IDENTIFICATION OF FLOOD VULNERABILITY FOR AN EFFECTIVE FLOOD-PRONE ZONE MAPPING IN KUALA LUMPUR CITY

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ABSTRACT

Kuala Lumpur city has suffered from higher occurrences of flash flood due to the rising numbers of rainfall frequencies resulting from the rapid urban development and climate changes, namely the Urban Heat Island (UHI) effect. It has imposed various threatening impacts on the city and its dwellers. Hence, the flood vulnerability needs to be well-observed so that the flood-prone zone mapping in Kuala Lumpur city can be accomplished. The assessment of flood-prone zone mapping is essential as it is a significant element in developing a flood resilience city. Therefore, systematic flood management initiatives can be constructed and be implemented throughout city planning and development. This study aims to establish a flood-prone zone mapping in Kuala Lumpur city by evaluating the flood vulnerability of the city. A critical assessment of literary works is undertaken to identify the direct and indirect impacts of the flash flood in Kuala Lumpur city. Afterwards, a questionnaire form is distributed among the target respondents to verify the findings accumulated through the literature review. Meanwhile, the flood vulnerability is assessed by analysing the daily rainfall data collected from twenty rainfall stations in Kuala Lumpur between 1970 and 2019, which are retrieved from the Department of Irrigation and Drainage (DID). The daily rainfall data is then analysed using the Standardised Precipitation Index (SPI) at a 3-month (SPI-3) time scale. The frequency of the extremely wet and severely wet occasions is used to propose the flood-prone zone mapping. The components and indicators affected by the flash floods are discovered, and the flood vulnerability for each constituency are illustrated to offer an effective flood-prone zone mapping. Adopting and considering the flood-prone zone mapping into various flood management initiatives will reduce the risk and impacts of the flash flood to the urban landscape. Implementing this approach would contribute to a vision of a flood resilience city in Kuala Lumpur city and consequently, improve the quality of life.

ABSTRAK

Kejadian banjir kilat di Bandaraya Kuala Lumpur semakin berleluasa belakangan ini disebabkan oleh peningkatan kadar kekerapan hujan berpunca daripada pembangunan yang pesat dan kesan perubahan iklim, lebih dikenali sebagai pulau haba bandar. Hal ini telah memberi pelbagai ancaman ke atas ibu kota dan penduduknya. Oleh itu, kerentanan banjir perlu diberi perhatian yang menyeluruh agar pemetaan kawasan mudah banjir di Bandaraya Kuala Lumpur dapat dilaksanakan. Penilaian bagi pemetaan kawasan mudah banjir amat mustahak kerana ia merupakan unsur utama dalam membangunkan bandar berdaya tahan banjir. Justeru, daya usaha pengurusan banjir yang sistematik dapat dilahirkan serta dilaksanakan dalam perancangan dan pembangunan bandar. Kajian ini bertujuan untuk mewujudkan pemetaan kawasan mudah banjir di Bandaraya Kuala Lumpur dengan menilai kerentanan banjir di bandar ini. Penilaian yang kritis terhadap karya literatur telah dijalankan bagi mengenal pasti kesan banjir kilat sama ada secara lansung dan tidak lansung di Bandaraya Kuala Lumpur. Seterusnya, borang kaji selidik telah diedarkan dalam kelompok sasaran bagi membuktikan penemuan yang dikumpul melalui tinjauan literatur. Usai itu, kerentanan banjir telah dinilai dengan menganalisa data hujan harian yang dikumpulkan dari dua puluh stesen hujan di Bandaraya Kuala Lumpur antara tahun 1970 dan 2019. Data hujan harian ini diperolehi daripada Jabatan Pengairan dan Saliran (DID) dan dinilai menggunakan Indeks Kerpasan Piawai (SPI) pada skala masa tiga bulan (SPI-3). Kadar kekerapan hujan yang basah dan sangat basah telah digunakan bagi membentuk pemetaan kawasan mudah banjir. Maka, komponen dan penanda aras yang terjejas oleh banjir kilat dapat dikenal pasti dan kerentanan banjir bagi setiap mukim dapat dizahirkan melalui pemetaan kawasan mudah banjir dengan lebih berkesan. Penggarapan dan pertimbangan terhadap pemetaan kawasan mudah banjir dalam pelbagai daya usaha pengurusan banjir dapat mengurangkan akibat dan kesan banjir kilat dalam kawasan bandar. Dengan demikian, pelaksanaan langkah ini dapat meyumbang kepada wawasan bandar berdaya tahan banjir di Bandaraya Kuala Lumpur, lantas meningkatkan taraf hidup.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

