Natural Flood Influencing Factors: A Case Study of Perlis, Malaysia

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Abstract- **In the year 2005, 2010, as well as 2011 severe floods stroked Perlis State, which is situated in the northern part of Peninsula Malaysia. The floods caused tremendous damages to properties and lives as a whole. Flood is basically one of the weather related natural catastrophes. Numerous techniques exist in an attempt to provide most reliable solutions to reduce the flood risk level to the maximum by detecting those areas that are vulnerable to flooding. The purpose of this paper is to identify the natural flood influencing factors in the study area. GIS spatial database was created from a geological map, land cover map, meteorological station, drainage map, topography map and soil map respectively. An attribute database was equally created from field investigations and historical flood areas reports of the study area. A number of natural flood influencing factors were identified and discussed herein.**

Keywords: Flood Catastrophes, Natural Flood Influencing Factors; GIS-based Multi-Criteria Decision Making

I. INTRODUCTION

Numerous nations experience fatalities, traumas, damage to property, monetary as well as interpersonal disruption caused by natural calamities. Natural calamities, such as earthquakes, tornados, flash floods, volcanic outbreaks, along with landslides have constantly make-up an issue in most developing and even developed nations. The natural hazards slay thousands and thousands of men and women and destroy billions of dollars' worthy of habitat as well as property every year. The speedy increase of the world's human population has escalated equally the number and rigorousness of the natural catastrophes. Flood tragedy possesses a very special place in natural hazards. Floods are definitely the priciest types of natural hazards on earth and it also make-up 31% of the financial losses resulting from natural catastrophes [1]. In Malaysia, it has been recorded that since 1973, the nation's flood catastrophe; floodwater control turned a rising matter of debate between authorities, researchers as well as non-public sectors [2]. More than thirty-five years, flood degree and frequency accelerated tremendously particularly triggered by means of human actions for example land clearing for urbanization or farming activities, building of structure such as freeways, roads together with bridges, which often times altered the flood tendencies [2-3]. Statement from Department of Irrigation and Drainage Malaysia equally reported that around twenty nine thousand kilometers of the entire land area and over 4.82 million individuals (22%) suffers from flooding every year along with damage approximated to cost RM915 million [4].

Inhabitants residing in the lower lands, near to river bank and also flood inclined locations have been identified as most susceptible when compared with when it occurred in urban areas. Flood connected with what is known as "flash floods" is typical in Malaysia. Numerous significant urban areas encountered flash floods, which usually happened in the time of monsoon periods from November to March (North-East monsoon) and May to September (South-West Monsoon) [2]. The fundamental cause is the occurrence of serious monsoon rainfall as well as the resultant huge concentration of run-off, which exceeds river systems [5-6].

Accelerated urbanization within the city river catchments also have served to increase the problem with greater run-off as well as damaged river capacity which have resulted in accelerated flood frequency and degree. Activities of the urban areas are leading to a growing number of urban areas becoming more responsive to brief period with higher intensity rainfall leading to flash flood (2 to 5 hours) [2]. With serious rain between 2000mm to 3000mm annually, flash floods are among the most typical threats after monsoon floods [2]. The hazard contributed a lot hindrance to the livelihood of the urban people; in several incidents houses were inundated and people were compelled to vacate. Moreover, traffic flows were interrupted and occasionally, certain lives were lost as a result of drowning.

Hence, the main objective of this paper is to identify the actual factors referred herein as natural flood influencing factors because there is an ultimate need to identify those factors in order to be able to detect the actual flood susceptible areas and risk areas within the study area by utilizing GIS-based Multi-Criteria Decision Analysis technique.

II. GIS AND MULTI-CRITERIA DECISION ANALYSIS

Since GIS-based Multi-Criteria Decision Analysis (MCDA) became one of the most helpful techniques for spatial planning and management [7, 8] the request for tools aiding collaborative decisions has risen over the past ten years [8]. GIS could be used to support spatial decision-making since it offers awesome capabilities of handling spatial problems. Managing a complicated as well as numerous criteria problem without spatial analytical and visualization tools could be computationally challenging, or even unattainable, [9]. Methods of the MCDA being an independent tool have already been computerized to the extent that most software program could be accessed and utilized. Even though, it is uncommon that such type of software program to be capable of handling spatial problems in the form of maps.

There are two techniques: loose and tight, regarding integrating GIS together with MCDA methods, [10]. In the loose coupling, this will depends on a file swap mechanism which in turn provided an interface between the two kinds of software to communicate. Similarly, specific tasks are done in each of the softwares. In carrying out land suitability analysis, selecting a pair of criterions with their rankings so that the decision table could be exported directly into MCDA program, GIS is employed. The MCDA component is been utilized in carrying out the evaluation of the multi-criteria and the result is carried once more into the GIS environment for display. On the other hand, the tight coupling technique as an alternative is realized through a normal interface as well as database for GIS and MCDA.

