Landslide Possibilities using Remote Sensing and Geographical Information System (GIS)

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Abstract. There are a lot of landslides occur in Malaysia and one of the landslide-prone areas in Malaysia is Ulu Kelang. Integration of satellite remote sensing data which is called ArcGIS software is one of the applicable software to detect the landslide mapping and identification of high landslide risk in a certain area. Since 1993, several landslides have been reported in Ulu Kelang, Malaysia. These landslides would cause the property damaged and economic losses. The landslides cause which are geological covering the aspect such as rainfall, hilly areas, highland areas, morphological, physical and human causes. These are the major role in inducing the landslides in the study area. The objective of this research is to analyse and validate the data of the soil moisture index (SMI), temperature index (LST) and water index (NDWI) from the remote sensing Landsat Images with the electronic tool devices. There are two methods for this research paper which are by using a remote sensing and a ground-based measurement. The remote sensing software is ArcGIS. The U.S Geological Survey, USGS in coordination with NASA operates and distributes data from Landsat satellites and provides access to the space-based land remote sensing data. The ground-based measurement method, the electronic tool devices are called as LCD Soil Tester Meter and Digital Temperature Humidity Time Display. These devices are to detect the moisture of the soil, calculate the surrounding’s temperature & humidity. Also, the rainfall data has been taken for supporting the water index information. The results of the three specified parameters; soil moisture, temperature and water index; SMI, LST and NDWI shown the more moisture of the soil, the more the tendency of the landslides to occur. This research founds out that the lower the temperature, the higher possibilities on occurrences of the landslides. While, the NDWI results are depends on the data rainfall. The higher the distribution of the rainfall leads the higher possibilities on the landslide’s occurrences.

1. Introduction

There are a lot of landslides that occur in Malaysia and one of the landslide-prone areas in Malaysia is Ulu Kelang. Integration of satellite remote sensing data which is called ArcGIS software is one of the applicable software to detect the landslide mapping and identification of high landslide risk in a certain area. Since 1993, several landslides have been reported in Ulu Kelang, Malaysia. These landslides would cause the property damaged and economic losses. The landslides cause which are geological covering the aspect such as rainfall, hilly areas, highland areas, morphological, physical and human causes. Soil moisture, the temperature of the surrounding and the water index were contributed to the landslide occurrences. The landslides can cause a serious threat to property damaged and economic losses. The development of the hilly areas is a vital area in increasing the occurrences of the landslides in Malaysia. Most of the landslide events that caused a damaged in Malaysia occurred in man-made
slopes. Examples of some landslide events occurred at the Highland Towers (year 1993), Taman Zooview (year 2001) and Bukit Antarabangsa (year 2008). Landslide is one of the major natural disasters in hilly areas in Malaysia especially in the Ulu Kelang area, where the possibility of landslide occurrences is quite high. Landslides would occur often during the rainy season [2]. As for the software, the remote sensing software is being used to complete this research paper.

The integration of satellite remote sensing data which is called ArcGIS software is one of the applicable software to detect the landslide mapping and identification of high landslide risk in a certain area. ArcGIS is a software based on geographic information system (GIS) for working through maps and geographic information. It is applied to create and used maps, compiled geographic data, and analysed mapped information, shared, and discovered geographic information. This software can use maps and geographic information in a range of applications and manage geographic information in a database. As for the Landsat Images data, this research has used the USGS Earth Explore in order to get the crop mapping images in the study area which is Ulu Klang. The Earth Explorer (EE) user interface is developed by the United States Geological Survey (USGS), which is provided an online search, discovery, and ordering tool. EEs can be used in satellite search, aircraft, and other remote sensing inventory via interactive and text-based query resources. As for the hardware, the electronic tool devices are being used in order to get the calibration values of the three parameters: SMI, LST and NDWI.

