

Mapping land slide occurrence zones using Remote Sensing and GIS techniques in Kelantan state, Malaysia

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Abstract. Integration of satellite remote sensing data and Geographic Information System (GIS) techniques is one of the most applicable approach for landslide mapping and identification of high potential risk and susceptible zones in tropical environments. Yearly, several landslides occur during heavy monsoon rainfall in Kelantan river basin, Peninsular Malaysia. In this investigation, Landsat-8 and Phased Array type L-band Synthetic Aperture Radar-2 (PALSAR-2) remote sensing data sets were integrated with GIS analysis for detect, map and characterize landslide occurrences during December 2014 flooding period in the Kelantan river basin. Landslides were determined by tracking changes in vegetation pixel data using Landsat-8 images that acquired before and after December 2014 flooding for the study area. The PALSAR-2 data were used for mapping of major geological structures and detailed characterizations of lineaments in the state of Kelantan. Analytical Hierarchy Process (AHP) approach was used for landslide susceptibility mapping. Several factors such as slope, aspect, soil, lithology, Normalized Difference Vegetation Index (NDVI), land cover, distance to drainage, precipitation, distance to fault, and distance to road were extracted from remote sensing satellite data and fieldwork to apply AHP approach. Two main outputs of this study were landslide inventory occurrences map during 2014 flooding episode and landslide susceptibility map for entire the Kelantan state. Modelled/predicted landslides with susceptible map generated prior and post flood episode, confirmed that intense rainfall in the Kelantan have contributed to weightage of numerous landslides with various sizes. It is concluded that precipitation is the most influential factor that bare to landslide event.

1. Introduction

Remote sensing imagery can play an important role for production of landslide inventory map and generation of thematic maps related to landslide occurrences in a region at both regional and district scales. Integration of GIS techniques with remote sensing imagery is a very effective method for potential landslide mapping and geological structural analysis especially in tropical environments [1,2,3].

Landslide and flooding are the most common geohazards leading to economic losses and death in Southeast Asia during the last few decades [4]. Natural force is one of the main reasons of their occurrences, followed by human interruption to the environment such as ‘cut-and-fill’ the hillside, mineral reserve exploitation and deforestation. Landslide hazard assessment and risk reduction can be accomplished by providing the accurate information using satellite remote sensing data and GIS analysis for risk management, which is urgent need to access easily and continuously on the landslide occurrence zones [5]. Thus, landslide susceptibility mapping after natural disaster such as flood episode, using recently launched satellite remote sensing data can provide important information for the majority of users in public and private sectors, government agencies and the scientific communities at the local and international levels.



In this investigation, multitemporal Landsat-8, the Phased Array type L-band Synthetic Aperture Radar-2 (PALSAR-2) data and GIS techniques were integrated to detect and map landslide occurrence zones in the Kelantan state following by massive rainfall during December 2014.

2. Materials and Methods

2.1 Geology of the study area

The state of Kelantan is located in the north-eastern corner of Peninsular Malaysia (Fig. 1). A wide variety of rocks consisting of igneous, sedimentary and metamorphic rocks are distributed in a north-south trend in the Kelantan state. Typically, four types of rocks are classified in the region, including granitic rocks, sedimentary/metasedimentary rocks, extrusive rocks (volcanic rocks) and unconsolidated sediments [1,2]. Two distinct wet seasons from September to December and February to May are reported by Malaysian Meteorological Department (MMD) in Peninsular Malaysia [6].

2.2 Remote sensing data and GIS techniques

Two level 1T (terrain-corrected) Landsat-8 OLI images were obtained through the US Geological Survey Earth Resources Observation and Science Center (<http://earthexplorer.usgs.gov>). The image data (Path/Row 127/56) were acquired on December 5, 2014 (before the flooding event) and 11 March 2015 (after the flooding event) with low cloud cover. The image data cover four river basins in Kelantan, including Sungai Golok (103,918.37 hectares), Sungai Kelantan (1,308,690.95 hectares), Sungai Kemasin (30,927.82 hectares) and Sungai Semerak (59,076.48 hectares) (Fig. 1).

