavy rain.

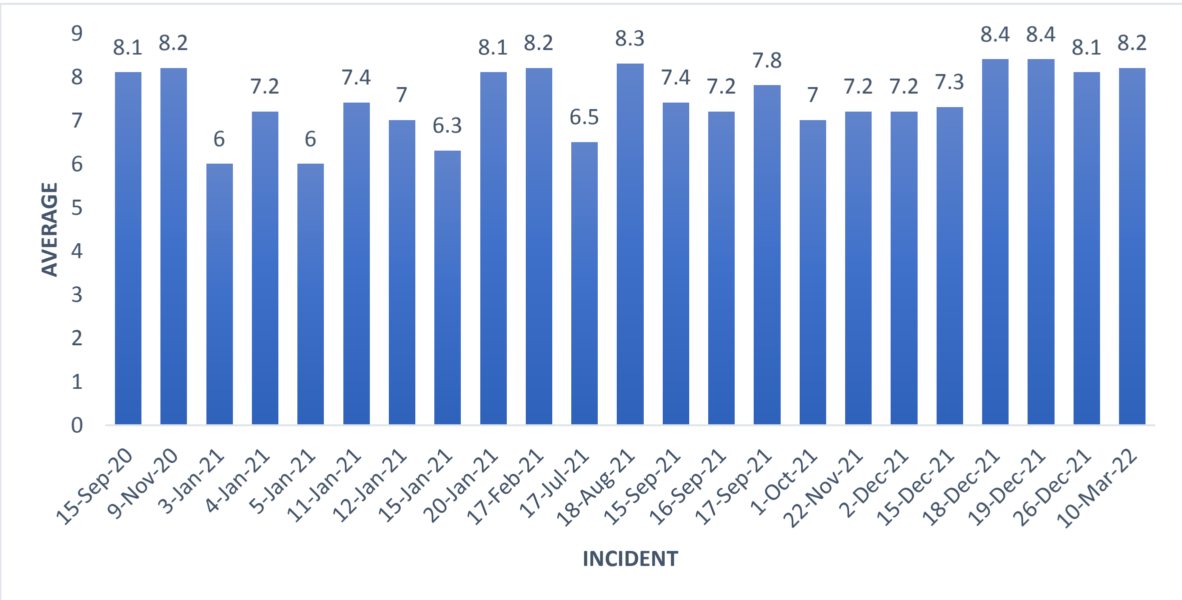

Figure 4.1: Average score for Landslides Incidences in Malaysia from Sep 2020 – Mar 2022

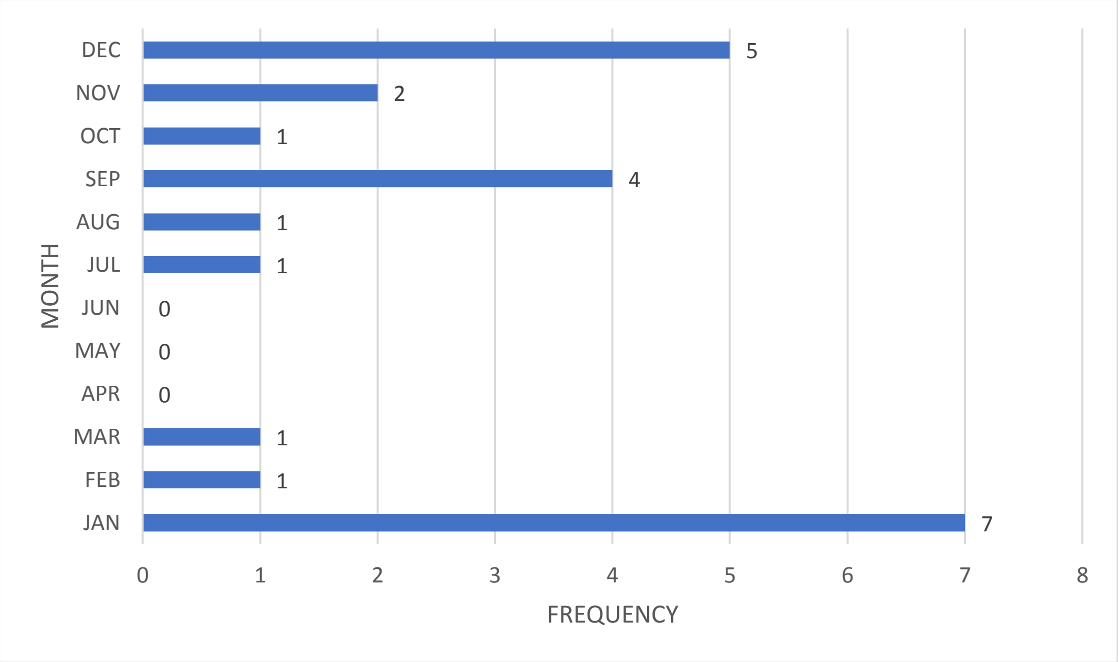

Figure 4.2: Monthly Wise Landslides Occurrences in Malaysia from Sep 2020 – Mar 2022

