Geospatial Information for Landslide Hazard Assessment in Lombok, Indonesia

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Abstract

Landslide has been one major catastrophic disaster in Indonesia. Landslide causes serious threats to settlements, agricultures, and infrastructures that support transportation, natural resources management and tourism. Many of landslide phenomena can be prevented or mitigated by scientific investigation. This is a crucial step towards empowerment of human resources to guarantee the sustainable of life and livelihoods, rebuilding their shattered communities and infrastructure and environment in the landslide vulnerable area.

Most of the disaster related data are spatial in nature involve some geographic component. For planning, monitoring and decision making; there is typically a need for geospatial data. Therefore, geospatial information could play an important role in hazard assessment. This paper presents a joint project of The Geological Agency of Indonesia and BGR (German Federal Institute for Geosciences and Natural Resources) to develop and test practical hazard assessment methodologies.

Lombok Island is the pilot area of this project. The development in Lombok grows rapidly so that human activity will trigger more geological hazards. One of these hazards is landslide. To cope with these hazards impact, study about more detailed geological hazard map, information on the landslide prone areas, and identification of area susceptible to landslide is recommended. The project includes a geospatial technology of Geographic Information Systems (GIS) and Remote sensing (RS) tools and methods for improved landslide hazard assessment.

Keywords: geospatial, landslide, hazard, assessment, Lombok

I. Introduction

Landslide is the downslope movement of the rock, soil and/or vegetation due to gravity in a process that can be in abrupt collapses or in slow gradual slides. Landslide hazard defined as the probability of occurrence within a specified period of time and within a given area of a potentially damaging phenomenon (Varnes, 1984). Landslides occur naturally or triggered by human activity. It is significant because the distribution spread across the country, and based on the records of events, landslides are the most intensive of occurrence, and can occur simultaneously with other geological hazards, such as earthquakes and volcanic eruptions.

Geological Agency of Indonesia is mandated to manage geological hazards such as earthquake and tsunami, volcanic eruption and landslide. The term geological hazards used instead of natural disasters due to geological factors as the dominant sources of these disasters. This paper will only explain about landslide as one type of the geological hazards in Lombok.

Landslide causes serious threats to settlements, agricultures, and infrastructures that support transportation, natural resources management and tourism. Basically, it is almost impossible to prevent the occurrence of landslides. However, it is possible to reduce the impact of landslides. Thus, regional landslide hazard assessment is becoming an important task for government at local and national level together with the community in order to realize the optimum protection to the community and social assets, economy and environment from possible disasters.

The main objective of this project is to develop and test practical hazard assessment methodologies in Lombok island. This project involves The Geological Agency of Indonesia and Georisks Project (BGR) at national level and local government of West Nusa Tenggara Province in Lombok.

II. Landslide in Lombok

Lombok is an island in West Nusa Tenggara Province of Indonesia with an area of 5.435 km^2 with 3.098.480 inhabitants (Statistics Center/*BPS*, 2010). Lombok is located next to Bali island (Fig.1). Recently, it is considered as an internationally alternative eco - tourism destination after Bali. Due to this, various human activities took place in sectors and regional development undertaken by the government and the private sector with intensive.

Figure.1 Lombok Island.

During the period of 25 years in Lombok have occurred several landslides that caused many casualties and properties damage. Landslides in Lombok mostly occurred on the mountainous and hilly areas. The most destructive events with casualties occurred in West Lombok District, a large landslide triggered by 6.5 RS earthquake in Tanjung Subdistrict, caused 28 people killed, more 100 people injured, destroyed more than 200 buildings and 9845 houses. On 1994, a landslides at Gerung killed 4 people and destroyed many houses. Following that year, on 4 and 6 November occurred in Aikmel Subdistrict, killed 31 people and damaged hundreds buildings and houses. Landslide at Cerorong, Central Lombok District occurred prior to 1994 which continues until today, forming a deep and wide valleys (50-75 m), and located <40 m from settlements, roads and schools (Fig.2) (Djaja, 2011).

This region vulnerable to some naturally hazardous phenomenon such as landslide. There are conflicts of interest, between hazard assessment concerning the preservation of natural resources with the growth of economic activities. Public and private economic losses from landslides include not only the direct costs of replacing and repairing damaged facilities, but also the indirect costs assosiated with lost productivity, disruption of utility and transportation systems, and reduced property values (Schuster and Fleming, 1986).

