Review of Landslides Factors at Rinjani Mountain, Lombok Island, West Nusa Tenggara

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Abstract. On July 29th, 2018, the Lombok Island had a tectonic earthquake around 6.4 SR which causes landslide in Rinjani volcano. Fault plates have an impact on earthquakes that causes land movement rising 25 cm in the north of the island near the epicentre. The purpose of this research is to review the causes of dominant at Lombok Island. This research is processing satellite imagery landslide data location, lithology data, fault data, land cover data, and seismic data that has occurred. In conclusion, that the factors have been determined affect landslide. For further analysis of land movement can be use statistic bivariate method and AUC values is expected to be used as a reference basis for controlling land uses in land movement-prone area.

1. Introduction
On July 29th 2018, a tectonic earthquake shook Lombok at 05.47 WIB. According to BMKG data, the epicenter was on coordinates of 8.4° South Latitude and 116.5° East Longitude with a strength of 6.4 SR at a distance of 47 km northeast of Mataram city and at 24 km depth. On the record, some 33 aftershocks record occurred until August 5th, 2018 with different magnitude forces.

The earthquake that occurred in West Nusa Tenggara Lombok has caused at least 468 people to die, 1,416 people were injured, 431,416 people were displaced, and around 81,813 houses were damaged (Haryanto, 2018). In addition of causing damage and casualties, this earthquake also caused by mass movement in the area around Mount Rinjani. Based on the BMKG data, earthquake that occurred on the West Nusa Tenggara Lombok did not have the potential to cause a tsunami.
The purpose of this research is to review the landslide factors on Lombok Island. The study was conducted by reviewing the image data of mass movement locations, rock lithology data, fault data, land cover data, and seismic data that have occurred. It can be concluded from the research that the study determines factors influence landslide.

2. Method
The method of this research is by reviewing data from Geospatial, BMKG and PVMBG for lithological data, seismic data, land cover data and fault data and analyzing satellite image data processed using Global Mapper for slope factor analysis.

3. Result
3.1 Satellite Imagery Data
Based on satellite imagery data processed with Global Mapper, the area around Mount Rinjani has elevation of 500 to 2000 meters. Based on the Van Zuidam classification of 1985 [10], the elevation include into elements of high morphography to mountains. Areas experiencing mass movement at altitudes of 500 to 750 meters based on the Van Zuidam classification are included in the highly hill morphography elements.

![Image 1. Morphography Map of Lombok Island](image)

3.2 Slope Data
Based on Van Zuidam's 1985[10] classification, the slope of the Lombok island morphometry ranges from wavy to steep mountains with a slope of about 8.8-72%. Slope with wavy - wavy class occupies around 50% -60% spread from west to eastern part of Lombok Island, while steep slope with steep class occupies around 40% -50% of Lombok Island in the north and south of the study area.
3.3 Lithology Data
The formation in North Lombok is the Lekopiko Formation. Formations in East Lombok are the Ekas Formation, Kalipalung Formation and Lekopiko Formation. Based on regional geological maps, the North Lombok region is dominated by tuff, lava, breccia, and lava breccia. In the East Lombok area, the southern part is dominated by limestone, calcareous breccia and tuffaceous sandstone. While in the north it has the same lithology as North Lombok.
Based on the interpretation of PVMBG data the area affected by mass movement with lithology of rocks from sheet geological map Lombok, West Nusa Tenggara [8] is lithology of rocks which are often affected by mass movement areas, namely tuff, breccia and lava rock.

3.4 Fault Data
Distribution of earthquakes that occurred south of Sumbawa and surrounding areas was the result of activities in the Indo-Australian plate subduction zone which subducted
beneath the Eurasian plate. In addition to the earthquake distribution, the Indo-Australian oceanic plate subduction activity which slides under the Eurasian Continent plate with a speed of 7.5 cm/year (e.g. Curray, 1989) has resulted in a new geological structure in the form of an active fault located north of Flores Island. The fault experienced an extension to the northeast of Bali (Yazid, 1999) known as Back Arc thrust. It is this activity from the fault that rises behind the archipelago that causes earthquakes to occur in the north of the islands of Sumbawa to Flores.

Image 4. Flores Fault Location

3.5 Land Cover Data

**East Lombok**

Land cover is used for paddy fields covering an area of 47,763 ha, non-paddy fields covering 94,365 ha, non-agricultural land covering 18,427 ha with a total area of 160,555 ha in East Lombok in 2015.

| Sub-District       | Paddy Field | Non-Paddy Field | Non-Agricultural Field | Total   |
|-------------------|-------------|-----------------|------------------------|---------|
| Keruak            | 2.021       | 785             | 1.243                  | 4.049   |
| Jerowaru          | 4.384       | 8.573           | 1.321                  | 14.278  |
| Sakra             | 2.063       | 176             | 270                    | 2.509   |
| Sakra Barat       | 2.848       | 95              | 287                    | 3.230   |
| Sakra Timur       | 3.263       | 234             | 207                    | 3.704   |
| Terara            | 2.607       | 547             | 987                    | 4.141   |
| Montong Gading    | 2.066       | 186             | 314                    | 2.566   |
| Sikur             | 3.093       | 4.258           | 476                    | 7.827   |
| Masbagik          | 1.993       | 450             | 874                    | 3.317   |
| Pringgasela       | 1.868       | 10.220          | 1.338                  | 13.426  |
| Sukamulia         | 945         | 283             | 221                    | 1.449   |
| Suralaga          | 2.188       | 228             | 286                    | 2.702   |
Table 1. Land Area in East Lombok Based on Land Use and District, 2015

| Sub-District | Paddy Field | Non-Paddy Field | Non-Agricultural Field | Total   |
|--------------|-------------|-----------------|------------------------|---------|
| Pemenang     | 417         | 3.906           | 3.786                  | 8.109   |
| Tanjung      | 714         | 5.460           | 5.390                  | 11.564  |
| Gangga       | 1.238       | 8.324           | 6.173                  | 15.735  |
| Kayangan     | 2.619       | 3.960           | 6.056                  | 12.635  |
| Bayan        | 3.316       | 20.225          | 9.369                  | 32.910  |
| **East Lombok** | **47.763** | **94.365**      | **18.427**            | **160.55** |