Monthly-wise landslide occurrences in Malaysia are shown in Figure 4.2. It is demonstrated that December and January have the higher number of landslide experiences compared to the others, followed by September. Considering the climatic parameters such as rainfall and temperature, both December and January are in the rainy season in Malaysia, which may be the reason for slope failure. The other reasons why landslides occurred in Malaysia can also be interpreted as a man-made or human activity. Most heavy construction in the hilly areas, such as constructing a condominium with improper design without considering the risk and poor drainage system, may also lead to landslide occurrences in Malaysia.

4.2 Flash Floods

According to Doswell (2015), the term "flash flood" refers to floods that occur during or shortly after the precipitation that causes the surge in water. As a result, flash floods happen in small catchments where the drainage basin's response time is short. The devastation from flash floods can be disastrous partly because of the quickly rising waters. Thunderstorms, defined as deep, moist convection, are responsible for most flash floods connected to rainfall. The typical flash flood results from multiple thunderstorms moving successively over the same area. These thunderstorms are known as training thunderstorms because they resemble the movement of cars in a train. A single thunderstorm cell is unlikely to produce enough rainfall to cause a flash flood.

4.2.1 Experience of Flash Flood in Malaysia

Table 4.2 below shows that annual flash floods occurred in Malaysia, which provides several interpretations and perspectives that relate to physical, ecological, infrastructure and social connections.

Table 4.2: Flash Floods Incidences in Malaysia Oct 2020 – June 2022

DATE OF INCIDENT	PLACE	TYPE OF PROBLEMS	NO. OF DEATH
5 Oct 2020	(Kota Kinabalu, Kota Belud, Tuaran) Sabah	Heavy rain	-
23 Nov 2020	Terengganu, Perak, Melaka, Selangor	Heavy rain > 550 mm/d	-
17 Dec 2020	Kelantan, Terengganu, Pahang	Heavy rain brought by annual monsoon season	-
Jan 2021	Johor, Pahang, Kedah, Perak, Selangor, Kelantan, Terengganu, Sabah, Sarawak	Heavy rainfall	10
May 2021	Sabah, Sarawak	Heavy rainfall	-
18 Aug 2021	Gunung Jerai, Kedah	Heavy rain > 219 mm/day	4
15 Sep 2021	Sabah	Heavy rain	3
20 Oct 2021	Selangor, Negeri Sembilan, Melaka	Overflow of water in the river due to heavy rain, clogged drainage	1
Dec 2021	Selangor, Pahang, Kelantan, Kuala Lumpur, Melaka, Negeri Sembilan, Perak, Terengganu	Heavy rainfall > 300 mm/day, climate change, low land area, high tide	48
1 Jan 2022	Melaka, Johor, Negeri Sembilan, Sabah, Pahang	Heavy rainfall	7

24 Feb 2022	Besut, Dungun, Hulu Terengganu, Jeli, Kemaman, Kota Bharu, Kuala Krai, Kuala Terengganu, Kuantan, Machang, Marang, Pasir Mas, Pasir Putih, Setiu, Tanah Merah	Heavy Rainfall	-
7 Mar 2022	Gombak, Hulu Langat, Jasin, Jelebu, Kuala Langat, Kuala Lumpur, Petaling, Sepang	Heavy Rainfall	-
14 Mar 2022	Malacca, Negeri Sembilan, Selangor	Heavy Rainfall	-
18 Mar 2022	Bentong, Pahang	Heavy Rainfall	-
25 April 2022	Kuala Lumpur	Heavy Rainfall	-
6 May 2022	Melaka	Heavy Rainfall and overflow water from a nearby river	-
11 May 2022	Janda Baik, Bentong,Pahang	Heavy Rainfall Water column with mud flood	-
24 May 2022	Seremban, Kuala Lumpur	Heavy Rainfall	-
1 June 2022	Gurun, Kedah	Heavy Rainfall	-

Using the matrix method that is usually implemented in Environmental Impact Assessment (EIA), the average score was assigned based on the minor, medium and significant categories of impact using the matrix method that is usually implemented in Environmental Impact Assessment (EIA). Figure 4.3 shows the average score based on Malaysia's latest flash flood incidences from October 2020 until June 2022. This matrix method considered ten aspects of stressors, similar to the landslide. The average value for each landslide disaster was calculated based on these aspects. The highest score for the latest incidences was in Selangor, Pahang, Kelantan, Kuala Lumpur, Melaka, Negeri Sembilan, Perak, and Terengganu, with 9.2 that occurred in December 2021, with 48 fatalities recorded during that disaster. The incidence affected a lot of people and ecological conditions. More than 40,000 people were involved during that incident, with severe damage to vehicles and houses.

