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Landslide Assessment Using Normalized Difference Vegetation Index (NDVI) Technique in Sentong, Lojing, Kelantan, Malaysia

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Abstract

The study area is a part of Lojing and it is lies between latitude 4° 45' 30" N – 4° 49' 0" N and longitude 101° 45' 30" E – 101° 48' 30"E. This study was focused on assessing of vulnerable locations of landslide based on satellite imageries of different years (2006, 2014 and 2015) which selected for visual interpretation and vegetation indices (VIs). As a result, there were 18 locations of landslide determined which landslide had occurred. With the aid of historical satellite imagery and the obtained quantitative data, the areas for landslide occurred were detected. Besides, the approach of remote sensing technique in landslide assessment was defined in terms of the early precautions for landslides, thus, the lost from landsides can be reduced. Furthermore, the condition of existing landslide areas was monitored by referring to the satellite imagery. This study can helpful to develop the inhabitant of the area and as well as to improve the poverty eradication.

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1. Introduction

Aurelio (2004) stated that earthquake, mass movement and volcanic hazard are the groups of geological hazard. Landslide is a most common geologic hazard. Landslide is the mass movement of surface materials in a down slope displacement under the gravitational force (Smith and Petley, 2009). These mass movements are responsible for a large amount of damages. According to Highland et al. (2008), the rapid movements kill greatest number of life while the slower movements cause significant economic losses and long term costs. Most mass movements are triggered by natural process, such as earthquake and intense rainfall. However, human activity also plays a role in the causation and triggering of mass movement. For example, some of the most damaging landslides occurred in the materials formed by human activities such as mining waste, fill or garbage.

The value of losses that associated with landslide has probably under estimated since most mass movements occur in rural area or mountainous environments are rarely reported. In urban area, the development of land use has enhanced the possibility of landslides occur. Besides, the changes in climate may result the higher frequency of landslides occur in future. Therefore, a responsible planning is needed to predict the potential areas for landslides occur and determine the major factors that initialize landslide failure.

In Malaysia, large-scale landslides are still existed; and they are mainly gravity-induced coupled with heavy and prolonged rainfall. A scenario of large-scale landslide hazards identification and disaster risks mitigation measures from some case studies in Malaysia namely Kundasang Sabah, Teluk Datai Langkawi, and Gunung Pass Perak. The Kundasang area as a whole is sited on a large-scale landslide complex. The "Kundasang Landslide Complex" consisted of a number of km-scale, active, landslide systems and it has been identified as the first natural large-scale landslide phenomena ever reported in Malaysia (Komoo, et al. 2005).

Lojing is located at the east coast of Peninsular Malaysia, thus the monthly rainfalls are fluctuating along the whole year. Table 1 shows the amount of rainfall distribution in Lojing, Kelantan from 2005 to 2014 in the unit of mm. Year 2011 shows the highest amount of rainfall while 2005 shows the lowest amount of rainfall. There are several tools available for monitoring geomorphological change and landslide movements. According to Franklin (1984), inclinometer, tiltmeters, extensometers and land surveying devices are the traditional instruments. While the modern tools include Global Positioning System (GPS) and remote sensing techniques such as satellite imagery.

According to Mantovani et. al. (1996), the present satellite image data can be compared to the historical satellite imagery data to assess landslide conditions over different periods of time and to examine progressive development. In this research, satellite imagery was used to determine the locations of landslide assessment. Satellite imagery is the basic resource for this research to be carried out. The application of satellite imagery to landslide assessment has brought some distinct benefits. By using satellite imagery, the relationships between the various

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landscape elements are more obvious than from ground perspective in the study area. Besides, satellite imagery can support the planning of site investigation efficiently without the need of site visit to the field, especially in inaccessible areas.

