SOIL WATER INDEX APPROACH FOR LANDSLIDE DISASTER ASSESSMENT IN SABAH

FONG PUI YEE

FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
2022

UNIVERSITI MALAYSIA SABAH

SOIL WATER INDEX APPROACH FOR LANDSLIDE DISASTER ASSESSMENT IN SABAH

FONG PUI YEE

THESIS SUBMITTED IN FULFILMENT FOR THE DEGREE OF BACHELOR OF CIVIL ENGINEERING

FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
2022

UMS
UNIVERSITI MALAYSIA SABAH

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL : SOIL WATER INDEX APPROACH FOR LANDSLIDE DISASTER ASSESSMENT IN SABAH

IJAZAH : SARJANA MUDA KEJURUTERAAN AWAM DENGAN KEPUJIAN (UH6526001)

SAYA : FONG PUI YEE (HURUF BESAR)   SESI PENGAJIAN : 2-2021/2022

Mengaku membenarkan tesis *(LPSM/Sarjana/Doktor Falsafah) ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis adalah hak milik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/)

[ ]	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di AKTA RAHSIA RASMI 1972)
[ ]	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
[/]	TIDAK TERHAD	

Disahkan oleh:

ANITA BINTI ARSAD
PUSTAKAWAN KANAN
UNIVERSITI MALAYSIA SABAH

(TANDATANGAN PUSTAKAWAN)

FONG PUI YEE

Alamat Tetap:
JALAN CECILY,
90000 SANDAKAN,
SABAH.

TARIKH: 02/08/2022

(DR. SITI JAHARA MATLAN)

TARIKH: 02/08/2022

Catatan:
*Potong yang tidak berkenaan.
*Jika tesis ini SULIT dan TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.
*Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana Secara Penyelidikan atau disertai bagi pengajian secara kerja kursus dan Laporan Projek Sarjana Muda (LPSM).

UMS
UNIVERSITI MALAYSIA SABAH

DECLARATION

I hereby declare that this thesis, submitted to Universiti Malaysia Sabah as partial fulfilment of the requirements for the degree of Bachelor of Civil Engineering. This thesis has not been submitted to any other degree or other university. I also certify that the work described herein is entirely my own, except for quotations and summaries sources of which have been duly acknowledged.

This thesis may be made available within university library and may be photocopied or loaned to other libraries for the purposes of consultation.

20 JULY 2022

Fong Pui Yee
BK18110099

UMS
UNIVERSITI MALAYSIA SABAH

CERTIFICATION

NAME : **FONG PUI YEE**

MATRIC NO : **BK18110099**

TITLE : **SOIL WATER INDEX APPROACH FOR LANDSLIDE DISASTER ASSESSMENT IN SABAH**

DEGREE : **BACHELOR OF CIVIL ENGINEERING**

FIELD : **CIVIL ENGINEERING**

VIVA DATE : **20 JULY 2022**

CERTIFIED BY;

Signature

SINGLE SUPERVISION

SUPERVISOR
Dr. Siti Jahara Matlan

UMS
UNIVERSITI MALAYSIA SABAH

ACKNOWLEDGEMENT

First and foremost, I want to thank the Great Almighty, the creator of knowledge and wisdom, for His endless love and for giving me the strength to accomplish what I have aspired for in this thesis. I am thankful to Him for being surrounded by all the individuals who were ready to aid me in finishing my thesis.

I would want to thank you my Final Year Project Supervisor, Dr. Siti Jahara Matlan for firstly, approving me as her Final Year Project student. I would want to further express my appreciation for her support, guidance and knowledge including the opportunities to improve academically and professionally. I could not have capable of completing my thesis without her.

I would also like to deliver my appreciation to the authorities such as Public Work Department and Department of Irrigation and Drainage who were willing to participate in this research by providing the necessary information and data needed to complete this thesis.

I would also want to extend my appreciation to my family and acquaintances for their unwavering support during my thesis. Thank you to my family for all the encouragement and financial aids enabling me to finish my thesis throughout this pandemic. Thank you also to my acquaintances for always being keen to assist me in completing my thesis. Special appreciation to my parents, without them, everything would not have been possible.