Figure.2. Landslide at Cerorong, Central Lombok District (Rachmat, 2004).

The project assisted a geospatial technology of Geographic Information System (GIS) and Remote Sensing (RS) tools and methods for improved landslide hazard assessment in Lombok by incorporating spatial distribution of landslide inventory, geological, land cover, and environment (climatic, and vegetation index data). The incorporation of landslide hazard assessment with geospatial should result in a more reliable landslide susceptibility map for local spatial planning and its potential misuse can be minimized.

III. Geospatial Data

In many cases, landslides occur in remote areas that are difficult to access. As remote and large areas are often difficult to access, conventional ground-based mapping is of limited use. Consequently, suitable earth observation technique has to be provided that is capable of collecting reliable data and information for such areas. Remote sensing belongs to earth observation technique of proven performance that could be utilized in this context (Kuehn, et.al, 2011). Satellite RS is providing a systematic, synoptic framework for advancing scientific knowledge of the Earth as a complex system of geophysical phenomena that, directly and through interacting processes, often lead to natural hazards (Zoran, 2008) or in this case geological hazards.

Landslide hazard assessment requires an analysis of all factors affecting landslides. The following factors assessed using geospatial technology (Fig.3):

- Additional landslide inventory using ASTER images and Google Earth.
- Updated lineament map using the 1995 Landsat TM image completed by shaded relief maps derived from ASTER GDEM data.
- Land cover data derived from 2004 and 2009 Landsat ETM+ images.
- Topographic features: slope angle, slope aspect, flow direction, elevation derived from ASTER GDEM data.
- Streams of 1st and 2cd order derived from ASTER GDEM data.
- Vegetation Indices; Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) derived from ASTER and MODIS images.