A ScanSAR mode dual polarization (level 3.1; acquired on 6 February 2015) and two Fine mode dual polarization (level 3.1; acquired on 6 February 2015) PALSAR-2 scenes were obtained from ALOS-2 data distribution consortium online system Remote Sensing Technology Center of Japan (RESTEC).

In this investigation, Analytical Hierarchy Process (AHP) approach was used for Landslide Susceptibility Mapping (LSM). The AHP is a multi-objective, multi-criteria decision-making approach that enables the user to arrive at a scale of preferences drawn from a set of alternatives [7]. In this investigation for applying AHP approach, 10 factors such as slope, aspect, soil, lithology, NDVI, land cover, distance to drainage, precipitation, distance to fault, and distance to road were extracted from Landsat-8 images, PALSAR data and fieldwork as shown in Figure 2. Figure 3 shows methodology flowchart to produce LSM by using AHP GIS-based statistical models in this study.

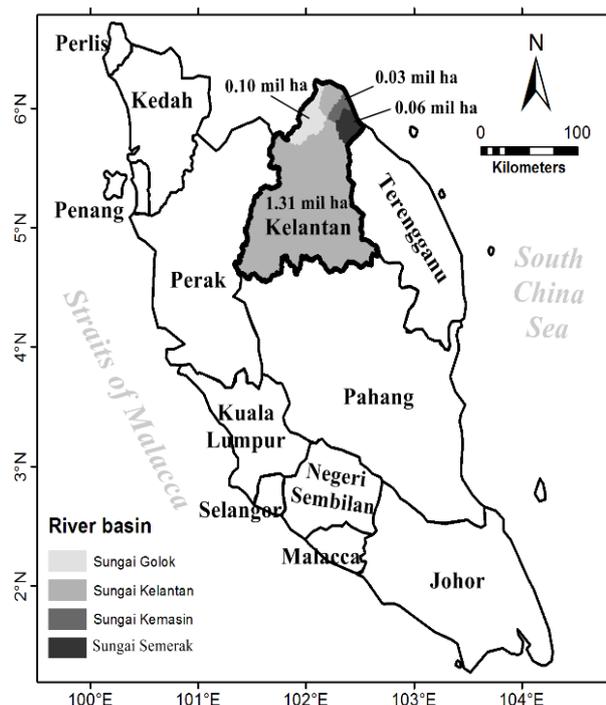


Figure 1. Location of the Kelantan state in Peninsular Malaysia. Major river basins were delineated in the image