Integrating GIS and MCDA is really a great method for land suitability evaluations [8]. In a nutshell, it signifies that; the multi-criteria evaluation capabilities are set into the GIS software which will consequently aid in executing tasks with much less difficulty. Therefore the advantage here is that all the required features are in place and challenging data trading is prevented. Generally, Multi-Criteria Evaluation (MCE) with regards to GIS can be carried out in two stages. Stage (i) field study and stage (ii) early site identification. In the initial stage, site is investigated for possible choices using deterministic decision criteria. What happens here is that, each of the locations that falls into the choices considered possessing unique criteria (constraints) altogether are stated and taken out from the analysis.

This particular stage is known as suitability analysis, normally conducted manually and referred to as a manual map overlay; the previous is modernized, that's the reason why these day there are GIS electronic maps. The second is, early site identification as the second stage is done by MCE methods. First and foremost, secondary locating elements are detailed as well as weighted based on their order of significance. Aforementioned stage enables dealing with several objective problems, [10-11]. The concept behind the multiple criteria overlay was initially recommended by reference [12] who suggested classifying the physical, economical as well as environmental criterions to assure social and economic feasibility of development.

Therefore, a GIS-based Multi-Criteria Evaluation flood susceptibility analysis/mapping will be proposed as this study is part of the on-going research taking place in Perlis State, Malaysia.

II. STUDY AREA

Perlis was basically selected as the study area based on a number of factors; a state in which flood happens substantially, suitable size of area to be examined, accessibility of data and cost of procuring the actual required satellite image. The coordinates of the study area are presented in Table 1 below:

TABLE 1: COORDINATES OF PERLIS

Coordinates	East	North
Top	100 07’ 02”	6 43’ 19”
Bottom	100 22’ 33”	6 15’ 13”

The state of Perlis is surrounded by Thailand in the north, Kedah in the south, whilst its western coastline is bordered by the Straits of Malacca. The weather, which is normally warm and wet, is actually controlled by the yearly fluctuations in position of the Inter Tropical Convergence Zone since it follows the obvious movement of the sun north and south of the equator. This results in two distinct rainy periods, and a prolonged drought period. It experiences a Monsoon Tropical climate and "Winter Winds" (East Coast Wind from Teluk Siam).

IV. THE NATURAL FLOOD INFLUENCING FACTORS

Flood basically depends on some influencing factors for it to occur. Amongst these influencing factors are the natural factors such as land use, drainage density (rivers and canals), geology, soil type, topography (elevation and slope) and amount of rainfall, runoff, and infiltration [13]. These factors below have been identified as relevant ancillary data or supporting data required to support the GIS analysis to be carried out.

A. Influence of Rainfall on Flood

Rainfall is the key source to many hydrological systems, and the primary concern for hydrological science and practice is to evaluate the significance of the spatial structure of rainfall along with its representation in the flood run-off creation. Rainfall input is the primary factor affecting the degree of the run-off responses during the flood occurrence. It's temporal as well as spatial distribution adds up substantially to the generation of hydrograph sizes and shapes, optimum discharge, and also inundation volume. Measurements of rainfall are made using a rainfall gauge, comprising an exterior and interior cylinder, through which rainwater is amassed via a funnel and decanted into a measuring decanter or glass.

In Perlis the rainfall has peaks during both the post-equinoctial transition periods between the monsoons. The two periods of rainfall are associated with the advance and retreat of the south-west monsoon, in April–May and September–October. The latter period produces greater depths of rainfall which immensely causes flood to occur tremendously. The annual range of the temperature is from 21^{o}C to 32^{o}C while the mean annual rainfall is between 2000mm to 3000 mm respectively. Figure 1 illustrates the 14 4ainfall stations in Perlis State, Malaysia.