Table 1: Amount of rainfall in Lojing, 2005-2014 (in mm)

Month Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	**Total**
2005	0.0	15.5	97.5	150.6	-	-	-	-	6.0	27.5	0.0	0.0	**297.0**
2006	-	-	-	-	101.5	148.5	68.0	64.0	-	-	58.0	325.5	**765.5**
2007	357.5	66.0	0.0	-	-	-	-	-	-	-	-	-	**423.5**
2008	0.5	120.0	513.5	67.5	0.0	52.5	321.0	207.5	82.0	-	201.0	303.0	**1868.5**
2009	294.0	167.0	224.0	158.0	195.0	84.5	177.5	191.0	124.5	236.0	365.0	85.5	**2302.0**
2010	161.0	75.5	146.0	358.5	199.5	151.0	239.0	317.5	527.0	56.0	425.0	256.0	**2912.0**
2011	549.5	150.3	347.2	215.5	237.0	147.0	104.5	293.5	199.5	315.5	467.5	614.5	**3677.5**
2012	333.5	322.0	350.5	276.6	116.5	87.0	132.5	109.5	108.0	291.5	382.0	375.5	**2883.0**
2013	220.0	301.5	216.0	273.0	235.0	80.0	94.0	148.5	163.0	206.0	337.0	349.5	**2623.5**
2014	227.5	23.0	160.5	309.0	274.5	144.0	40.0	256.0	309.5	387.0	316.5	706.5	**3204.0**

2. Materials and Methods

2.1. Satellite Imagery Analysis

The flowchart of satellite imagery analysis was shown in Figure 1. Firstly, selecting and obtaining the suitable satellite images from different years (LANDSAT 7 and LANDSAT 8). Next, selected satellite images went through image correction also known as pre-processing correction to filter and remove cloud cover and atmospheric noises in the aim of enhancing the accuracy of images.

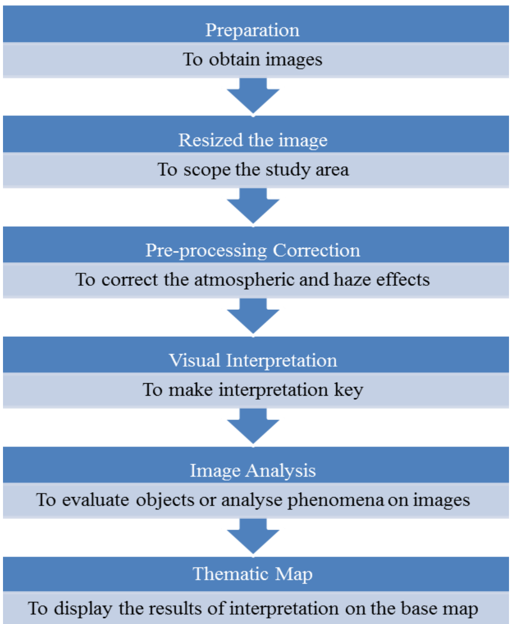

Figure 1: Flowchart of satellite imagery data processing

After that, proceed to visual interpretation which the landslide locations were spotted by comparing the image of before and after landslide occurred. Then, entered the equations of the chose vegetation indices (VIs) into the band math in the aim to compare and analysed the targeted locations from the images of different years. Next, evaluated and interpreted the data which were obtained from the VIs analysis to determine the topographic changes and to prove that the existing of landslide in those spotted locations. After that, the accuracy of the satellite imagery data was defined when comparing with the ground true values. Lastly, a map which shows the locations of landslide is produced.

2.2. Visual Interpretation

Based on the visual interpretation between the satellite imagery of 2006 with 2014 and 2015 respectively, there were few locations were targeted that landslide had happened. Figure 2 is the satellite imagery of 2006 which before landslides occurred while Figure 3 and Figure 4 are the satellite imagery after the occurrence of landslides during 2014 and 2015 respectively. There were 18 locations of total landslides were detected during the visual interpretation of satellite imagery between 2006 with 2014 and imagery between 2006 with 2015. In Figure 3, there are 13 locations of landslide spotted in 2014. For 2015, there are another 5 spots of landslide were recognized as shown in Figure 4. All these spotted landslide locations were analysed with the evidence of analysis and interpretation based on the Normalized Difference Vegetation Index (NDVI).

Figure 2: Satellite Imagery on 2006

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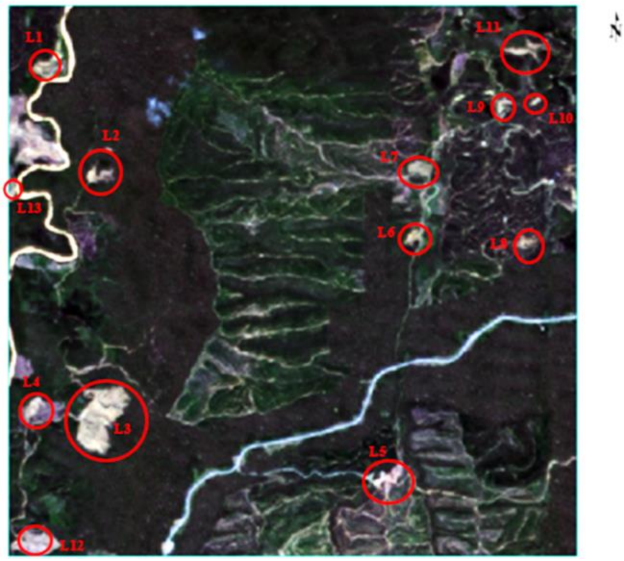