In this study, three parameters were used to analyse a possibility location of the landslide in the Ulu Klang area which is the soil moisture, temperature, and the water index. The SMI is referring to the proportion of the difference between the current soil moisture and the permanent wilted point to the field capacity and the residual soil moisture. The SMI values range is from zero to one (0 to 1). Zero indicates dry conditions while 1 indicates wet conditions [3]. However, the LST measures the surface of earth temperature in Kelvin (K). Surface temperature data are very useful in monitor crop and vegetation health and indicate the extreme heat events such as natural disasters. While the NDWI is a remote sensing-based indicator in the changes of the water content of leaves. NDWI is proposed for remote sensing in estimation of vegetation liquid water from space. NDWI is less sensitive to atmospheric effects compare to NDVI. This is because NDWI does not completely remove the effect of background soil reflectance, like NDVI. Therefore, NDWI should be considered as an independent vegetation index [4]. The purpose of this research is to analyse and validate the data of the soil moisture index (SMI), temperature index (LST) and water index (NDWI) from the remote sensing Landsat Images with the electronic tool devices.

2. Methodology

2.1. Data Collection

This research project was conducted in Ulu Klang, Malaysia. Figure 1 shows the topography map where the research analysis has been conducted. The image has been taken from the year of 1994 to the current year, 2019 directly from the ArcGIS Software after been subset and raster according to the required coordinates. The GPS coordinates for the specified area is located at the latitude of 3°12’30”N and longitude of 101°45’28’’ E. The location of Ulu Klang has the high demand of its land. This leads to the fast track of urbanization in this area. As a close by area of Kuala Lumpur city, Ulu Klang has also in demand of its land resulted in a rapid increase in intensity of development and housing project in this area particularly in Klang Valley [5][6][7].

The Landsat Data which have been taken for this research paper were Landsat 5, 7 and 8. The date of acquisition for Landsat 5 and 7 were 2nd April 1994, 12th September 2001 and 27th January 2008. The path/row is 127/58. Landsat 5 images consist of seven spectral bands with 30 meters for Bands 1 to 5 and 7. Landsat 7 is a 30 meter spatial resolution images which consists of eight spectral bands known as Bands 1 to 7. While for the Landsat 8 images is provided with nine spectral knowns as Bands 1 to 7 and 9 with a spatial resolution of 30 meters. The date of acquisition for Landsat 8 was 10 June 2019. The path/row is 127/58.
2.2. Project Overview

Figure 2 shows the methodology flowchart of the overall project based on the Landsat 5, 7 and 8 which divided into two categories as indicates below. There are two framework types of development of the research which is software and hardware. The three parameters which are SMI, LST and NDWI are being analysed between these two different methods. The software is based on the remote sensing data while the hardware is depending on the electronic devices. Another understanding for the flowchart is the first phase is categorized as sources. There are two types of sources which are USGS and the ground-based measurement. It is followed by the second phase; data input which are the Landsat Images and the electronic tools devices. For the third phase, it is the process of those parameters’ calculation of SMI, LST and NDWI. These are recorded by the advanced satellites using the ArcGIS Software with the help of USGS and this website provides the online search for free, browse display, metadata export and data download for Earth science data.

2.2.1 Hardware

The ground-based measurement of soil moisture, temperature & humidity and water index data are used to analyse the possibilities of landslides in Ulu Klang, Malaysia. As for the hardware part, it is clearly showing that there are three electronic devices that need to be use in this research. The devices are LCD Soil Tester Meter and Digital Temperature Humidity Time Display. There are five major places which have been highlighted in this paper which are Highland Tower, Taman Hillview, Kampung Pasir, Taman Zooview and Taman Bukit Mewah. These are the popular spots on happening the landslides because of

Figure 1. Topography map of Ulu Klang, Malaysia

Figure 2. Flowchart of the overall project
the some factors the hardware devices could detect the moisture of the soil, calculate the surrounding’s temperature & humidity. Also, the rainfall data has been taken for supporting the water index information. The unit of the LCD Soil Tester Meter has graduated the display into three levels which are Dry, Moist and wet. The values should be times with hundred to get the percentage values. This referring to the reading of SMI. The more the moisture of the soil, the more the tendency of the landslides occur. If the reading is lower than the tendency of landslide occurrences will be decreased. Most likely, the landslides will happen when the SMI is high and the temperature in the soil is high too. Same goes to the humidity, the higher the percentage of the humidity, the higher the possibilities for the landslides to occur. In this case, the humidity will play a role as the NDWI part for the hardware, that is because there is no current device for detecting the NDWI at the moment. Other than humidity, the data rainfall is also been taken to support the NDWI values for the hardware part.