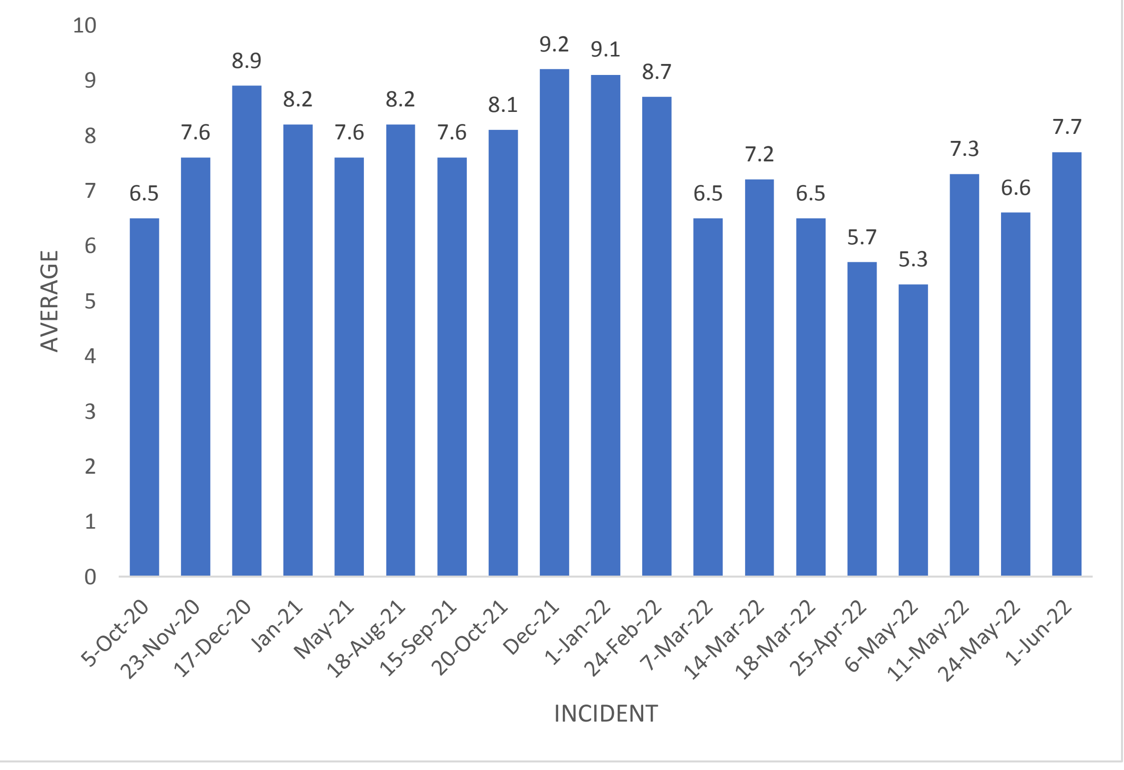

Figure 4.3: Average score Flash Flood Incidences in Malaysia Oct 2020 – June 2022

4.3 Potential Causal Effects on the Environmental

Environmental degradation is the breakdown of the planet or deterioration of the environment due to the depletion of resources, including soil, water, and air, the loss of ecosystems, and the extinction of wildlife. It is any alteration or aggravation to the natural world deemed harmful or unpleasant. Environmental degradation is considered one of the most significant threats that are being looked at in our world today. It can happen in various ways that can even wreck our environment and be considered corrupted and harmed. The ecosystem is to be left alone as it will result in a bad situation, which aligns with the pollution prevention mitigating measures. There are two fundamental consequences which are landslides and flash floods.

4.3.1 Landslides

Malaysia is a tropical country that is annually associated with high annual rainfall. Construction activities are primarily done in Malaysia, with the most significant projects that can hurt the environment. A combination of these factors, i.e., heavy rain in a tropical area and too many construction activities, would lead to an unfavourable situation. Soil movement could cause severe damage occurred because of man-made actions. Earth clearing, human activities and uncontrolled construction induce the seriousness of floods from precipitation due to peak discharge and concentration time.

The occurrence of both landslides and flash floods in Malaysia due to environmental degradation leads to severe consequences. For instance, frequently landslides recorded in Cameron Highland and Kuala Lumpur have been recorded in the previous two decades. The most famous tragedy occurred in Highland Tower in 1993, leading to the concern of most researchers about the hazard of hillside construction development. Highland Towers tragedies were reported because of inadequate slope design and improper design with a lack of consideration of the water table in that area. Previous hill slope development guidelines have been revised for stricter compliance with the developers and contractors after these incidents. Other than that, many constructions developed, especially in a hilly area with multiple ranges of slope design—the steeper the hill, the higher risk of soil movement and the higher occurrence of landslides. The construction in the hilly area will face a significant risk of soil erosion and slope failure; without a proper design considering the slope, soil and water table, the higher possibility of a landslide occurring.