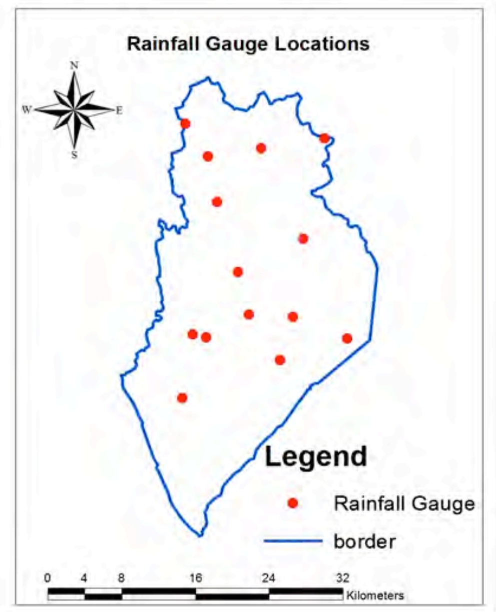

Figure 1: Rainfall Gauge Locations of Perlis

B. Influence of Land Use on Flood

Land use is a human being action greatly associated with farming as well as water availability. The types of land use might rely on a number of factors, like soil type, rainfall, topography and accessibility. In Perlis a substantial part of the state is covered by agricultural crops such as rubber plantations, sugar cane plantations and paddy. Paddy covers a significant portion of Perlis particularly in the southern as well as central Perlis. This very portion constitutes a clay soil, which has fewer pore spaces, being impermeable, and in turn worsens the flood runoff responses. Sugar cane is planted in north-eastern area while rubber is mainly in the northern regions. Regions of human settlements as well as forest reserves form a relatively small part of the state. Forested areas are mostly found in the northern and western Perlis, bordering with Thailand.

A major water body is the Timah Tasuh Dam and reservoir, while rivers and several small lakes could also contribute towards flooding in this area. Hence, the main variations in land use affecting hydrology and results in flood are afforestation, deforestation, intensification of agriculture, drainage systems, roads construction, as well as urbanization. Also the most apparent impact of land use on the water stability associated with a catchment is on evapotranspiration process [14]. This is because several types of land uses possess different evapotranspiration rate; for instance different plants have different vegetation covers, leaf area indices, root depths, and albedo. Consequently, during stormy weather the interception rate of various land uses varies. Land use equally influences the infiltration as well as soil water distribution process particularly saturated hydraulic conductivity is influenced by plant root and tiny holes caused by soil fauna [15]. Figure 2 below illustrates the various land uses of Perlis. This was generated using the Erdas Imagine 8.6 by processing the SPOT satellite image of Perlis through satellite image reclassification to the coordinate system and image classification using unsupervised classification. Finally, the satellite image that had been utilized through the classification process now had to be processed using ArcGIS 9.3 software to create the land use map.

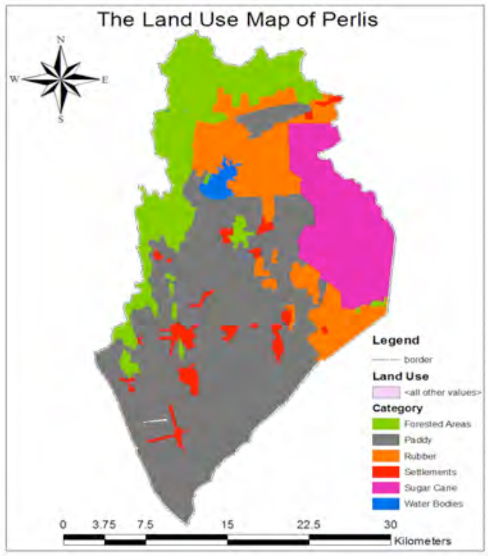

Figure 2: Land Use Map of Perlis

C. Influence of Geology on Flood

As shown in figure 3 on the geology map of Perlis, alluvium covers a huge area of the central and southern regions of the state. This alluvium comprises unconsolidated sediments like sand as well as gravel. Paddy covers a significant part of the alluvium lying parts. Also, alluvium happens to be low-lying and can at least moderately become inundated during intense event; perhaps even the thin alluvium tracts connected with smaller tributary valley could be susceptible to flash-flood. The Kubang Pasu- Singa formation, which is made up of shale, mudstone, siltstone, flagstone, sub-greywacke, greywacke and quartzite covers most of the northern together with central areas. There are actually two distinct limestone formations namely: the Chuping limestone that makes up the central spine within the Kubang Pasu- Singa formation, as well as the Setul limestone which is obtained in western Perlis bordering Thailand. The Bukit Arang formation which is actually a formation of semi-consolidated clays, sands and gravels along with some thin coal seams and oil shales are obtained only in the north-eastern region. Whilst a minute outcrop of granite is obtainable at the northern tip of Perlis bordering Thailand. Consequently, flooding coming from rivers occurs across most of these natural landforms which have a characteristic geomorphology together with geologic make-up. The related geological deposits present an important clue in pinpointing exactly where flood has took place previously and accentuate other methods of forecasting exactly where flood would likely take place in the near future. On a catchment's level, the ability of the ground surface to soak up water is proportional to the hidden geology. For example, clay-rich stones as well as other quaternary deposits are impenetrable. Hence, these kinds of geological landscapes will probably be susceptible to high-speed run-off, increasing the likelihood of severe flooding downstream in the course of excessive rainfall incidents.