Fong Pui Yee
20 JULY 2022

UMS
UNIVERSITI MALAYSIA SABAH

ABSTRACT

Landslide disaster assessment and management have become challenging concerns in recent years. Hence, this paper has been written to study on Soil Water Index (SWI) approach for landslide disaster assessment at three different regions in Sabah which are Ranau, Tambunan and Sandakan. Landslide is described as a mass of rock, rubble, or soil moving down a slope under the force of gravity. Landslides are influenced by different variables which are the factors that contribute to landslides (e.g., design errors, construction errors, maintenance errors, geological features and human causes) as well as the factors that triggered the landslides (e.g., earthquake and rainfall). Hence, the objective of this project is to study the landslide cases and rainfall data in the three regions chosen in Sabah. Second objective is to calculate the SWI associated with the landslide events. Third objective is to analyse the effect of rainfall on landslide events based on the SWI method. The SWI is equivalent to the total storage volume of the tank model, where rainfall is utilized as an input to create outputs such as surface runoff, subsurface flow, intermediate flow, and sub-base flow, as well as infiltration, percolation, and water storage in the tank. The critical SWI of each site is computed based on the landslide incidences and rainfall data from the three regions analysed, with a high level of SWI suggesting that rainfall plays a considerable role in destabilizing the slope. Thus, more detailed scientific study of the connection between rainfall events and landslide occurrences in Sabah is necessary for landslide disaster assessment.

UMS
UNIVERSITI MALAYSIA SABAH

ABSTRAK

(PENDEKATAN INDEKS AIR TANAH UNTUK PENILAIAN BENCANA TANAH RUNTUH DI SABAH)

Penilaian dan pengurusan bencana tanah runtuh menjadi kebimbangan yang mencabar dalam beberapa tahun kebelakangan ini. Oleh itu, makalah ini ditulis untuk mengkaji pendekatan Indeks Tanah Air (SWI) untuk penilaian bencana tanah runtuh di tiga daerah yang berbeza di Sabah iaitu Ranau, Tambunan dan Sandakan. Tanah runtuh digambarkan sebagai jisim batu, runtuhan, atau tanah yang bergerak menuruni cerun di bawah kekuatan graviti. Tanah runtuh dipengaruhi oleh pemboleh ubah yang berbeza yang merupakan faktor yang menyumbang kepada tanah runtuh (mis. kesalahan reka bentuk, kesalahan pembinaan, kesalahan penyelenggaraan, ciri geologi dan punca manusia) serta faktor-faktor yang mencetuskan tanah runtuh (mis. gempa bumi dan hujan). Oleh itu, objektif projek ini adalah untuk mengkaji kes tanah runtuh dan data hujan di tiga daerah yang dipilih di Sabah. Objektif kedua adalah mengira SWI yang berkaitan dengan kejadian tanah runtuh. Objektif ketiga adalah untuk menganalisis kesan hujan pada kejadian tanah runtuh berdasarkan kaedah SWI. SWI setara dengan jumlah simpanan model tangki, di mana curah hujan digunakan sebagai input untuk membuat output seperti larian permukaan, aliran bawah permukaan, aliran perantaraan, dan aliran sub-dasar, serta penyusupan, perkolasi, dan air simpanan di dalam tangki. SWI kritikal setiap daerah dihitung berdasarkan data kejadian tanah runtuh dan hujan dari tiga daerah yang dianalisis, dengan tahap SWI yang tinggi menunjukkan bahawa hujan memainkan peranan yang cukup besar dalam menjejaskan kestabilan cerun. Oleh itu, kajian ilmiah yang lebih terperinci mengenai hubungan antara kejadian hujan dan kejadian tanah runtuh di Sabah diperlukan untuk penilaian bencana tanah runtuh.

UMS
UNIVERSITI MALAYSIA SABAH

TABLE OF CONTENTS

UMS
UNIVERSITI MALAYSIA SABAH

UMS
UNIVERSITI MALAYSIA SABAH

LIST OF TABLES

UMS
UNIVERSITI MALAYSIA SABAH

LIST OF FIGURES

UMS
UNIVERSITI MALAYSIA SABAH

UMS
UNIVERSITI MALAYSIA SABAH

LIST OF ABBREVIATIONS/SYMBOLS

SWI	Soil Water Index
PWD	Public Works Department
LVAs	Landslide Vulnerability Assessment
MPAJ	*Majlis Perbandaran Ampang Jaya*
DID	Drainage and Irrigation Department
$WL_i(t)$	Water Table of Corresponding Tank
H_i	Height of Lateral Outlet
i	Number of Lateral and Vertical Outlets for The Respective Tanks
α	Lateral Discharge Coefficients
β	Vertical Discharge Coefficients
$Q_i(t)$	Lateral Flow Discharge
$I_i(t)$	Vertical Seepage Volume
S	Fluctuation in Water Storage
$R(t)$	Rainfall Intensity at Specific Time