In Malaysia, soil erosion and slope failure always happen during heavy rainfalls with more than 70 mm per hour. As a tropical country, Malaysia gets 2400 mm of rain annually, adding the rainfall intensity and slope failure and erosion a perfect relationship. It will frequently trigger landslide occurrence in Malaysia, considering groundwater levels that have always been overlooked in designing the slope.

4.3.2 Flash Floods

Flash floods in Malaysia lead to high monetary losses and are always related to development. Flash floods severity in Malaysia caused significant problems, especially in the latest incident in December 2021 until January 2022. There were 48 fatalities recorded in the December 2021 flash floods incident, while seven deaths were recorded during flash floods in January 2022 that mainly affected Peninsular Malaysia and the Sabah area. These incidents are due to heavy rainfall and improper maintenance of water basins, especially in urban areas. The severity of this incident is related to terrain conditions, amount of rain and human activities. The amount of rainfall recorded was more than 300 mm per day with the occurrence of high tide, especially in a low land area. Sediment deposition, which comes from poorly controlled construction, flows into the nearby rivers, causing the river's flow carrying capacity—besides, forest clearance with logging activities minimalises the absorption of rainwater by the forests. High rain intensity with a cleared forest area leads the rainwater 100% flows as run-off on the land into the rivers. This incident occurs in Yan, Kedah, with both flash and mud floods because of forest clearance. Soil erosion results in shallow riverbeds and causes ineffective functions of the catchment area as water conveyance due to high-sediment deposition that affects the primary function of the water catchment. The river’s capacity is due to silt deposition from exposed land development due to soil erosion and rapid growth in that area. The sediment released from improper development, especially construction, will block the natural course of the waterway and then will associate with the high flash flood incidences in urban areas.

4.4 Mitigation Measure on Environmental Impacts

Legal instruments provided by the Department of Environment (DoE) and the Department of Irrigation and Drainage Malaysia (DID) must be complied with by developers, contractors and agencies. Compliance with all guidance from related agencies can reduce upcoming landslides and flash floods disaster in Malaysia. Following the guidelines will prevent problems, especially on the soil erosion control and eliminating any possible pollution during the development of the construction area. The contractors must comply with a proper slope design and drainage system to reduce the slope failure tragedies. Considering groundwater table also needed to be taken importantly in development that can trigger landslide according to the soil gradation that has always been overlooked in designing slope. Flood management needs to focus more on land use, uncontrolled forest clearing and development in Malaysia. The design must comply with Urban Stormwater Management Manual (MSMA). The construction of small dams and retention ponds along the river to divert some rainwater, especially during high-intensity rainfall, minimises flash floods disaster.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion and Recommendation

Based on this study, both landslides and flash floods occur because of both natural and man-made aspects. Both disasters affect Malaysia's tropical country’s heavy rainfall and rapid development. The affected area for both landslide and flash floods because of the environmental degradation measured using the matrix method, we can conclude that the landslide disaster occurred in Malaysia; the highest score is 8.4 in Putrajaya and Kuala Lumpur. Both of these locations always encounter landslide problems every year. This landslide occurred in December 2021 and affected 284 people and 24 damaged properties. While for flash floods incidences in Malaysia, Selangor, Pahang, Kelantan, Kuala Lumpur, Melaka, Negeri Sembilan, Perak, and Terengganu recorded a score of 9.2 for matrix method in December 2021. This flash flood is one of the worst flash floods happening in Malaysia in history. It involved a lot of humans and the environment. This incident affected more than 40,000 people, with 48 fatalities recorded. This incident happened during a rainy season with an improper drainage system in urban areas and low maintenance for retention ponds in certain areas.

The effects of environmental degradation from development in Malaysia, particularly for landslides and flash floods, can be observed by the data collected for both flash floods and landslide incidences in Malaysia. The incidence recorded for flash floods in December 2021 and January 202 says that the incidence happened because of the improper drainage system and low maintenance of retention ponds in the affected area.

This happens because of high surface runoff that can affect the situation in a particular area. High surface runoff and low impervious surface areas can prevent rainfall from infiltrating into the ground, thereby causing an excess for the local drainage capacity.

To avoid further environmental risks, better legal instruments must be in place to ensure all related parties carry out all the requirements to protect the biological, physicochemical and human nearby land clearing and construction projects. Proper mitigation measures to reduce the environmental impact should be constantly improved and revised along with legal instruments such as Environmental Impact Assessment (EIA) in Malaysia. Rainfall and soil erosion needed to be taken care of, especially during construction and development, to make sure any further disasters because of landslides and flash floods could be reduced. Hence, the current legislation regarding the development in Malaysia, especially towards the environment, needs to be continuously strengthened to protect both humans and the environment from any undesired disaster.