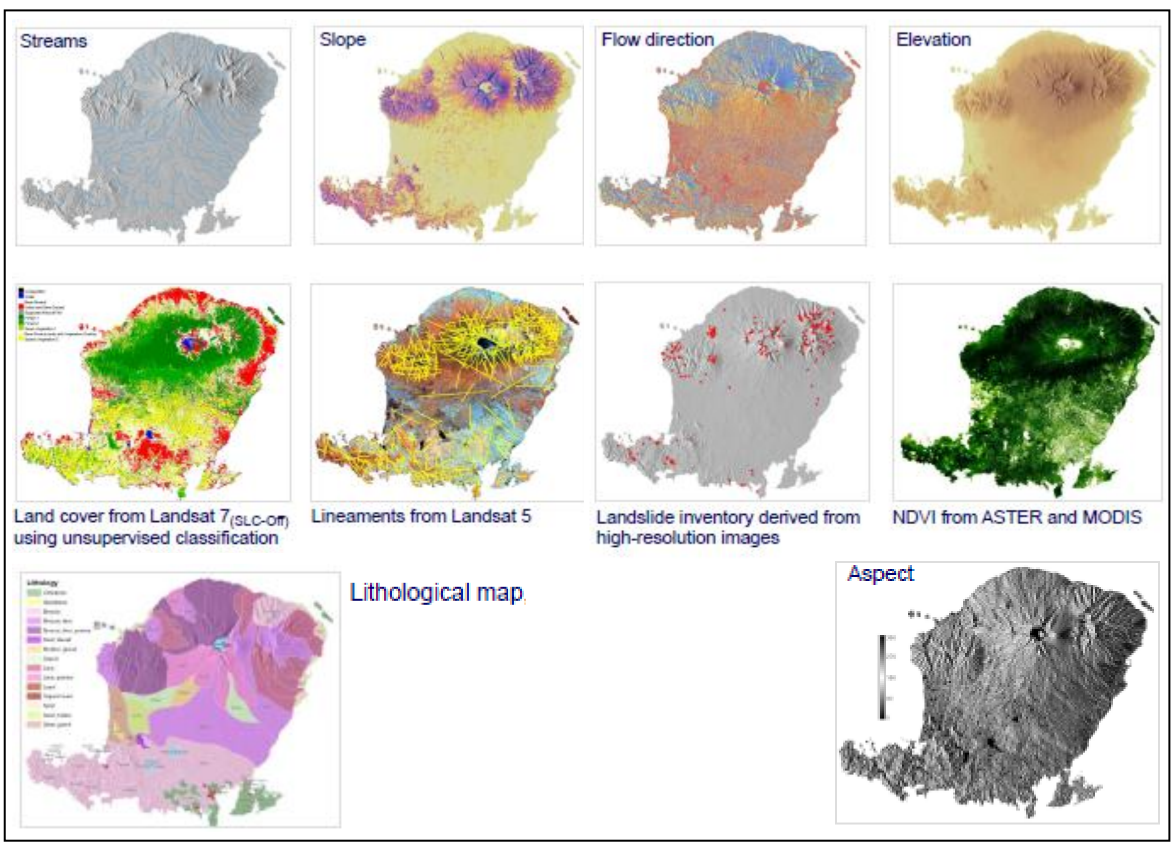

Figure.3. Factors related to landslide assessment using geospatial technology.

The results of remote sensing data interpretation had been spot-checked in the field between September 19 and 22, 2011. Landslide inventory is also prepared by collecting historical information from local government and Geological Agency. Other factor such as lithology was made based on Geological Map of the Lombok Sheet, West Nusa Tenggara produced by Geological Agency.

IV. Process Analysis

Image processing was done with the ENVI 4.8 software. Other data layers listed above were processed and added to a Geo-database with Arc GIS 10 software. Then, a statistical approach using probability and weighting methodology was applied to extract standardized weights for the different layers (Teerarungsigul, 2006). The methodology uses a combination of components published by Greenbaum (1995) and by Lee and Min (2001) allowing for increase of reliability of the landslide susceptibility map as the final product.

The spatial data analysis and integration for landslide assessment can be divided into three steps (Teerarungsigul, et.al, 2011):

- To overlay the landslide distribution with factors (Fig.4).
- To perform the probability analysis and weighting.
- To produce the landslide susceptibility map (Fig.5).

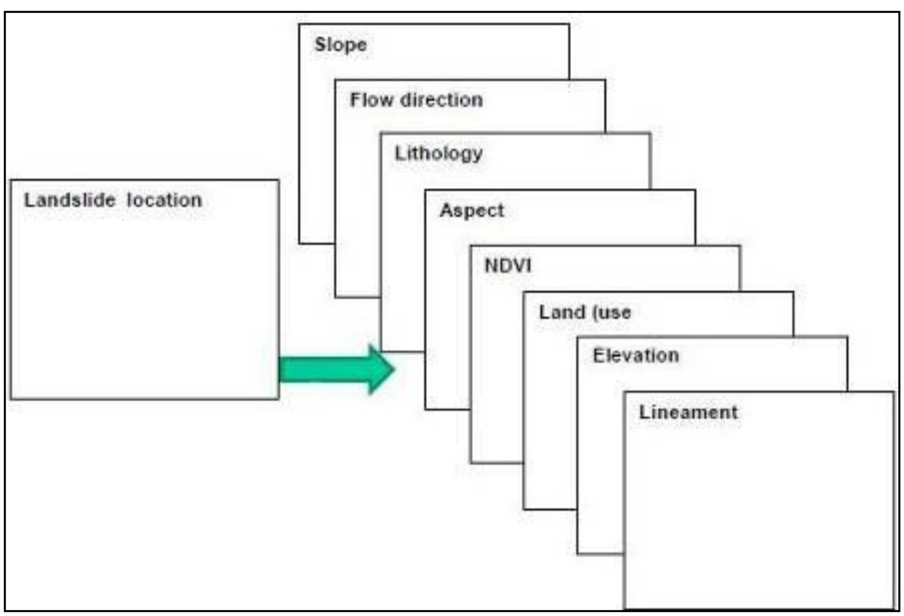

Figure 4. Landslide distribution overlaying with factors (Teerarungsigul, et.al, 2011).

Five levels of relative landslide occurrence are difined on a landslide susceptibility map: (1) very low hazard; (2) low hazard; (3) moderate hazard; (4) high hazard; (2) very high hazard (Teerarungsigul, et.al, 2011).