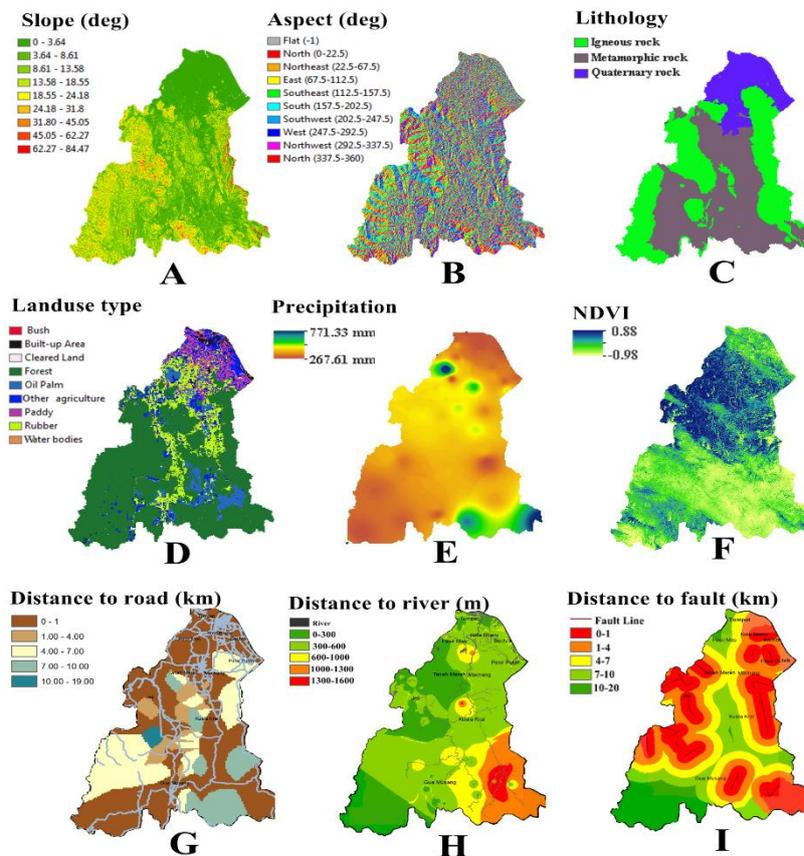


Figure 2. List of extracted factors from from Landsat-8, PALSAR, and fieldwork. A: Slope (degree), B: Aspect (degree), C: Lithology types, D:Landuse type, E:Precipitation (mm), F: NDVI, G: Distance to main road, H: Distance to main river (m), and I: Distance to fault line (km)

3. Results and discussion

A total of 36 landslides exceed 900 m² in size were identified and verified in the field. All 36 points has experienced the changes of NDVI from value of NDVI range for vegetation (> 0.50-1.0) to the NDVI range for bare soil (> 0.10 to 0.35). Statistic of landslide occurred on different types of land use shows that large landslides is most common in forestry areas (26 out of 36 identified), especially in the central part of the Kelantan and riverbank of the Sungai Kelantan. Active illegal logging may cause an increase of landslide occurrence during the rainy season. A total of 416 small and medium sizes of landslides that less than 900m² had been recorded through field observation. GPS surveying was used to record all locations of landslides as well as a rough observation in the surrounding area to assemble other supporting information. Based on the identified landslide distribution after December 2014 flood episode in the Kelantan, it indicates that the Gua Musang has the highest number of small landslides, mostly occurred in semi-sloping hill and along the roadside and the riverside. The similar observation was made in the Kuala Krai.