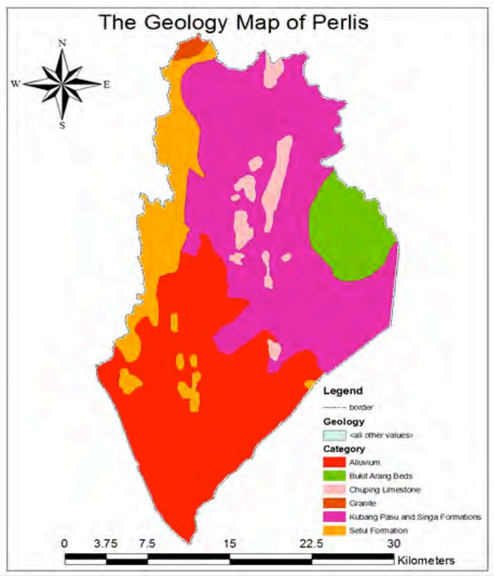

Figure 3: Geology Map of Perlis

D. *Influence of Soil on Flood*

Soils are generally connected with sedimentary origin, certainly not cemented, free to compact, and are also not tremendously compacted. A sizable majority of soils are made up of inorganic nutrient particles, organic matters, and also rock particles along with water and air. Soil is made as a result of weathering process on rocks, that has occurred more than millions of years and years. This particular weathering process is mainly responsible in its physical structure as well as chemical make up. Soils which have greater particle shapes are usually consist of sand predominant particles: as a result made up of strong minerals like quartz tourmaline together with feldspars. These particles are usually quite circular thus giving the soil high durability, density, as well as permeability. Conversely, soils having tinier particles are usually consists of clay minerals: thus with attributes of very poor durability, low density, as well as impermeable, which in turn adds up considerably to the degree of runoff responses during the course of intense occurrences of flooding. Clay soils generally displays plasticity; is readily remoulded whenever wet and contains an extremely substantial strength once completely dried up. The soil classification of Perlis is basically based on four main categories as illustrated in figure 4; namely:

i. Lithosols and shallow latosol on steep mountainous and hilly lands are considered unsuitable for extensive agricultural development.
ii. Low humid clay soils, being moderately and poorly drained soils developed over coastal plains and the valleys of floodplains of the larger rivers, of very variable fertility.
iii. Red and yellow latosol and red and yellow podzolic soils on flat, gently and strongly sloping land, mostly below average to average fertility developed over raised terraces and platforms of older alluvium and sub-recent alluvium.
iv. Red and yellow latosol and red and yellow podzolic soils on gently to strongly sloping land of variable fertility derived from variety of sedimentary rocks.

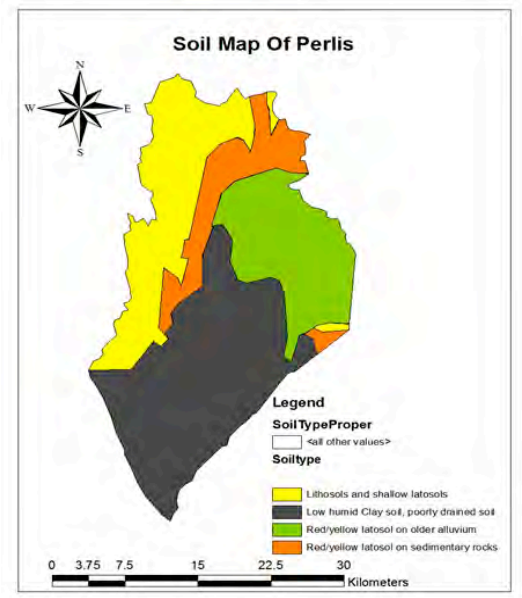

Figure 4: Soil Map of Perlis

E. *Influence of Drainage Density on Flood*

Drainage in the study area consists of rivers and irrigation canals. The distribution of drainage density is really a likely factor when it comes to identifying flood susceptible areas. River run-off is often as the result of several discharge events. In almost any river discharge there'll be a subsurface component along with a floor water component of river flow. Water may possibly runoff upland regions and gets penetrated in lowland areas at the outset of a storm, and keeps on till infiltration areas commence to receive water at a quicker rate than they can tolerate. Runoffs after that occur at this point. Therefore, drainage density was defined by reference [16] as the percentage of the overall length of streams inside a watershed over its own contributing region. It explained the degree of drainage system development and was identified by a lot of authors being substantially effective on the generation of flood flows. Drainage in the study area of Perlis consists of rivers and irrigation canals. The distribution of drainage density is a potential factor in determining flood susceptible areas. Figure 5 illustrates how settlements are situated or developed on natural drainage systems, which might put the populace living in these settlements into jeopardy whenever flood occur. So, this demonstrates the level of risk as well as susceptibility in which these particular settlers are into.