Figure 3: Satellite Imagery of 2014

Figure 4: Satellite Imagery of 2015

2.3. Normalized Difference Vegetation Index (NDVI) Analysis

Vegetation indices (VIs) are mathematical transformation that in ratios or linear combinations of the reflectance measurement in different spectral bands, especially the visible and near-infrared bands. In this study, vegetation indices use in image classification, to separate vegetated from non-vegetated areas. There are many vegetation indices have been proposed for determining the vegetation covers, ranging from very simple to very complex band combinations.The vegetation indices that commonly used is Normalized Difference Vegetation Index (NDVI). NDVI (Equation 1) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum and is adopted to analyse remote sensing measurements and assess whether the target being observed contains live green vegetation or not (Francesco et. al., 2014). It enables to eliminate topographic effects and variations in the sun illumination angle, as well as other atmospheric elements such as haze. Generally, NDVI values are represented as a ratio ranging in value from -1 to 1, values of 0.2-0.3 and values over or equal to 0.5 as stated in Table 2.

$$NDVI = (NIR - Red) / (NIR + Red) \quad \text{(Equation 2.1)}$$

From NDVI analysis, the spotted landslide locations were proven by comparing its values of different years. Based on Figure 5, there were significant changes of the landslide locations based on NDVI analysis between 2006 with 2014 and 2015 respectively. It also shows there was a change in the vegetation cover in each of the targeted landslide locations. The range of NDVI is between -1 to +1, where -0.5 to 0 indicates water body or wetland, less than 0.1 shows barren area of rock, sand or snow, between 0.2-0.3 refers grass and shrub while ≥ 0.5 describes temperate and tropical rainforest or thick vegetation cover.

Table 2: NDVI value (Source: Liu et. al., 2004)

NDVI value	Feature Description
-1 to 1	Type of land canopy which refers to the vegetation biomass ratio.
0.2-0.3	grass and shrub
over or equal to 0.5	dense green vegetation

Table 3: NDVI values for 2006, 2014 and 2015

LOCATION	COORDINATE	NDVI 2006	NDVI 2014	NDVI 2015
L1	4° 48’ 47.42” 101° 45’ 45.20”	0.523370	0.360953	0.404734
L2	4° 48’ 7.40” 101° 45’ 55.91”	0.495537	0.289856	0.562093
L3	4° 46’ 36.58’ 101° 45’ 57.14”	0.539508	0.237165	0.308148
L4	4° 46’ 47.86” 101° 45’ 34.87”	0.511258	0.321013	0.543543
L5	4° 46’ 25.28” 101° 47’ 34.40”	0.484671	0.121939	0.204436
L6	4° 47’ 46.18” 101° 47’ 44.48”	0.559748	0.393785	0.351962
L7	4° 48’ 0.71” 101° 47’ 40.56”	0.524263	0.319704	0.464496
L8	4° 47’ 43.87” 101° 48’ 18.89”	0.447748	0.264550	0.376596
L9	4° 48’ 30.93” 101° 48’ 13.59”	0.481125	0.281755	0.514671
L10	4° 48’ 31.73” 101° 48’ 24.70”	0.541794	0.388191	0.598940
L11	4° 48’ 48.24” 101° 48’ 21.72”	0.477832	0.392107	0.522732
L12	4° 46’ 3.11” 101° 45’ 41.80”	0.500724	0.276953	0.394713
L13	4° 48’ 0.53” 101° 45’ 28.25”	0.497912	0.259431	0.275578
L14	4° 47’ 13.47” 101° 45’ 41.77”	0.522421	0.802521	0.297494
L15	4° 48’ 15.19” 101° 45’ 34.23”	0.492535	0.237583	0.281979
L16	4° 47’ 0.55” 101° 47’ 37.10”	0.544518	0.830048	0.374246
L17	4° 47’ 10.55” 101° 48’ 0.02”	0.360344	0.740570	0.353220
L18	4° 46’ 28.27” 101° 46’ 43.49”	0.458204	0.501440	0.275755