2.2.2 Software
For the software part, the software sources are from the Landsat Images which is called USGS. The data available and free of charge is through the USGS Earth Explorer (EE). The coordinates can be key into a certain study area or use a direct click inside the map to select the certain location. After that, the ArcGIS will be taking the part. ArcGIS Software is a powerful software package that is used (by remote sensing) for manipulating and analyzing data. After analyzing, the parameters can be produced here such as the soil moisture index, temperature and water index.

2.3. SMI, LST and NDWI Calculation.
The calculation for the SMI is as equation \([8][9]\) (1):

\[
SMI = \frac{(LST_{max} - LST)}{(LST_{max} - LST_{min})}
\]  

(1)

Where, LSTmax and LSTmin are the maximum and minimum surface temperature for a given NDVI. While LST is Land Surface Temperature, the surface temperature of a pixel for a given NDVI derived by using remote sensing data. This paper highlights two formula for the LST which are in Landsat 5 or 7 and Landsat 8. The calculations are as bellows.

The calculation for LST’s Landsat 5 and 7:
This equation 2 below is a conversion to radiance and Qcal corresponds to band 6;

\[
L_{rad} = \frac{(L_{max} - L_{min})}{(Qcal_{max} - Qcal_{min})} \times (Qcal - Qcal_{min}) + L_{min}
\]  

(2)

\[
T = \frac{K2}{\ln (K1/L_{rad} + 1)}
\]  

(3)

As for equation 3, this converts the radiance into a brightness temperature (Kelvin) where the value of K1 and K2 are constant. As for the Landsat 5, the value of K1 is 607.76 and K2 is 1260.56. And as for the Landsat 7, the value of K1 is 666.09 and K2 is 1282.71. While equation 4, it converts the Kelvin Temperature into a Degree Celcius;

\[
C = T - 273.15
\]  

(4)

LST’s Landsat 8 [10]: Equation 5 is a calculation of TOA (Top of Atmospheric) spectral radiance.

\[
TOA (L) = ML \times Qcal + AL
\]  

(5)

Where ML is a band-specific multiplicative rescaling factor from the metadata. Qcal corresponds to band 10. AL is a band-specific additive rescaling factor from the metadata. The value of TOA is 0.0003342 * “Band 10” + 0.1. Hence, these equations must be solved using the Raster Calculator tool in ArcMap. (ArcGIS). Equation 6 below is where the TOA turning into brightness temperature conversion.

\[
BT = \frac{(K2 / (\ln (K1/L) + 1)) - 273.15}{273.15}
\]  

(6)
Where the value for $K_1$ and $K_2$ is a band-specific thermal conversion constant from the metadata. Therefore, to obtain the results in Celcius, the radiant temperature is adjusted by adding the absolute zero which approximately to -273.15° celcius. Next equation 7 is by calculating the NDVI;

$$NDVI = \frac{(\text{Band 5} - \text{Band 4})}{(\text{Band 5} + \text{Band 4})}$$

(7)

The calculation of the NDVI is important, the proportion of vegetation ($P_v$) is highly related to the NDVI, and emissivity ($\varepsilon$). The $P_v$ is calculated by using Equation 8.

$$P_v = \text{Square} \left(\frac{\text{NDVI} - \text{NDVImin}}{\text{NDVImax} - \text{NDVImin}}\right)$$

(8)

While calculation for the emissivity $\varepsilon$ is as the equation 9 below:

$$\varepsilon = 0.004 \times P_v + 0.986$$

(9)

The value of 0.986 is used to corresponds to a correction value of the equation. Last equation for getting the value LST for the Landsat 8 is as below.

$$LST = \frac{BT}{1 + (0.00115 \times \frac{BT}{1.4388}) \times \ln(\varepsilon)}$$

(10)

The calculation for the NDWI is as equation 11 and 12.