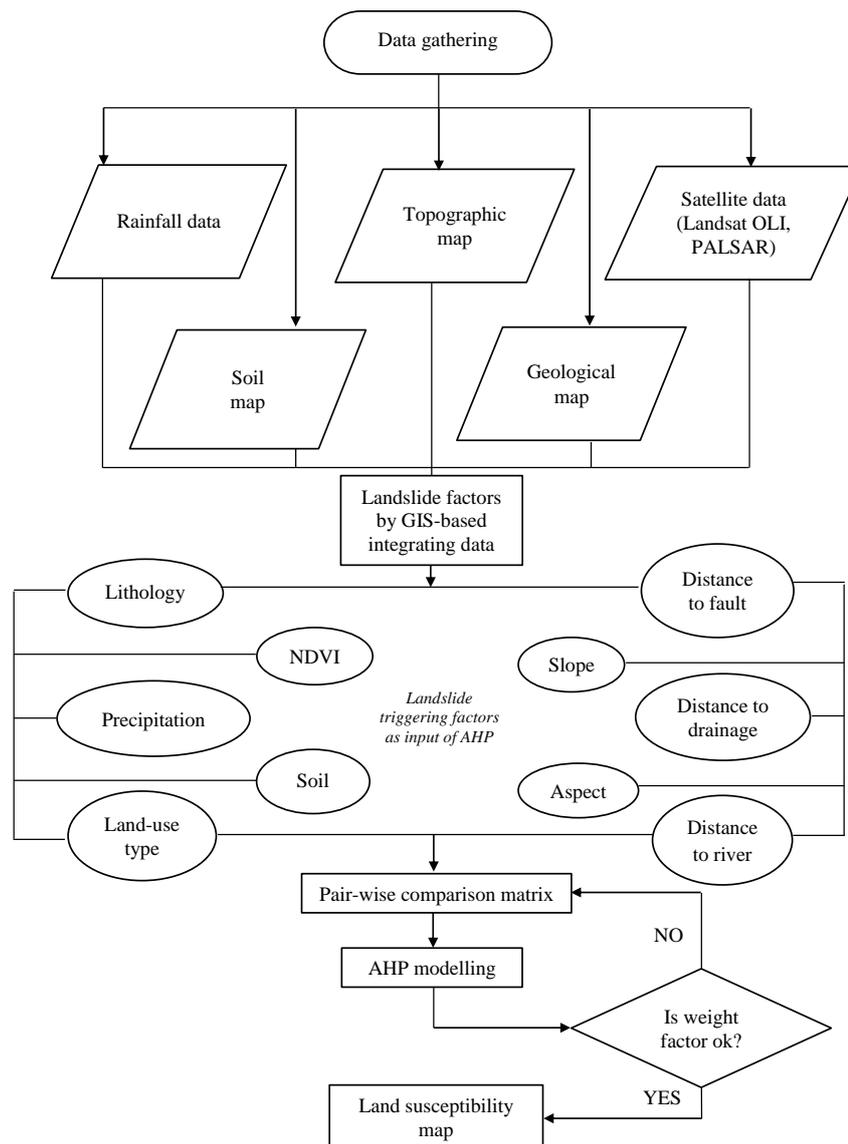


Figure 3. Methodology flowchart to produce landslide susceptibility map using AHP approach

Figure 4 shows the spatial distribution of landslide susceptibility map of each class extracted from the AHP approach during and before December 2014 flood episode in the Kelantan. Five classes category was used to indicate susceptibility of the area prone to landslide occurrences, including low risk (LR), fair risk (FR), moderate risk (MR), high risk (HR) and very high risk (VHR). Matrix of AHP category shifting before and after December 2014 flood episode is shown in Table 1. Landslide Susceptibility Maps (LSM) for before and during December 2014 flood episode was produced using related factors contributed to landslides event in Kelantan state (Fig. 5).

In overall, the number of landslides consisting of large and small size is 452. About 36.7% occurred in the area of rubber plantation area, while 34.3% occurred in forest areas. Location of landslides occurrences at different land use/cover type in the Kelantan is shown in Figure 6. Forest is the dominant land use/cover in the Kelantan besides rubber and oil palm. Young rubber trees that typically planted on a hillside are proved to be a triggering factor for increment of the risk of landslides occurrences. The study found that mature rubber areas have less risk of landslides compared to young rubber. Even the number of lower debris avalanche occurred in the forest than in the area of rubber cultivation, but the size of the landslide in the rubber is smaller than in the forest. Observing the scene showed that cleared the forest in a secluded place mostly experienced large landslide for horizontal and vertical dimensions.