REFERENCES

Akter, A., Noor, M.J.M.M., Goto, M., Khanam, S., Parvez, A. and Rasheduzzaman, Md. (2019). Landslide Disaster in Malaysia: An Overview. *International Journal of Innovative Research and Development*, 8(6). doi:10.24940/ijird/2019/v8/i6/jun19058.

Astroawani.com. (2022). [online] Available at: https://www.astroawani.com/berita-malaysia/kasa-ambil-tindakan-segera-tangani-masalah-banjir-di-janda-baik361541 [Accessed 14 Jun. 2022].

Berita Harian. (2021). *Bah besar penutup 2021*. [online] Available at: https://www.bharian.com.my/berita/nasional/2021/12/905583/bah-besar-penutup-2021

Boardman, J. (2010). A short history of muddy floods. *Land Degradation & Development*, 21(4), pp.303–309. doi:10.1002/ldr.1007.

Conserve Energy Future (2014). *Causes, Effects and Solutions to Environmental Degradation - Conserve Energy Future*. [online] Available at: https://www.conserve-energy-future.com/causes-and-effects-of-environmental-degradation.php#:~:text=Effects%20of%20Environmental%20Degradation..

Cruden, D.M., 1991. A simple definition of a landslide. *Bulletin of the International Association of Engineering Geology-Bulletin de l'Association Internationale de Géologie de l'Ingénieur*, *43*(1), pp.27-29.

Dai F, Lee C, Ngai Y (2002) Landslide risk assessment and management:an overview. EngGeol 64(1):65–87

DID (Department of Irrigation and Drainage), Urban Stormwater Management Manual for Malaysia, Government of Malaysia, 2010

DOE (Department of Environment), "Environmental impact assessment guidelines in Malaysia," Ministry of Natural Resources and Environment, 2016

Doswell, C., 2015. HYDROLOGY, FLOODS AND DROUGHTS | Flooding. *Encyclopedia of Atmospheric Sciences*, [online] pp.201-208. Available at:<https://www.sciencedirect.com/science/article/pii/B9780123822253001511 > [Accessed 14 June 2022].

Food and Agriculture Organization (n.d.). *Environmental impact assessment and environmental auditing in the pulp and paper industry*. [online] Available at: https://www.fao.org/3/v9933e/v9933e02.htm.

Gariano, S.L. and Guzzetti, F. (2016). Landslides in a changing climate. *Earth-Science Reviews*, 162, pp.227–252. doi:10.1016/j.earscirev.2016.08.011

Hudson, N.W. (1971). *Soil conservation*. London: Batsford.

Khalid, M.S, and Shafiai, S. (2015). *Flood Disaster Management in Malaysia: An Evaluation of the Effectiveness Flood Delivery System*. [online] Available at: https://www.researchgate.net/publication/283245095_Flood_Disaster_Management_in_Malaysia_An_Evaluation_of_the_Effectiveness_Flood_Delivery_System.

Leh, F.C. and Mokhtar, F.Z. (2021). Resilience in the face of flash floods, landslides and mudflows: the experience of tourist spots in Cameron highlands. *IOP Conference Series: Earth and Environmental Science*, 683(1), p.012069. doi:10.1088/1755-1315/683/1/012069.

Majid, N.A. (2020). Historical landslide events in Malaysia 1993-2019. *Indian Journal of Science and Technology*, [online] 13(33), pp.3387–3399. Available at: https://sciresol.s3.us-east-2.amazonaws.com/IJST/Articles/2020/Issue-33/IJST-2020-884.pdf [Accessed 17 Aug. 2021].

Malaysia Disaster Management Reference Handbook. (2019). [online] Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/Malaysia%20Disaster%0Management%20Reference%20Handbook%202019.pdf.

Mohamad Yusoff, I., Ramli, A., Mhd Alkasirah, N.A. and Mohd Nasir, N. (2018). Exploring the managing of flood disaster: A Malaysian perspective. *Malaysian Journal of Society and Space*, 14(3), pp.24–36.

Mohd Fozi, A. (2000). *Universiti Putra Malaysia The Effect Of Slope Steepness On Soil Loss Under Natural Rainfall Distribution Mohd Fozi Bin Ali*. [online] Available at: https://core.ac.uk/download/pdf/43000539.pdf [Accessed 29 Jun. 2022].

MPAJ (1994). *Report of the Technical Committee of Investigation on the collapse of block 1 and the stability of blocks 2 and 3 Highland Towers Condominium, Hulu Klang, Selangor Darul Ehsan*.

Saleh, A., Yuzir, A. and Sabtu, N. (2022). Flash Flood Susceptibility Mapping of Sungai Pinang Catchment using Frequency Ratio. *Sains Malaysiana*, [online] 51(1), pp.51–65. Available at: http://journalarticle.ukm.my/18347/1/5.pdf [Accessed 29 Apr. 2022].