UTM	-	Universiti Teknologi Malaysia
UHI	-	Urban Heat Island
DID	-	Department of Irrigation and Drainage
SPI	-	Standardised Precipitation Index
SPI-3	-	SPI for 3-month time scale
UN	-	United Nations
DBKL	-	Kuala Lumpur City Hall
IPCC	-	Intergovernmental Panel on Climate Change
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
GDP	-	Gross Domestic Product
EPU	-	Economic Planning Unit
DOSM	-	Department of Statistic Malaysia
NEM	-	North-East Monsoon
SWM	-	South-West Monsoon
SMART	-	Stormwater Management and Road Tunnel
SPSS	-	Statistical Package for the Social Sciences
PYTHON	-	Python Programming Language
R	-	The R Project for Statistical Computing
MSMA	-	Urban Stormwater Management Manual for Malaysia
DO	-	Development Order

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Preface

The world's urban population has developed rapidly over the past decades. The enormous expansion in urbanisation and the overall growth in the world's population have projected to increase the urban population by 2050, with the majority of the rise in Asia and Africa (UN, 2018). Simultaneously, urbanisation has improved economic activity and the quality of life, which is beneficial to humankind. However, the rapid urbanisation has triggered several aftermaths towards the environment, including the loss of agricultural land, habitat destruction, contamination of air, soil, water, and the Urban Heat Island (UHI) effect (Son et al., 2017). UHI is defined as a microclimatic phenomenon in the cities due to the differences in temperature between the urban setting and the surrounding rural areas (Oke, 1973); correspondingly, many cities worldwide have experienced the UHI effect.

Concurrently, urbanisation has threatening impacts on local climate change, which has worsened at an unprecedented rate over the years. The combined effects of climate change and rapid urbanisation intensify and trigger the UHI effect against the urban setting and affect human life quality. Likewise, other elements which influenced this occurrence, including the city size and its morphology, topography, climate zones, meteorological conditions, urban materials, and air pollution (Ramakreshnan et al., 2019). One of the most significant impacts of the UHI effect is the disruption to precipitation frequency and intensity (Lin et al., 2008). The West Coast of Peninsular Malaysia has observed an immense frequency of the very wet and extremely wet hours over the years due to the rapid urbanisation within the

vicinity. Thus, it amplifies the occurrence of the flash flood in the developing areas (Syafrina et al., 2015).

1.2 Background of the Study

In recent years, flooding incident in Malaysia escalates rigorously due to the rapid urbanisation, especially in the metropolitan area. This catastrophic event has resulted in extensive damages, be it physically or psychologically. Flooding is a disastrous event that occurs due to an extreme rainfall on land, or when a river or stream overflows from its natural or artificial banks, which outpour the adjacent area (Ching et al., 2015). According to Petersen (2001), flood is characterised into four types corresponding to its feature; flash floods of a few hours' duration, single-event floods of a longer period, multiple-event flood and seasonal. On the other hand, the Malaysian Department of Irrigation and Drainage (2017) has classified the flood as monsoonal flood, coastal flood or flash flood.

Flash flood is the most threatening catastrophe due to its speed and unpredictability; hence, it becomes indestructible (Doocy et al., 2013). Flash flood is defined as a rapid overflow of water on land due to the extreme rainfall or a sudden release of impounded water within a short period (Hong et al., 2013). Meanwhile, the US National Weather Service (2009) mentioned that the flash flood occurs within six hours, and often within three hours during an extreme rainfall intensity. Flash flood commonly takes place on small headwater basins in relation to ephemeral convective, frontal, or orographic storms with extreme precipitation (Petersen, M. S., 2001). It is a destructive event which can cause calamity and severe impacts, therefore, requires clear communication and assimilation among the stakeholders in mitigating the flash flood risk and severity.

Generally, the flash flood occurs due to two main factors; human and natural elements comprising of rainfall duration and intensity, antecedent soil moisture conditions, land cover and soil type, watershed characteristics, and land use (Schroeder et al., 2016). Risk is the probability of an event occurring during a period

of interest and the consequences associated with the event. Meanwhile, severity is a degree of seriousness of an event. The risk of the flash flood is managed by considering the threat identified as a risk. Meanwhile, the consequence of flash flood is described as the severity of its impact towards the social, economic and environment. These impacts can be further catagorised as direct and indirect damages, secondary damages, and intangible damages (Petersen, M. S., 2001).

1.3 Problem Statement

Urban development in Kuala Lumpur city causes the city to experience menacing impacts of the UHI effect due to increased ambient temperature. As a result, it changes the urban microclimate and increases the extremely heavy rainfall events. On 10 September 2020, the city is struck by more than five percent of the rain it should have observed in an entire year. However, it is noted that the flash flood perchance occurred because of the rivers breaching its limit and possible overflowing, and overdevelopment that could have gone unchecked (NST, 2020). Moreover, the flash flood in Kuala Lumpur city is also due to other factors, such as the high surface runoff discharge due to impervious surfaces which limiting the rate of water absorption, poorly maintained drainage causing blockage and insufficient design of the drainage and waterways (Samsuri et al., 2018).