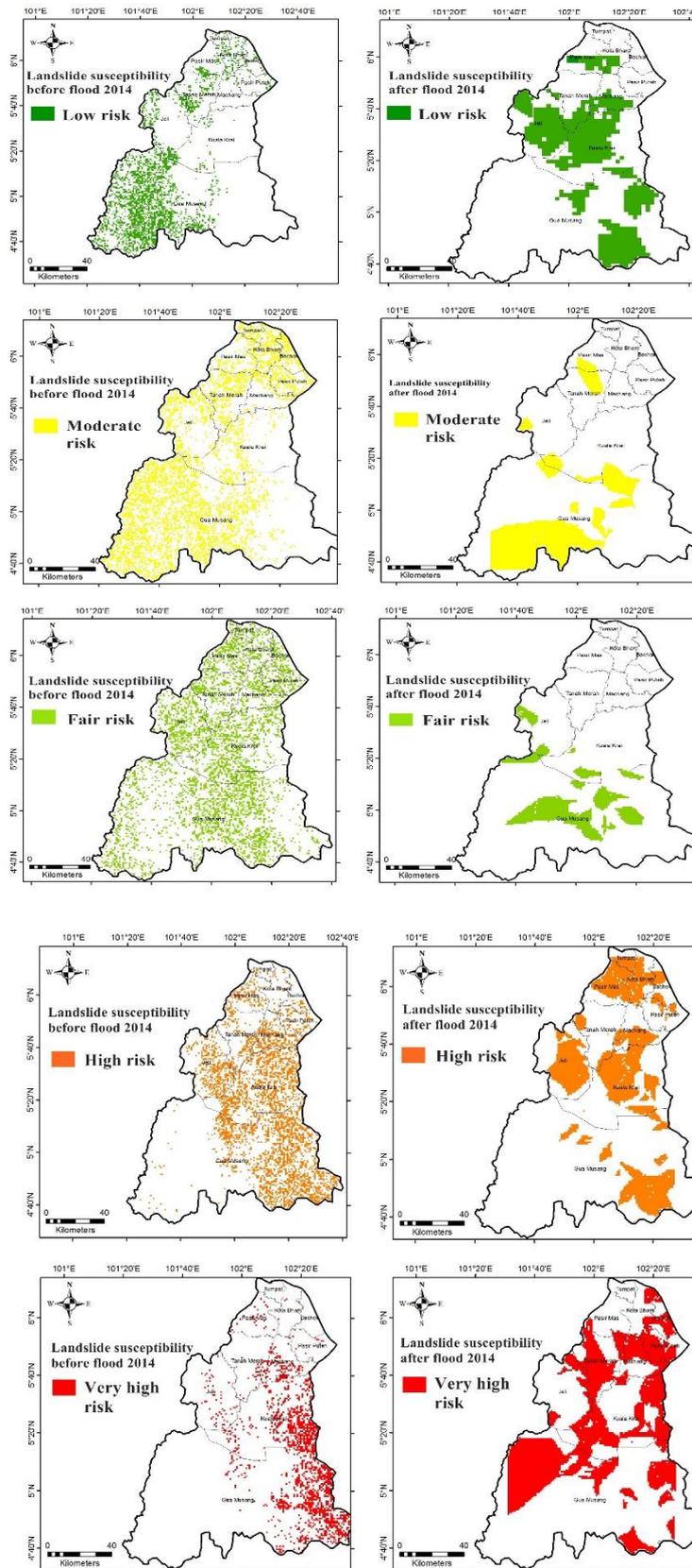


Figure 4. Spatial distribution of landslide susceptibility map of each class before and after flood episode in Kelantan 2014