Shith, S., Ramli, N.A., Razman, M.R., Nazir, A.U.M., Zainordin, N.S., and Madhoun, W.A. (2021). Procedural Effects of Environment Impact Assessment on Controlling Natural Disaster (Landslides and Flashflood) Based on Environmental Degradation from Development in Malaysia. *International Journal of Environmental Science and Development*, 12(9), pp.274– 281

Tahir, P.A. (2009). Flood management in Malaysia. Flood Hazard Mapping Seminar. Retrieved from http://www.icharm.pwri.go.jp

Tan, M.L., Ibrahim, A.L., Duan, Z., Cracknell, A.P., & Chaplot, V. (2015). Evaluation of six high-resolution satellite and ground-based precipitation products over Malaysia. Remote Sensing, 7, 1504-1528

The Landslide Blog. (2022). *Ampang: a deadly urban landslide in Malaysia*. [online] Available at: https://blogs.agu.org/landslideblog/2022/03/14/ampang-1/.

USGS (2016). *Landslide Types and Processes*. [online] Available at: https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html.

USGS (n.d.). *What is a landslide, and what causes one? | U.S. Geological Survey*. [online] www.usgs.gov. Available at: https://www.usgs.gov/faqs/what-landslide-and-what-causes-one.

Zin, O. (2022). *Lebih 30,000 terpaksa pindah, 55 maut akibat banjir, dua masih hilang - PM*. [online] Utusan Digital. Available at: https://www.utusan.com.my/terkini/2022/01/lebih-30000-terpaksa-pindah-55-maut-akibat-banjir-dua-masih-hilang-pm/ [Accessed 15 Jul. 2022].

APPENDIX A

This section kept the record of data collection for this study.

A1. Compilation of Flash Flood and Landslide Disaster Occur in Malaysia from September 2020 to June 2022

Table A.1 shows the compilation of flash floods and landslide disasters in Malaysia from September 2020 until June 2022. This data includes date, place, type of disaster and no. of deaths for each incident.

Table A.1: Compilation of Flash Flood and Landslide Disasters Occur in Malaysia from September 2020 to June 2022

DATE OF INCIDENT	PLACE	TYPE OF DISASTER (Flash Flood/ Landslide)	NO. OF DEATH
15-Sep-20	Batu 10 & 16 Jalan Tapah-Cameron Highlands, Batu 20 Jalan Tapah-Ringlet	Landslide	-
5-Oct-20	(Kota Kinabalu, Kota Belud, Tuaran) Sabah	Flash Flood	-
9-Nov-20	The Banjaran Hotsprings Retreat, Tambung Perak	Landslide	2
23-Nov-20	Terengganu, Perak, Melaka, Selangor	Flash Flood	-
17-Dec-20	Kelantan, Terengganu, Pahang	Flash Flood	-
3-Jan-21	Hulu Chukai, Kemaman	Landslide	-
4-Jan-21	Gua Musang, Kelantan	Landslide	-
5-Jan-21	Kuantan, Pahang	Landslide	-
11-Jan-21	Johor Bahru, Johor	Landslide	-
12-Jan-21	Padawan, Sarawak	Landslide	-
15-Jan-21	Bau and Lundu, Sarawak	Landslide	-

20-Jan-21	Tamparuli-Ranau, Sabah	Landslide	-
Jan-21	Johor, Pahang, Kedah, Perak, Selangor, Kelantan, Terengganu, Sabah, Sarawak	Flash Flood	10
17-Feb-21	Pasir Mas, Kelantan	Landslide	-
1-May-21	Sabah, Sarawak	Flash Flood	-
17-Jul-21	Kuching, Sarawak	Landslide	1
18-Aug-21	Gunung Jerai, Kedah	Flash Flood	4
18-Aug-21	Gunung Jerai, Kedah	Landslide	6
15-Sep-21	Jalan Penampang-Tambunan, Kota Kinabalu, Sabah and Forest Hill, Penampang, Sabah	Landslide	2
15-Sep-21	Sabah	Flash Flood	3
16-Sep-21	Sungai Palas, Cameron Highland, Pahamg	Landslide	1
17-Sep-21	Jalan Kemensah Heights, Kuala Lumpur	Landslide	-
1-Oct-21	Tanjung Bungah, Georgetown, Penang	Landslide	-
20-Oct-21	Selangor, Negeri Sembilan, Melaka	Flash Flood	1
22-Nov-21	Tanah Rata	Landslide	-
2-Dec-21	FT 185, KM 27.10 Jalan Simpang Pulai-Blue Valley, Ipoh, Perak	Landslide	2
15-Dec-21	Kampung Air Sejuk, Kuaka Terengganu, Terengganu	Landslide	1
18-Dec-21	Kampung Sungai Merab Hulu, Putrajaya	Landslide	-
19-Dec-21	Jalan Pelimbayan Indah, Kampung Sungai Penchala	Landslide	-
26-Dec-21	International Islamic University Malaysia, Gombak	Landslide	-
Dec-21	Selangor, Pahang, Kelantan, Kuala Lumpur, Melaka, Negeri Sembilan, Perak, Terengganu	Flash Flood	48
1-Jan-22	Melaka, Johor, Negeri Sembilan, Sabah, Pahang	Flash Flood	7
24-Feb-22	Besut, Dungun, Hulu Terengganu, Jeli, Kemaman, Kota Bharu, Kuala Krai, Kuala Terengganu, Kuantan, Machang, Marang, Pasir Mas, Pasir Putih, Setiu, Tanah Merah	Flash Flood	-
7-Mar-22	Gombak, Hulu Langat, Jasin, Jelebu, Kuala Langat, Kuala Lumpur, Petaling, Sepang	Flash Flood	-
10-Mar-22	Taman Bukit Permai 2, Ampang	Landslide	5
14-Mar-22	Malacca, Negeri Sembilan, Selangor	Flash Flood	-
18-Mar-22	Bentong, Pahang	Flash Flood	-