Table 3 shows the NDVI values for 2006, 2014 and 2015; there is a decreasing trend in NDVI values for

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L1 until L13 and also L15 between 2006 and 2014. This shows that the existing vegetation covers have been removed due to the occurrence of landslides in these few locations. While for L14 and L16 to L18 which compared between 2006 and 2015 showed a sharp drop in the NDVI values. The significant changes in the NDVI values for all the targeted landslide locations had proved that there are landslide occurred during 2014 and 2015.

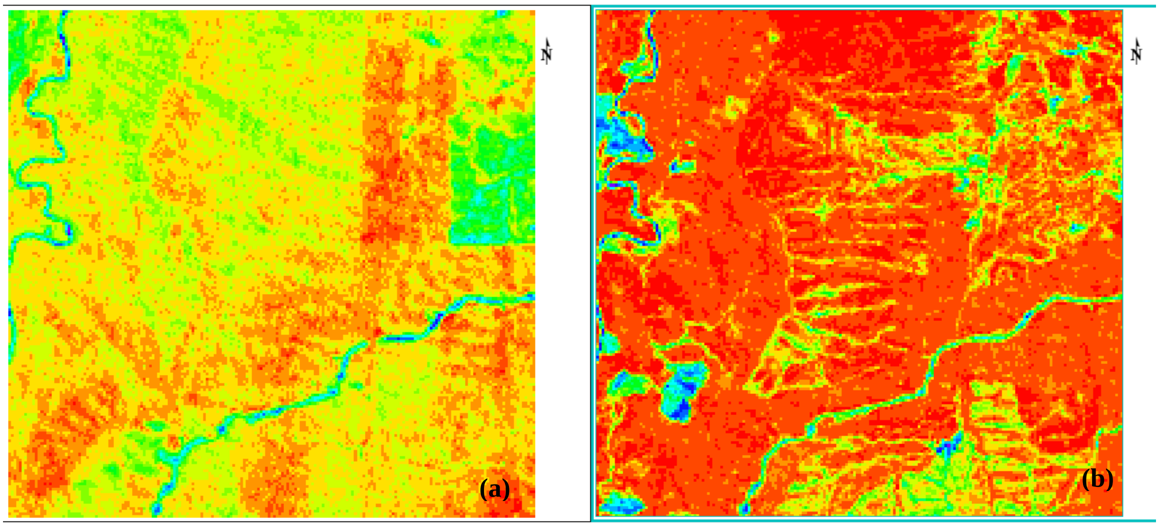

Figure 5: NDVI Analysis in Raster Colour (a):2006, (b) 2014

3. Results and Discussion

3.1. Topography

Topography basically refers to the elevation and relief of the Earth's surface and usually used to describes about the Earth's surface. Topography includes a variety of different features which known as landforms. The study area, Lojing is dominated by the topography of mountainous area. Figure 6 illustrates the contours in 3-dimension which indicates the landform.in the study area. The lowest elevation is 160 m while the highest value is 460 m.

3.2. Landslide Location Map

The determined landslide locations were marked on the base map of the study area, Sentong, Lojing as shown in Figure 7. The landslide locations were mostly located at the limestone area. The continuous rainfall was one of the factors that triggered landslide as the rising in water table. The landslide locations were found in the area with lower elevation as the direction of water flow was from the highland area to lowland area. Thus, the lowland areas were usually the water catchment area and when the water flowed from the area of higher elevation continuously and the rate of water infiltration in the lowland area had reached the limit, landslide occurred consequently.

Besides, the landslide locations were located close to or nearby the stream or river. The soil particles that nearby the stream and river were looser compared to those away from drainage system since the water table nearby the drainage system was shallower. The higher moisture content in the particles which weakening its resisting forces and thus, landslide happened when driving force was greater than its resisting force.

4. Conclusion

For the study of landslide assessment by using remote sensing technique, the landslide locations in the study area were determined and a thematic map was produced. Visual interpretation is one of the effective remote sensing techniques to extract information from satellite data. For this purpose, satellite data need to be visualised on a computer screen by Geographic Information System (GIS) software. Visual interpretation technique has been successfully applied in the study of monitoring landslide assessment. Multi-temporal images are widely used to measure the changes on surface, thus, quantify the morphological effects of the underlying processes.