$$\text{NDWI (Landsat 5 and 7)} = \frac{(\text{Band 2} - \text{Band 5})}{(\text{Band 2} + \text{Band 5})}$$

(11)

$$\text{NDWI (Landsat 8)} = \frac{(\text{Band 3} - \text{Band 6})}{(\text{Band 3} + \text{Band 6})}$$

(12)

3. Result and discussion

3.1. Hardware

3.1.1 Soil Moisture Analysis (SMI) - LCD Soil Tester Meter

The SMI is identified as the proportion of the difference between the current soil moisture and the permanent wilted point to the field capacity and the residual soil moisture. The SMI values range is in between 0 to 1 which is indicating extreme dry to extreme wet conditions [3]. As stated in the table 1, the range of the SMI is all wet and this led to landslide occurrences. Generally, every type of soils has a unique characteristic such as material composition, porosity and bulk density. These characteristics related to soil strength, pore pressure and matrix suction of the soil [11]. The higher the content of water in the soil, the higher the chances of the possibilities of the landslide occurrences.

3.1.2 Landsat Surface Temperature (LST) - Digital Temperature Humidity Time Display

The method of ground-based measurement using the temperature & humidity devices to detect and monitor the landslide is also an efficient way to detect the prone landslides. By referred at table 1, the analysis of the output results of the temperature of the soils could be stated the 26°C and above. It has been concluded where the higher the temperature in the soil plus the wetness could lead to landslides.

3.1.3 Water Index (NDWI) – Rainfall data

Malaysia is a country located near by the equator line with tropical climates which receives high abundant rainfall. This makes Malaysia prone to the landslide events as rainfall is one of the main triggering factors that can be occurs a landslide event. Most of the landslides events in Malaysia are mainly impact by frequent and prolonged rainfalls, in many cases associated with monsoon rainfalls. Ulu Klang area has received the most exposure [12]. The area has constantly hit by fatal landslides since December 1993. In this study, the landslide events that occurred in Ulu Klang areas between years 1994 until 2019 were investigated and analysed using rainfall threshold based on effective working rainfall
and normalized difference water index methods. Figure 3 shows a continuous rainfall intensity occurred during these periods. The result indicates that the higher the frequent of rainfall which lead to higher values of the NDWI, the higher the possibilities of the landslides to occur. To conclude the relationship between these three parameters; SMI, LST and NDWI by referring to the Table 3, even though the SMIs are all in the wet category, the temperature and humidity values are different. It has been concluded that when the temperature is increase and the humidity is low, the chances on having a landslide is high. The examples are Highland Tower and Taman Hillview. While, if the temperature is low and the humidity is above 50%, the possibilities of the landslide occurrences are very high and risky.

Figure 3. Data Rainfall in Ulu Klang, Malaysia.

Table 1. Results of hardware measurement.

| No. | Places          | SMI | Temperature | Humidity | Possibilities of the landslide occurrences. |
|-----|----------------|-----|-------------|----------|--------------------------------------------|
| 1   | Highland Tower | Wet | 32°C        | 51%      | High                                       |
| 2   | Taman Hillview | Wet | 35°C        | 40%      | High                                       |
| 3   | Kampung Pasir  | Wet | 27°C        | 57%      | Very high                                  |
| 4   | Taman Zooview  | Wet | 26°C        | 67%      | Very high                                  |
| 5   | Taman Bukit Mewah | Wet | 32°C        | 47%      | High                                       |

3.2. Software

3.2.1 Soil Moisture Index Analysis (SMI).
Based on the results of the ArcGIS software on the Figure 4, year of 1994, 2001, 2008 and 2019 are being selected for SMI’s analysis purpose. These mappings represent the SMI parameter for landslide occurrences in Ulu Klang, Malaysia. From the year 1994 until the year of 2008, there are landslides occurrence based on the news while for this currently year which is 2019, there are no landslides detected. This research has been doing the analyzation from time to time where the possibilities of landslide will occur when the values of the SMI is higher. There are three classifications range of the SMI values; Dry is in between 0.1 to 0.33. Moist is in between 0.33 to 0.5. Wet is in between 0.5 to 0.8. SMI which in a dry range (red colour), has a less tendency on the landslide’s occurrences. The yellow colour which indicates the moist range has a tendency on the landslide’s occurrences while the green colour which indicates the wet range of SMI is the major tendency on the landslide occurrences. According to the Figure 5, it has shown where the year 1994 has the highest tendency of landslide occurrences. This is because less development area, intense rainfall, etc. While, the year 2019 has the
least tendency of the landslide occurrences. This is because the land has improved and stable a lot compared to the year before.