Source: Department of Agricultural and Livestock in East Lombok

North Lombok

Land cover is used for paddy covering an area of 8,304 ha, 41,875 ha of non-paddy fields, 30,775 ha of non-agricultural land with a total area of 80,953 ha in East Lombok in 2015.

Table 2. Land Area in North Lombok Based on Land Use and District, 2014

| Sub-District | Land Use (Ha) |
|--------------|---------------|
| Paddy Field  | Non-Paddy Field | Non-Agricultural Field | Total |
| Pemenang     | 417           | 3.906              | 3.786  | 8.109  |
| Tanjung      | 714           | 5.460              | 5.390  | 11.564 |
| Gangga       | 1.238         | 8.324              | 6.173  | 15.735 |
| Kayangan     | 2.619         | 3.960              | 6.056  | 12.635 |
| Bayan        | 3.316         | 20.225             | 9.369  | 32.910 |
| **North Lombok** | **8.304** | **41.875**        | **30.774** | **80.953** |

Source: Department of Marine, Fishery, Agricultural and Forestry in North Lombok
3.6 Earthquake Data

Earthquakes occur with magnitude 6.4 SR. The epicenter was at a depth of 24 km. Based on BMKG shakemap maps, the impact of earthquakes in the form of damage can occur in areas adjacent to the epicenter. Based on the results of the accelerographic data analysis, the closest station to the source is Mataram (MASE) station, which is about 42 Km from the epicenter with a ground acceleration value of 6.21 gals. While the largest land acceleration value (41,309 gals) was recorded by Taliwang station (TWSI) which is 55 km from the epicenter.

After shocks continued with smaller earthquake intensity. There were 213 aftershocks with 20 aftershocks felt and the strongest aftershocks were 5.7 SR and 3 earthquakes were felt (source: National Earthquake Centre).

The impact of the earthquake, namely the damage and collapse of the building occurred because the building was unable to anticipate the ground motion of the Peak Ground Acceleration (PGA) caused by it. The amount of ground vibration due to an earthquake is affected by three things, the source of the earthquake (source), the path of the wave propagation (path), and the influence of the local soil conditions (site). It can be understood that the source of a large and close earthquake will also cause a large ground vibration.
4. Discussion
Mount Rinjani is located between North Lombok Regency and East Lombok Regency, administratively. Based on the interpretation of the morphometric map of the DEM and the classification of the slope Mount Rinjani Region (Vanzuidam,1985), Lombok Island has a wavy to steep slope around 8.8 - 72%. Based on regional geological data, there are three rock lithologies namely volcanic breccia, tuff, and lava. Based on fault interpretation, distributions the earthquake that occurred in Lombok is caused by Flores back arc thrust. Based on land cover data, the land used in the Mount Rinjani’s area is more dominant to non-paddy fields. Based on seismic data, the impact of the earthquake that is damage and collapse of the building occurs because the building is unable to anticipate the ground motion Peak Ground Acceleration (PGA) caused by it. The amount of ground vibration due to an earthquake is affected by three things; the source of the earthquake, the path of the wave propagation, and the influence of the local soil site. It can be understood that the source of a large and close earthquake will also cause a large ground vibration.

Review from factors of mass movement, the factor of mass movement is divided into two events, namely before the earthquake and after the earthquake. The factors of mass movement before the earthquake can be viewed from satellite imagery data, lithology
data, and land cover data. Our interpretation, areas that have steep slopes to very steep are more likely to occur in the mass movement. Therefore, from the lithological data, volcanic breccia rock, tuff, and lava has the potential to cause mass movement because it has poor gradation and low porosity. Whereas, the land cover data, the area that is not covered by paddy-fields and agriculture has more potential for mass movement because there is not enough vegetation to stabilize the slope. The factors of mass movement after an earthquake can be reviewed from the same data before and after earthquake, but there are also dominant factors, and the most factor that gives a significant impact to mass movement is the seismic factor. This earthquake which happened 33 times in Lombok caused expand mass movements and make a potential vulnerability the disaster of mass movement. In the other side, the impact of this earthquake emerged new faults, one of them is founded in North Lombok. Certainly, the emerge of this new fault could make a potential of the disaster of mass movement which could increase.

5. Conclusion
By this paper, we concluded there are some factors that can give impact to the movement of the soil, which are:
- Rock Lithology. Areas that have tuff rock lithology could more trigger mass movement.
- Fault. The area traversed by a fault becomes a trigger for mass movement.
- Slope. Areas that have steep slopes could more trigger mass movement compared to the wavy ones.
- Land Cover. Land cover there is not rice field is more susceptible dominantly affected by mass movement.
- Seismicity. The existence of an earthquake can accelerate and expand land movements.

To find out the dominant factors of mass movement more accurately can use the bivariate statistical method and the AUC (Area Under Curve) value.

6. References
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