UMS
UNIVERSITI MALAYSIA SABAH

LIST OF APPENDICES

UNIVERSITI MALAYSIA SABAH

CHAPTER 1

INTRODUCTION

1.1 Overview

Malaysia is a country in Southeast Asia that is separated into two sections by the South China Sea: Peninsula Malaysia and Borneo Island. Malaysia is located in the equatorial zone, where the climate is tropical rainforest all year. The rainfall patterns in Malaysia are divided into two monsoon seasons: the Southwest Monsoon, which runs from late May to September, and the Northeast Monsoon, which runs from November to March, have the maximum rainfall during the transition time between the two monsoon seasons, known as the inter-monsoon season (Ng, 2012). Malaysia is rated tenth in the world for having a high frequency of landslides, based on landslide data from 2007 to 2016, which includes multiple large-scale landslides. Landslides are widespread in Malaysia during the monsoon seasons every year, and they always result in road closures, injuries and even structural damage (Gue & Tan, 2006b). This is due to the fact that rainfall during this season is significantly higher than normal rainfall during other seasons, and the stability of slope landslides in mountainous regions are affected by this weather pattern in tropical nations. In the hilly and mountainous regions of Malaysia, landslides have claimed many lives and caused significant economic loss. Since the 1980s, strategic and adequate low-lying locations for development have become scarcer in Malaysia as a result of fast growth. As a result, the growth of highland or steep terrain has accelerated, particularly in areas next to heavily populated cities, putting metropolitan areas at danger of landslides (Jamaludin & Hussein, 2006).

According to Tongkul (2016), a landslide near Mount Kinabalu, Sabah in 2015 destroyed around 1500 hectares of soil, rocks, and vegetation cover,

UMS
UNIVERSITI MALAYSIA SABAH

significantly diminishing the ability of the water catchment to collect and retain precipitation. The loose materials from landslides that collected on the slopes in the gullies and river valleys not only supplied an abundant source of debris for debris flow amid heavy rain, but also influenced water flow. In the last two decades, landslides have occurred often in Malaysian residential areas. Twenty years after the incident at the Highland Towers in Taman Hillview, Hulu Kelang, Selangor, Malaysian authorities have given considerable consideration to rules and regulations for building slope areas in Selangor. The subject of landslides in the Bukit Antarabangsa district of Selangor, which causes four deaths and destroyed 14 bungalows (Online, 2019), has piqued the interest of a variety of people. It has encouraged the state government and local authorities to strengthen slope area upkeep and laws, particularly in this affluent Selangor district (Tazin & Yaakop, 2015).

1.2 Definition

A landslide is a type of material loss that occurs when soil and rock are moved under high gravity pressure. Landslides, according to Varnes (1958), are downward and outward movements of slope-forming elements such as natural rock, soils, manmade fills, or mixtures of these elements. Likewise, Cruden (1991) defines a landslide as a mass of rock, debris, or soil flowing down a slope under the influence of gravity. Landslides are mass wastes that are described as any type of earth element movement down a slope (Lateh & Ahmad, 2011). Landslides, according to Zhang *et al.* (2014), are a natural event that arise as a result of weathering or external triggers such as earthquakes, melting snow, or rainfall. Landslides are a severe geologic danger that affects almost every country on the planet. Every year, landslides cost billions of dollars in damage and result in hundreds of fatalities and injuries throughout the world (Akter *et al.*, 2019). Although much effort has been made to reduce the risk, landslides are expected to become more common in the future. As a result, landslides are regarded as a natural hazard and dangerous occurrence capable of causing property damage and injuries. It also is split into geological elements like rock, shale, and earth. Debris flow, which is usually

UMS
UNIVERSITI MALAYSIA SABAH

associated with dirt or mud, as well as rockfall, is a sign of the well-known category of landslides.