25-Apr-22	Kuala Lumpur	Flash Flood	-
6-May-22	Melaka	Flash Flood	-
11-May-22	Janda Baik, Bentong,Pahang	Flash Flood	-
24-May-22	Seremban, Kuala Lumpur	Flash Flood	-
1-Jun-22	Gurun, Kedah	Flash Flood	-

A.2 Table A.2 below shows the data collection collected based on the matrix method of 23 landslides occurring in Malaysia from September 2020 to March 2022.

Table A.2: Data collection of matrix method by average for 23 incidents of landslide in Malaysia

INCIDENT	AVERAGE
15-Sep-20	8.1
9-Nov-20	8.2
3-Jan-21	6
4-Jan-21	7.2
5-Jan-21	6
11-Jan-21	7.4
12-Jan-21	7
15-Jan-21	6.3
20-Jan-21	8.1
17-Feb-21	8.2
17-Jul-21	6.5
18-Aug-21	8.3
15-Sep-21	7.4
16-Sep-21	7.2
17-Sep-21	7.8
1-Oct-21	7
22-Nov-21	7.2
2-Dec-21	7.2
15-Dec-21	7.3
18-Dec-21	8.4
19-Dec-21	8.4
26-Dec-21	8.1
10-Mar-22	8.2

A.2.1. Table A.2.1 below shows data collection of numbers of landslide incidents recorded for 23 landslides occurring in Malaysia from September 2020 to March 2022 based on months using data collected using the matrix method.

Table A.2.1: Data Collection of Landslide Incidents Based on Months

MONTH	NO OF INCIDENTS
JAN	7
FEB	1
MAR	1
APR	0
MAY	0
JUN	0
JUL	1
AUG	1
SEP	4
OCT	1
NOV	2
DEC	5

A.3. Table A.3 below shows the data collected based on the matrix method of 19 flash floods occurring in Malaysia from September 2020 to June 2022.

Table A.3: Data collection of matrix method by average for 19 incidents of flash flood in Malaysia

INCIDENT	AVERAGE
5-Oct-20	6.5
23-Nov-20	7.6
17-Dec-20	8.9
Jan-21	8.2
May-21	7.6
18-Aug-21	8.2
15-Sep-21	7.6
20-Oct-21	8.1
Dec-21	9.2
1-Jan-22	9.1
24-Feb-22	8.7
7-Mar-22	6.5
14-Mar-22	7.2
18-Mar-22	6.5
25-Apr-22	5.7
6-May-22	5.3
11-May-22	7.3
24-May-22	6.6
1-Jun-22	7.7

A.4 Results of Matrix Method for Landslide and Flash Floods Data

A.4.1 Results of matrix method for Landslides that occur from September 2020 to March 2022.

Table A.4.1.1: Results of Matrix Method for Landslide (15 September 2020, Sabah)

Stressor – Source of Risk	Population	Climate conditions	Atmosphere	Water conditions	soil	Flora and fauna and their biotopes	Landscape, structure and use of terrain, scenic aspects of the landscapes	The protected areas and their protective zones	The territorial system of ecological stability	The urban environment and land use
Landslides	8	8	8	8	9	8	8	8	8	8
Flash floods										

Description:

- Affected – 2725 pupils, 190 teachers and 132 pre-schools

- 6 schools need to be closed.

- Heavy traffics happened at the area.