Furthermore, Kuala Lumpur is more prone to the flash flood due to its geographical location. The city is a converging point of two major rivers; Klang River and Gombak River. The rivers located right at the centre of the valley caused the city at risk of flooding (Bhuiyan et al., 2018). Typically, the city suffers from two types of flash floods; the fluvial flash flood and drainage-system-induced flash flood due to the extreme rainfall. Two separate stakeholders monitor both types of the flash flood in the city; Drainage and Irrigation Department (DID) manages the river-related flash flood while Kuala Lumpur City Hall (DBKL) manages the drainage-and-street-related flash flood (Bhuiyan et al., 2018).

Flash flood impacts in Kuala Lumpur city affect the social, economic, and the environment simultaneously. It also profoundly affects its victim's psychological, and all these consequences can be long-lasting. The tangible and intangible components of the flash flood impact; either direct or indirect, can be quantitively evaluated based on the losses and damages imposed on the city (Bhuiyan et al., 2018). In order to minimise the loss and destruction due to the flash flood and to control and prevent the flash flood occurrences, flood mitigation initiatives have been imposed by various stakeholders through structural and non-structural measures. These initiatives have successfully lessened the flash flood phenomenon in the city and saved billions of ringgits (Samsuri et al., 2018).

Nonetheless, Kuala Lumpur city is still observing a regular occurrence of the flash flood, despite the enormous efforts in implementing the flood management initiatives by DID and DBKL as the city is vulnerable to the flash flood each year due to the rising numbers of continuous heavy rainfall (Wan Mohtar et al., 2020). Recent flash flood events on 10 September 2020 have disabled most of the main roads causing traffic chaos, and the city is submerged in water as high as between one and three metres in the affected areas (NST, 2020; Malay Mail, 2020). Several constituencies in the city are severely hit by the flash flood, including the non-traditional hotspots. Thus, DBKL acknowledged a need to identify the flood vulnerability in Kuala Lumpur city by developing a flood-prone zone map so that the appropriate measures can be adopted to enhance the infrastructure such as road and drainage systems (The Star, 2020).

Therefore, the flood vulnerability needs to be well-observed in order to establish a flood-prone zone mapping in Kuala Lumpur city. The flood vulnerability assessment is essential as it is a significant element in developing a flood resilience city. The intensity of precipitation can be computed by adapting the Standardised Precipitation Index (SPI) introduced by McKee et al. in 1993. Subsequently, an effective flood-prone zone mapping can be generated to serve as an indicator for areas which are more prone to wetter hours (Guerreiro et al. 2007). Nonetheless, creating a flood resilience city also depends on the cooperative efforts from all

stakeholders and the integration of appropriate structural and non-structural measures to mitigate the flash flood risk and impacts effectively.

1.4 Aim and Objectives

This study aims to establish a flood-prone zone mapping in Kuala Lumpur city by evaluating the flood vulnerability of the city. The objectives of this study are:

(a) To investigate the impacts of the flash flood in Kuala Lumpur city.

(b) To analyse the flood vulnerability in Kuala Lumpur city.

(c) To develop an effective flood-prone zone mapping in Kuala Lumpur city.

1.5 Scope of the Study

This study focuses on the flash flood impacts in Kuala Lumpur city. Comprehensive literature reviews are carried out to identify these impacts, and a survey is conducted on the target respondents so that the flash flood impacts in Kuala Lumpur city can be evaluated. Furthermore, the daily rainfall data between 1970 and 2019 from selected rainfall stations in Kuala Lumpur is collected from DID. The rainfall data is examined by adapting the SPI. Therefore, flood vulnerability in Kuala Lumpur city can be distinguished. The flood vulnerability leads to an effective flood-prone zone mapping by identifying the areas which are more prone to the extremely wet and severely wet hours within each constituency in Kuala Lumpur city.

1.6 Significant of the Study

This study is carried out in order to identify the flood-prone zone mapping of Kuala Lumpur city so that the appropriate structural and non-structural measures for an effective flood management in the city can be adopted. These findings are beneficial towards developing a flood resilience city. The contributions that can be achieved from this study are as follows:

(a) This study investigates the direct and indirect impacts of the flash flood occurrences in Kuala Lumpur city through the literature reviews and survey conducted on the target respondents.

(b) This study analyses the flood vulnerability in Kuala Lumpur city by devising the SPI through the analysis of daily rainfall data between 1970 and 2019 obtained from DID.

(c) This study established an effective flood-prone zone mapping of Kuala Lumpur city in order to provide a significant contribution in developing the appropriate measures in mitigating the flash flood impacts.

1.7 Expected Finding

The findings from this study are expected to offer an effective flood-prone zone mapping of Kuala Lumpur city by identifying the flood vulnerability. It significantly contributes in developing the structural and non-structural measures to mitigate the flash flood impacts based on the flood vulnerability of selected rainfall stations in the city. This study is predicted to improve the research from previous studies related to the flash flood reports and precipitation by Wan Mohtar et al. in 2020. It also will improve and establish a finer assessment of the flash flood impacts within the city. Simultaneously, it provides an effective projection of the flood-prone zone mapping in Kuala Lumpur city.

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