The types of material involved, and the way of movement may be used to distinguish the many types of landslides. Landslides or slope movements may be classified into six groups, according to (Akter *et al.*, 2019), which include falls, topples, slides, lateral spreads, flows, and complex. Landslides were caused by a variety of factors. Rainfall, earthquakes, volcanic activity, changes in groundwater, disturbances, and changes in slope profile caused by building operations, or a combination of these events, can cause landslides. However, more than 80% of landslides are at least partially caused by human activity, such as improper slope management.

The Soil Water Index (SWI) is produced using a several-layer tank model with hourly precipitation to indicate the conceptual water contained in the soil (Matsuyama *et al.*, 2021). The SWI estimates typical amounts of water retained in soil in certain locations, assisting in determining the danger of landslides induced by heavy rain. Rainwater seeps through the ground surface and into rivers or the ground. The risk of land slope collapse increases as the amount of water retained in soil increases. For landslide disaster assessment, the SWI is used as a long-term precipitation indicator. SWI is acknowledged as a long-term precipitation indicator for landslide disaster assessment since all precipitation does not instantly drain away but is held in the soil for a long period (Matsuyama *et al.*, 2021). This research will show how the SWI method may be used to analyse landslide cases in Sabah.

1.3 Research Background

Landslide disaster assessment and management have become challenging concerns in recent years, as societal development has moved into mountainous areas. Several initiatives on landslide hazard and risk assessment have been carried out by Malaysian government entities throughout the last decade. These initiatives

UMS
UNIVERSITI MALAYSIA SABAH

covered a wide range of topics, including land use, agriculture, and slope management (Jamaludin & Hussein, 2006).

The purpose of a landslide hazard assessment is to determine the likelihood of a landslide occurring, as well as the area, volume, speed, and route distance (Fukuoka *et al.*, 2005). The study of Soeters & Westen (1984) examined the frequency and likelihood of landslide severity using a variety of methodologies, including a landslide inventory, a heuristic and deterministic approach, and statistical analysis.

As a result, this study is being carried out in order to analyse the landslide hazard using the SWI technique in order to determine the critical SWI for the landslide-prone area in Sabah based on rainfall data. Hence, using the SWI approach, it will be possible to study the impact of rainfall landslides in Sabah.

1.4 Problem Statements

Although some authorities are actively using PWD data to successfully reduce the number of landslide events in Malaysia, some authorities are taking the necessary steps to mitigate landslides without using the data they provided due to a lack of funding and technical personnel to address the technical issues. The study of the SWI is necessary in mitigating the risk of landslide events because it only utilizing the rainfall data and previous landslide events in any selected area. This study may help the authorities to successfully reduce the number of landslide events in Malaysia by referring to the SWI values that have the possibilities in destabilizing the slope which eventually reduce the need of funding or technical personnel to assess landslide events. In Malaysia, it is found out that the scope of landslide research was limited, focusing primarily on landslide mapping, slope stability analysis, and slope design. One of the reasons for the difficulty in making effective decisions on land use planning, maintenance, and risk quantification in Malaysia is the lack of a data base on slopes and landslides (Abdullah, 2013).

UMS
UNIVERSITI MALAYSIA SABAH

Matlan *et al.* (2018) indicated in their study that there has been relatively few research done on the landslide concerns in Sabah, but that those studies did not include the impacts of rainfall intensity and duration, and that no association between rainfall and landslide has been explored for this location. Based on the literature studies, it is found that there is only a few of landslide assessments that are related to the method used in this study, which is SWI, and the area covered for the limited number of research papers were mostly in foreign countries such as Japan, Europe and China.

In a study conducted at Ranau-Tambunan Road in Sabah, the study attempted to test the concept that material parameters that govern slope stability varied between stable and failing soil slopes in the same area. The goal of the study, according to another research article, is to explore the effect of land uses in contributing to landslide initiation in Kundasang, Sabah, an area where land uses are changing to meet local, and tourist needs.

The research on the influence of rainfall on landslide occurrences in Sabah based on the SWI and other approaches is fairly limited, as seen by the few studies stated above that were undertaken in Sabah. For landslide disaster assessment, a thorough scientific research of the link between rainfall events and landslide occurrences in Sabah is required.