![Figure 4](image_url)

**Figure 4.** Soil Moisture Index (SMI) mapping for year (a) 1994, (b) 2001, (c) 2008 and (d) 2019

### 3.2.2 Land Surface Temperature Analysis (LST)

Based on the Figure 5, it shows the topography mapping of the LST in the desired study areas which is in Ulu Klang, Malaysia. LST is the heat emission measurement of land surface due to various activities related with the land surface. The increased of LST is because of the increase of paved cover which is indicated from concentrated of human activities. The NDVI and LST relationship has been used to retrieved surface biophysical parameters to extract the sub-pixel thermal variations, and to analyse land cover dynamics [12].

Temperatures can be monitored through space borne remote sensing sensors based on estimation of the top of the atmosphere (TOA) radiances in the thermal infrared (TIR) region. This study found out that the lower the temperature, the higher the possibilities on occurrence of the landslides. By referring to Figure 5, the LST’s classification range are cold temperature in between 20 to 23°C (green area), 23 to 26°C (yellow area) is in the average temperature and lastly 26 to 30°C (red area) is in the hot range temperature. It has shown the year 1994 and 2001 are the highest tendency for the landslide to occur, because of increasing the hot range temperature area.

![Figure 5](image_url)

**Figure 5.** Land Surface Temperature (LST) Index Mapping for year (a) 1994, (b) 2001, (c) 2008 and (d) 2019

### 3.2.3 Water index (NDWI)

The NDWI has a strongly related to the plant water content. It is provided a very good alternative for plant water stress. The NDWI is a satellite-derived index from the Short-Wave Infrared (SWIR) and Near-Infrared (NIR) channels [16-13]. The NDWI index is most applicable to map the water body. The water body has high absorbability and low radiation in the range from visible to infrared wavelengths. The index uses the Near Infra-red and green bands of remote sensing images based on this phenomenon. The NDWI can improve the information of water body effectively in the most cases. However, NDWI is often to measure over-estimated water bodies due to sensitivity to build-up land [4][13][14].
The NDWI values are larger than 0.5 is refer for water bodies. For vegetation area, the index is much smaller and easier to distinguish vegetation from water bodies. While built-up features index is between zero and 0.2 [14]. Figure 6, the NDWI classification has been divided into three classes. Low value of NDWI is in between -0.4 to -0.2, moderate value is in between -0.2 to -0.1 and the high value of NDWI is in between -0.1 to 0.3. The water index can be related to the rainfall data. The data rainfall were taken in Ulu Klang, Malaysia using the ground-based measurement. However, the rainfall is one of the triggering factors that contributes the landslides. If the rainfall data increase, that means the value of the NDWI will be also increasing and this could lead to landslides.

![Figure 6. Water Index (NDWI) Mapping for year (a) 1994, (b) 2001, (c) 2008 and (d) 2019](image)

4. Conclusion
Soil moisture, land surface temperature and water index were the parameters to monitor and detect the landslide occurrences, especially in Ulu Klang, Malaysia. The objective of this research is to analyse and validate the data of the soil moisture index (SMI), temperature index (LST) and water index (NDWI) from the Landsat Images with the electronic tool devices. Based on the analysis, the results indicated are showing where the higher the percentage values of SMI, the higher tendency for the landslides to occur. Same goes to the NDWI. While, for the LST, the colder the temperature, the moisture and humidity of the surrounding is, and these could lead to landslide. By using these two methods; remote sensing and ground-based measurement, this could be useful in monitoring the landslide occurrences and as well as prediction tool for future potential landslides in development, land cover planning and landslide risk management.

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