The analysis of remote sensing imagery involves the identification of various targets in an image, and those targets may be environmental or artificial features which consist of points, lines or areas. A set of aspects to express the characteristics of an image were used when observing the differences between targets and the backgrounds from the image. These characteristics including tone, texture, shape, size, pattern, shadow, elevation and association are known as interpretation elements and as guidelines on objects recognition. Besides, there are some obstacles of using the satellite imagery for landslide assessment. The radiance and reflectance for each band of the imagery data must be corrected before extracting any data for the study. Thus, the quality of the output can be enhanced.

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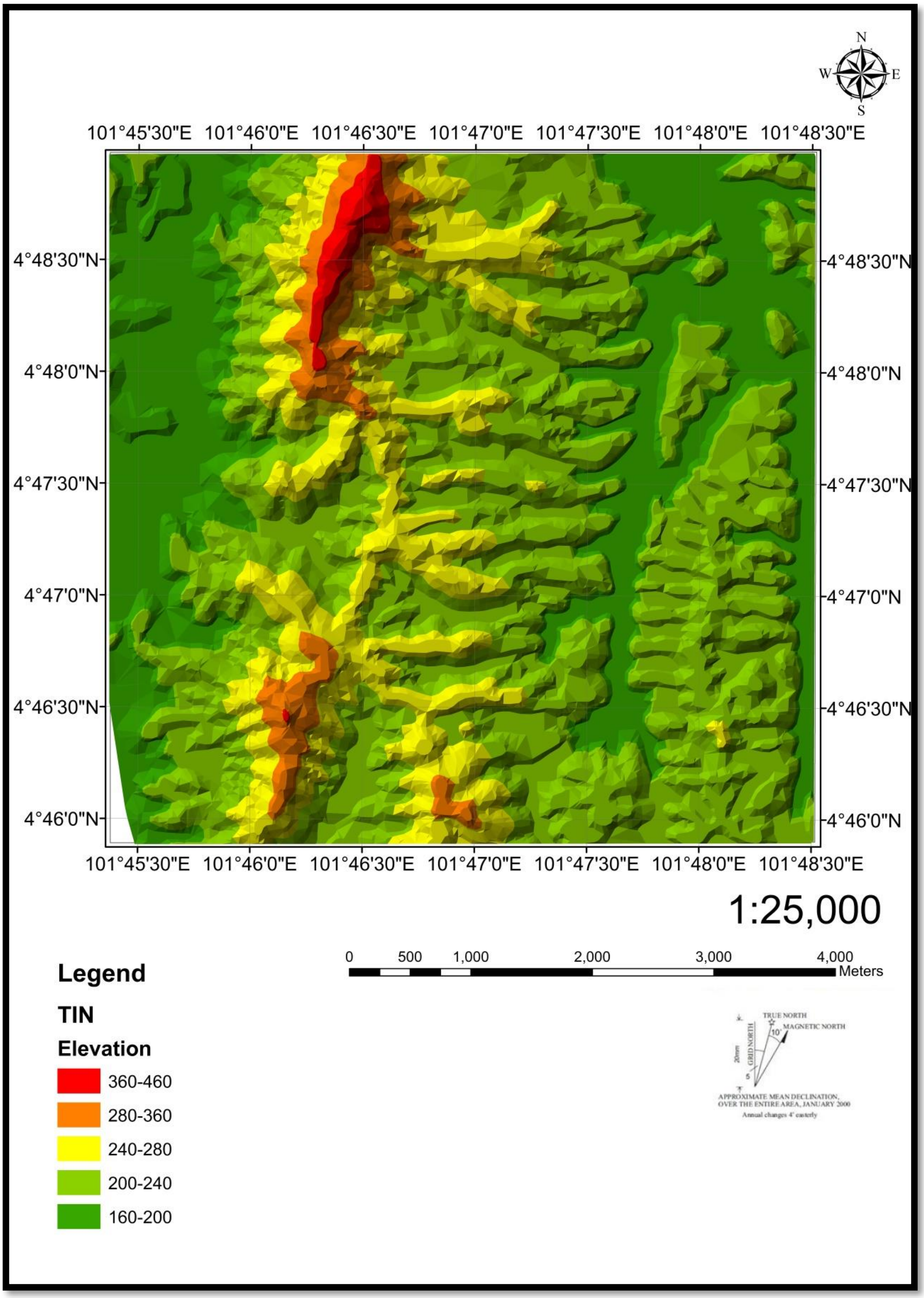