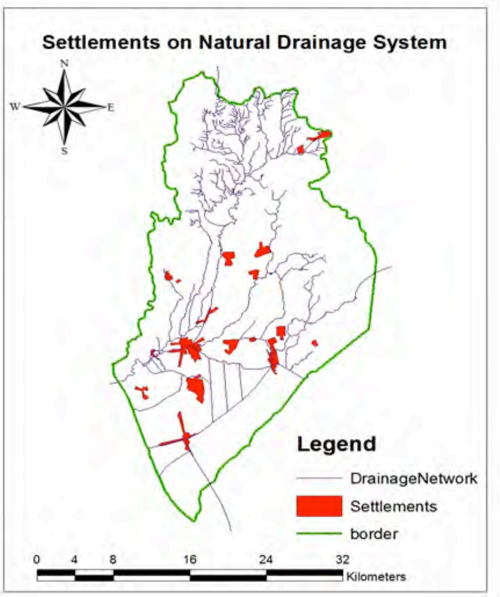

Figure 5: Drainage Density of Perlis

F. Influence of Topography on Flood

Topography as well as the stage of geomorphic development are essential elements influencing the development of a truly extensive weathered layer. Hence topography, its slope steepness as well as elevation is really a consideration in identifying regions which are most likely to be susceptible to flooding. For example a steep-sided channel or perhaps a river channel surrounded by steep slopes leads to quick surface area run-off. Furthermore, because of undulations within surface elevation, water within soils will certainly occur under different hydraulic potentials from wherever it begins to drain or flow. Such various hydraulic potential can also be referred to as pressure head or hydraulic gradient, which is the water pressure that causes the actual flow of water in soil as a result of the difference in water table or hydraulic potential.

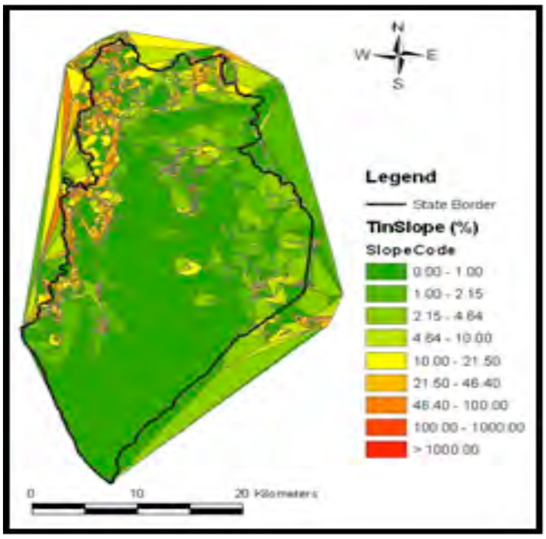

Figure 6: Slope Steepness in Perlis

V. SUMMARY AND FURTHER RESEARCH

In the expectation of main research, this conceptual paper has planned to go on with the research. The current situation of flood occurrence in the study area presents a quite different challenges based on the residents outcry; in which some of the residents houses were flooded and properties were intensively damaged. So far some data has been obtained through an extensive literature review to aid the researchers in identifying the actual factors influencing flood in the study area. Moreover, the geology map, soil map, land use map, drainage map, and rainfall gauge locations information were currently obtained, scanned, transferred into GIS software and digitized. The required spatial data layers of the area for criterions evaluation and assignment of weights based on the study criterions were obtained. By way of making an evidence base, there has been no published literature with respect to detailed examination of the current flood situation in the study area and no any flood GIS data in relation to the spatial datasets of the study area. Moreover, there is no any published comprehensive framework that identified the flood influencing factors of the study area. Therefore, this paper is part of on-going research aimed at identifying the flood influencing factors and detecting flood susceptible areas in Perlis. The proposed conceptual paper will provide a holistic guidance on how criteria for the detection of flood susceptible areas in the study area can be generated. More so, it will as well depicts how GIS and Multi-criteria Decision Making can be integrated in creating the required datasets and attaining at a better decision based on the criterions evaluation. This will enable the responsible authorities in Perlis to acquire the GIS data which is currently deficient; all the available data are in hardcopy not in GIS soft-copy format.

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