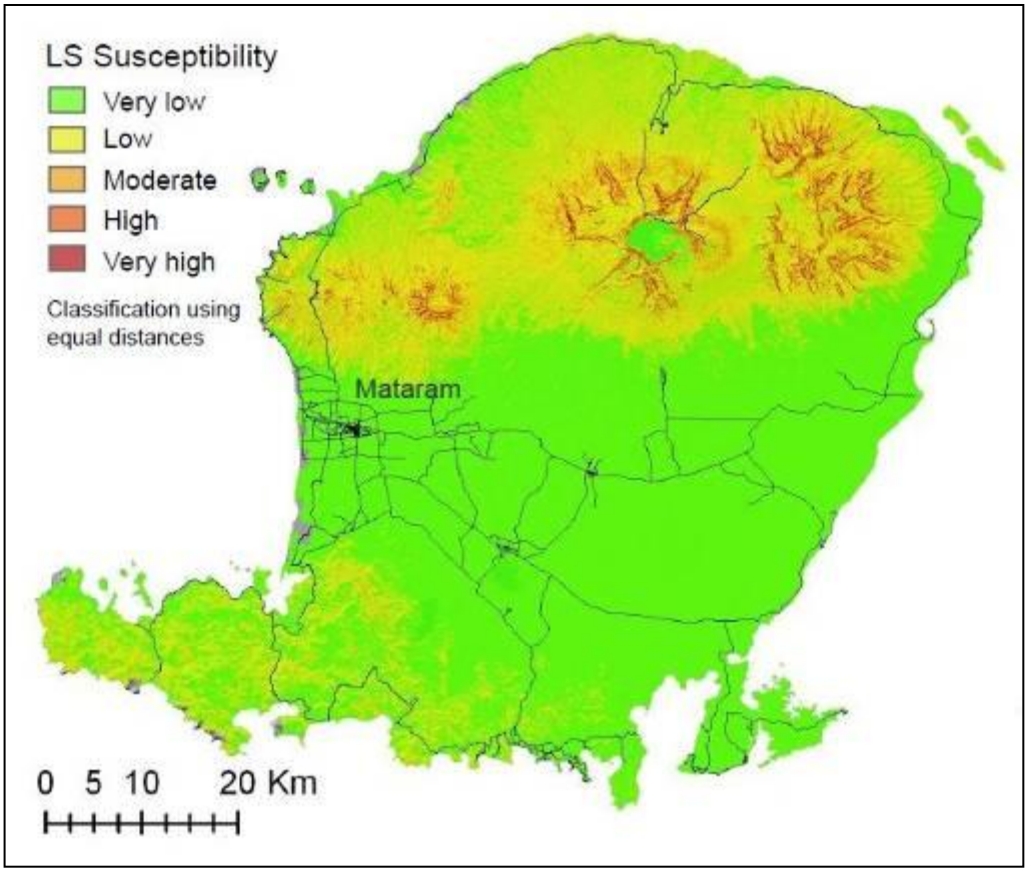

Figure 5. Landslide susceptibility map (Teerarungsigul, et.al, 2011).

V. Discussion

Geospatial information for landslide assessment applies some factors such as slope, elevation, flow direction, aspect, lithology, lineament, landuse and NDVI. The analysis resulted in slope, NDVI and lineament as the most influence factors. The slope factor ranges from 45 to 50 while dense forest is the land-use class that has a high probability of landslides. Landslides in Lombok mostly occurred on the mountainous and hilly areas.

Lithology and lineament was examined to find out how geological factor affect the landslides. The analysis demonstrates that lineament is more affected. It creates weak zone that vulnerable to landslides. This shape built by volcanic and fault activities. The presence of pumice as unconsolidated rock proceeds as a weak layer for landslides movement.

Field checking was carried out in 2011 and found 4 new landslides from 13 possible landslides that were detected by ASTER. The investigation classified 147 landslides are of natural origin and 47 landslides are man-made triggered. The type of landslide are mainly rotational and translational.

Geospatial Technology of Geographic Information System (GIS) and Remote Sensing can ease landslide hazard assessment. It also provides information for immediate planning and operation of disaster relief missions. It provides a high efficiency and optimizes time resources. The methodology has developed from exclusive technique to standard approach for provision of Geo-information, especially in a remote and inaccessible area. However a field work needs to be done to validate the analysis. The accuracy of the analysis also depends on the quality of input data. This landslide susceptibility can be predicts, where landslide will be occurs.

Acknowledgements
The authors would like to thank Suree T., Ketut T., F. Kuehn, M. Fuchs, J. Torizin, Dicky M., D. Balzer, and D. Kuhn, for their work and support in the research of Landslide Hazard Assessment in Lombok. This research was fully supported by the Geological Agency of Indonesia and Georisk Project (BGR).

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