Figure 6: Contours in study area (in 3D form)

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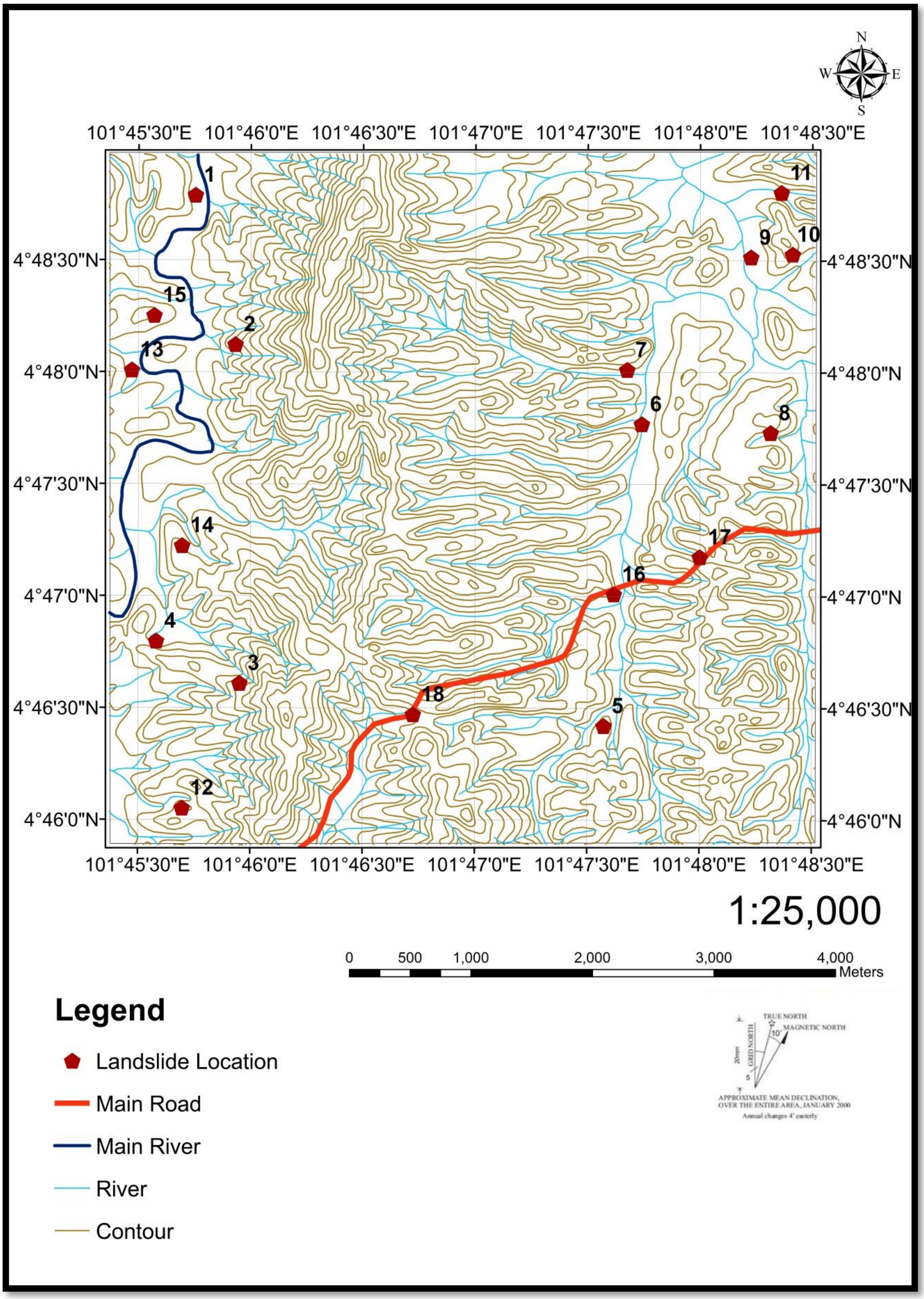

Figure 7: Landslide locations in the study area

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