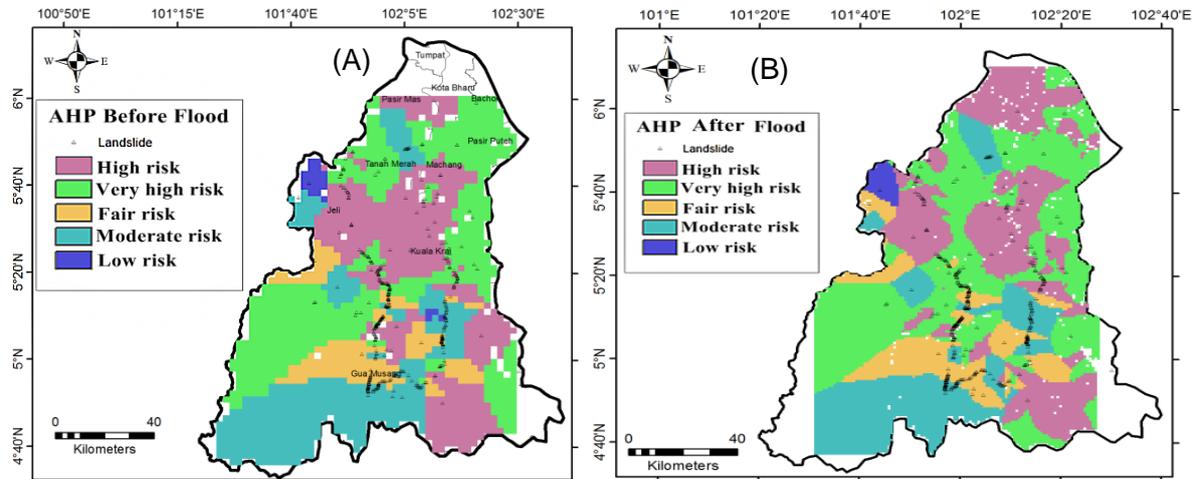


Figure 5. LSM before (A) and after (B) 2014 flooding episode in Kelantan state

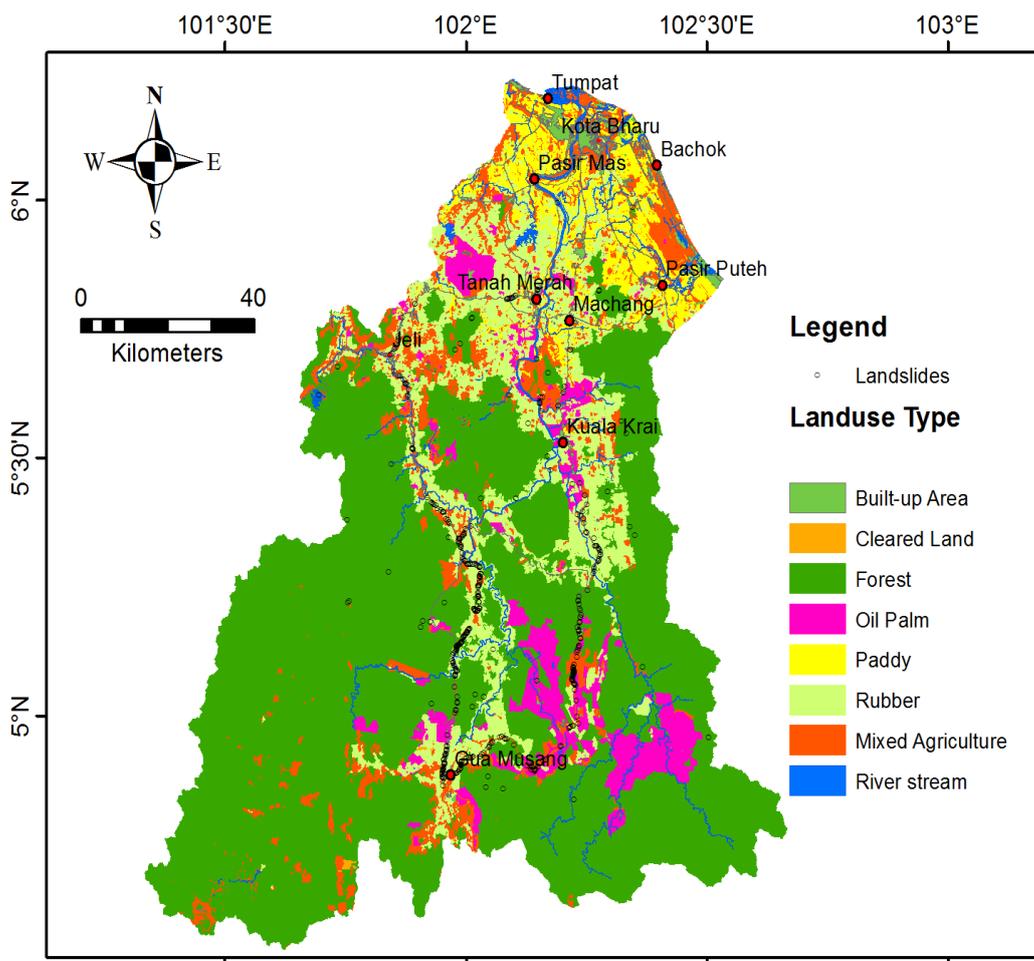


Figure 6. Landslides occurrences at different land use type in Kelantan state

Table 1. Matrix of AHP category shifting before and after flood episode

Before/After	LR	MR	FR	HR	VHR	Total (before)
LR	523	441	300	821	207	2292
MR	634	1314	216	982	520	3666
FR	576	105	1179	37	1736	3633
HR	238	100	57	2066	795	3256
VHR	200	81	105	49	1073	1508
Total (after)	2171	2041	1857	3955	4331	14355

4. Conclusion

This investigation indicate that the integration of satellite remote sensing data and GIS techniques is a applicable approach for landslide mapping and assessment in highly vegetated regions with tropical climate. Successful findings were achieved by combination of different sources of satellite remote sensing data and AHP approach using the 10 factors for landslide susceptibility mapping. Precipitation is the prime factor causing slope failure in the Kelantan state, followed by slope and distance to river factor, referred to weighting factor given by AHP with 0.5745 consistency ratio (CR). Based on the rainfall anomaly assessment, the 300mm precipitation in three days would trigger >15 landslides to occur. From the results, further action can be taken by relevant agencies of the Kelantan state to minimize flood impact to local residents in the future flooding event.

Acknowledgments

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