Table A.4.1.2: Results of Matrix Method for Landslide (18 August 2021, Gunung Jerai, Kedah)

Stressor – Source of Risk	**Population**	**Climate conditions**	**Atmosphere**	**Water conditions**	**soil**	**Flora and fauna and their biotopes**	**Landscape, structure and use of terrain, scenic aspects of the landscapes**	**The protected areas and their protective zones**	**The territorial system of ecological stability**	**The urban environment and land use**
Landslides	9	8	8	9	9	8	8	8	8	8
Flash floods										

Description:

- Affected area

  - Person (6 fatalities recorded)

- Because of *water column phenomenon (Kepala Air)

*Water column phenomenon is a vertical expanse stretching between the body of water's surface and the bottom.

Table A.4.1.3: Results of Matrix Method for Landslide (18 December 2021, Kampung Sungai Merab Hulu, Putrajaya)

Stressor – Source of Risk	**Population**	**Climate conditions**	**Atmosphere**	**Water conditions**	**soil**	**Flora and fauna and their biotopes**	**Landscape, structure and use of terrain, scenic aspects of the landscapes**	**The protected areas and their protective zones**	**The territorial system of ecological stability**	**The urban environment and land use**
Landslides	8	9	9	9	9	8	8	8	8	8
Flash floods										

Table A.4.1.4: Results of Matrix Method for Landslide (19 December 2021, Jalan Pelimbayan Indah, Kampung Sungai Penchala)

Stressor – Source of Risk	**Population**	**Climate conditions**	**Atmosphere**	**Water conditions**	**soil**	**Flora and fauna and their biotopes**	**Landscape, structure and use of terrain, scenic aspects of the landscapes**	**The protected areas and their protective zones**	**The territorial system of ecological stability**	**The urban environment and land use**
Landslides	9	9	9	8	9	8	8	8	8	8
Flash floods										

Description:

- Affected area

    - 284 people and 94 houses with 24 totally damaged.

A.4.2 Results of matrix method for Flash Flood that occur from September 2020 to June 2022.

Table A.4.2.1: Results of Matrix Method for Flash Flood (5 October 2020, Kota Kinabalu, Kota Belud, Tuaran, Sabah)

Stressor – Source of Risk	Population	Climate conditions	Atmosphere	Water conditions	soil	Flora and fauna and their biotopes	Landscape, structure and use of terrain, scenic aspects of the landscapes	The protected areas and their protective zones	The territorial system of ecological stability	The urban environment and land use
Landslides										
Flash floods	8	7	6	6	5	7	8	5	5	8

Description:

- Rainfall > 167 mm/d

- Affected area

    - Person (339 people – Kota Belud , 55 people – Tuaran)

    - 6 relief centers.

Table A.4.2.2: Results of Matrix Method for Flash Flood (January 2021, Johor, Pahang, Kedah, Perak, Selangor, Kelantan, Terengganu, Sabah, Sarawak)

Stressor – Source of Risk	**Population**	**Climate conditions**	**Atmosphere**	**Water conditions**	**soil**	**Flora and fauna and their biotopes**	**Landscape, structure and use of terrain, scenic aspects of the landscapes**	**The protected areas and their protective zones**	**The territorial system of ecological stability**	**The urban environment and land use**
Landslides										
Flash floods	9	9	9	8	7	7	9	7	8	9

Description:

- Severed damage to roads in Gua Musang

- Affected area

    - Person (6706 people – JB, 19146 people – Pahang, 130 people – Terengganu, 4000 people – Sarawak, 2000 people – Sabah, 154 people – Kelantan)

    - Fatalities (10 people)

Table A.4.2.3: Results of Matrix Method for Flash Flood (December 2021, Selangor, Pahang, Kelantan, Kuala Lumpur, Melaka, Negeri Sembilan, Perak, Terengganu)

Stressor – Source of Risk	**Population**	**Climate conditions**	**Atmosphere**	**Water conditions**	**soil**	**Flora and fauna and their biotopes**	**Landscape, structure and use of terrain, scenic aspects of the landscapes**	**The protected areas and their protective zones**	**The territorial system of ecological stability**	**The urban environment and land use**
Landslides										
Flash floods	10	9	9	9	9	9	9	9	9	10

Description:

- Damage – Submerged vehicles and houses

- Affected area

    - Person (Total more than 40,000 people)

    - Fatalities (48 people)

Table A.4.2.4: Results of Matrix Method for Flash Flood (January 2022, Melaka, Johor, Negeri Sembilan, Sabah, Pahang)

Stressor – Source of Risk	**Population**	**Climate conditions**	**Atmosphere**	**Water conditions**	**soil**	**Flora and fauna and their biotopes**	**Landscape, structure and use of terrain, scenic aspects of the landscapes**	**The protected areas and their protective zones**	**The territorial system of ecological stability**	**The urban environment and land use**
Landslides										
Flash floods	9	9	9	9	9	9	9	9	9	10

Description:

- Rainfall > 300 mm/d (Pahang), 229.8 mm/d (Johor)

- Affected area

    - Person (14,459 people)

    - Fatalities (7 people, 2 reported missing)