1.5 Objectives of Study

The aim of this study is to analysis the soil water index approach for landslide disaster assessment in Sabah. The specific objectives are set forth:

(a) To study landslide cases in Sabah.
(b) To study rainfall data in Sabah.
(c) To calculate the SWI associated with the landslide event.
(d) To analyze the effect of rainfall on landslide events based on the SWI method.

UMS
UNIVERSITI MALAYSIA SABAH

1.6 Scope of Study

This study of the SWI approach for landslide disaster assessment in Sabah is a case study that will focus on three regions: Ranau, Sandakan and Tambunan. This research report will examine the landslides that happened in the three areas chosen, using data from the data source of PWD Sabah, as well as performing literature studies on previously published research papers. The rainfall data of the sites for eleven years, from 2010 to 2020, is gathered from the rainfall gauge station of each of the places chosen, since this paper attempts to compute the SWI linked with landslide incidents at the specified regions.

The SWI method, which reflects the conceptual water stored in the soil and is calculated using a several-layer tank model with hourly precipitation established by Sugawara (1979), is then employed in this research. This tank model is a basic idea that uses rainfall as an input to create outputs such as surface runoff, subsurface flow, intermediate flow, sub-base flow, as well as the phenomena of infiltration, percolation, and water storage in the tank. The critical SWI of each location is estimated based on the landslide incidents and rainfall data from the three areas studied, with a high level of SWI indicating that rainfall plays a substantial role in destabilising the slope (Matlan *et al.*, 2018).

Okada *et al.* (2001) provided the parameters for the three-tank model that is being used in this study which includes the outflow height as well as the coefficient of tank holes for all the three tanks. The lateral flow discharge, $Q_i(t)$, and the vertical seepage volume, $I_i(t)$ are first computed to determine the SWI, which is equal to the total storage volume of the three tanks laid vertically in series. After determining the lateral flow discharge, $Q_i(t)$, and the vertical seepage volume, $I_i(t)$, the SWI, or storage volume of each tank, is computed by summing the values of S_1, S_2 and S_3.

The analysis is continued by describing the impact of rainfall on landslide events, where the critical duration of rainfall influencing the occurrence of

UMS
UNIVERSITI MALAYSIA SABAH

landslides at the three selected regions is classified into landslides that are triggered by cumulative antecedent rainfall as well as landslides that are triggered by the combination of antecedent and major rainfall.

1.7 Significance of Study

In this study, the landslide cases in Sabah are identify and the rainfall data of the city chosen based on the landslide events is obtained. Based on the rainfall data obtained from the rainfall gauge station of the selected areas in Sabah, it would help in the assessment of the landslide disaster in Sabah as the data obtained can be used to calculate the SWI of the areas that is associated with the landslide events. By using the SWI method too, the effect of rainfall on landslide events can also be analysed. As a result, it is critical to examine the link between rainfall and soil moisture state in order to minimize landslides during heavy rain.

Before analysing a landslide disaster, it is critical for an engineer to have a thorough understanding of previous landslides in terms of event occurrence, regulating variables, and trigger conditions. As a result, this study can help by giving the necessary frameworks for understanding the impact of rainfall on landslide occurrences throughout time in the monitored area, which is comprised of three regions: Ranau, Sandakan and Tambunan, as well as reviewing it during future surveys. As an engineer, understanding landslide mapping, prediction monitoring, and risk assessment is essential in order to limit the impact of landslides in specific locations.

Next, this study can assist the public in understanding landslide disaster assessment and taking the necessary precautions to prevent landslides from occurring. Furthermore, it can raise public awareness about the importance of analysing a landslide tragedy before it occurs. Landslides may be controlled or reduced if suitable measures are taken and science, technology, and wise policies are used. Education is maybe the most effective protection. To put it another way, people should have a good understanding of how landslides happen and what they

UMS
UNIVERSITI MALAYSIA SABAH

can and should do to prevent them (Lateh & Ahmad, 2011). Given the importance of environmental education in shaping attitudes and behaviour toward environmental hazards and disasters such as landslides, the purpose of this paper is to educate Malaysians' knowledge and attitudes about landslides, as well as to identify the actions they took to reduce the occurrence of landslides.

UMS
UNIVERSITI MALAYSIA SABAH