ENHANCING LANDSLIDES SUSCEPTIBILITY MAPPING BY COMBINING INSAR PROCESSED IMAGES INTO THE STATISTIC MODEL OF BAWAKARAENG MOUNTAIN, INDONESIA.

Ilham Alimuddin[1], Luhur Bayuaji [2], Abdul Rachman Rasyid [3,6], Purwanto[4], Bambang Setiadi[5], Netra Prakash Bhandary[6], Ryuichi Yatabe[6]

[1]Geology Department of Hasanuddin University, Indonesia, ialimuddin@hotmail.com
[2]Faculty of Engineering, University of Malaysia Pahang, Malaysia, ludiro96@gmail.com
[3]Planology Department, Hasanuddin University, Indonesia, rachman_rasyid@yahoo.com
[4]Mining Department, Hasanuddin Univerisity, Indonesia, rachman_rasyid@yahoo.com
[5]Indonesian Research Institute (LIPI), Jakarta, Indonesia, bambang@gmail.com
[6]Graduate School of Engineering and Science, Ehime University, netra@ehime-u.ac.jp

KEY WORDS: Landslide Susceptibility Map, InSAR, Statistic Model, Bawakaraeng Mountain.

ABSTRACT: Landslides have been one of the major natural disasters in most countries in the world. Indonesia has experienced landslides events annually in its mountainous areas and has been generating increasing number of casualties in recent years. One way of preventing the number of casualties from these landslides is by identifying those landslides prone areas and mitigates it by providing susceptible maps. Remote Sensing (RS) and Geographic Information Systems (GIS) are 2 growing modern technologies that have been used by many researchers in the provision of Landslides Susceptibility Maps (LSM). LSM has been created by many kinds approach by simple methodology like overlaying several parameters layers in GIS to combined methodologies such as using statistical approach and validation with remote sensing images or ground survey. The study area covers a mountainous area named Bawakaraeng and Lompobattang Mountain in South Sulawesi Province, Indonesia where rock formations are dominated by Miocene erupted volcanic. The objective of this research is trying to enhance the existing LSM created using frequency ratio model with higher resolution raster image of causal factors parameters used to create the LS index maps. In this research, we attempted to use the raster image created from Differential Interferometry of Synthetic Aperture Radar (SAR) image processing of ALOS PALSAR1 images of DInSAR repeated-pass method. The raw data is SAR level 1 data with 5 scenes of different acquisition year of 2007, 2008, 2009, 2010, and 2011 of similar seasons. We have processed 3 pairs of SAR and the raster image generated have indicated areas where slight surface displacement have occurred and confirmed where cracks were found that initiated surface movement of future landslides. This image was used to validate the landslide incidence location and as one parameter of the causal factors in frequency ratio analysis in enhancing the creation of LSM. The result showed zone of prone areas to landslides graded based on the Landslide Susceptibility Index.

1. INTRODUCTION

1.1 Background

One major natural disaster that often contribute to the high number of casualties in the world is landslides. As Indonesia lies astronomically on the equatorial line, this landslides incidences have a very strong correlation with its climate known as tropical. This contribute to the high rate of rain fall. Besides that, Indonesia also being squeezed tectonically by three major plates when it comes to geological placement setting. This condition undeniably has made Indonesia as one of the highest natural disaster incident countries in the world especially landslides. In recent years, natural disaster have occurred more often statistically compared to decades ago (BNPB, 2015). Compared with other type of disaster, landslides have the highest incident to occur particularly in hilly terrains because they can trigger debris flows and flash floods during the rainy season. Unfortunately, National Body for Natural Disaster Mitigation (BNPB) and local government and responsible bodies are not able to monitor the area because the lack of spatial information supporting the decision making and development planning for the area. The lack of detail an accurate susceptibility maps make it difficult to evaluate the extent of the affected area. Thus, establishment of a comprehensive database of disaster inventory is urgently required especially identification of landslides prone areas.

On the other hand, the availability of remote sensing data coupled with GIS based analysis have given a lot of contributions in preparing the mitigation of the prone areas. Some GIS and remote sensing application techniques have been developed especially in landslide research topic (Westen, et.al, 2008). Hence, the availability of satellite data in providing and supporting the creation of Landslide Susceptibility Map has been possible. However, the accuracy of such maps are still poor. Therefore, the objective of this study is to assess the possibility of enhancing the susceptibility map of landslide occurred in this area by combining the use of a statistical driven model and differential interferometry of SAR method.

1.2 Study Site

Mountain of Bawakaraeng and Lompobattang are two dormant volcanic origin mountains that lie at South part of Sulawesi Island in Indonesia side to side surrounded by seven districts called Kabupaten, and both give a lot of beneficial for them. The mountainous area has been dwelling places for people as well as sources of material and hydrology purposes. Despite the support of living condition, these two mountain areas have also contribute to fatalities in the occurrence of mass movement or sediment related disaster (Tsuchiya, et.al, 2009). The mountains provide area for cultivation and farming, and some areas particularly at upstream part are covered by forests. The upstream of Bawakaraeng is the source of drinking water of Jeneberang River. There are 86 small town/villages in this area and the hydrologic system have six watersheds; Jeneberang, Lantebong, Kelara,Apparang, Bijawang and Tangka (Figure 1).

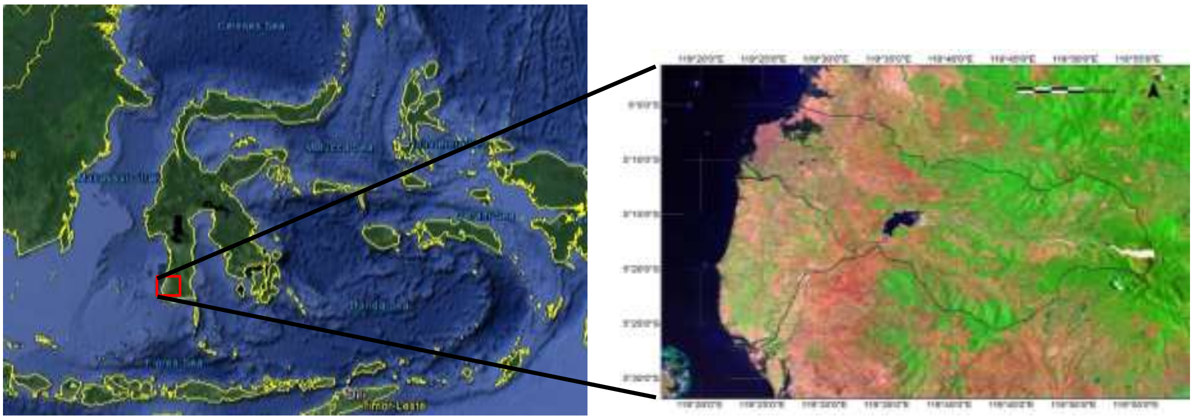

Figure 1. The Study Site of Bawakaraeng Mountain

2. DATA AND METHODOLOGY

2.1 DATA USED

Both optical and microwave remote sensing data covering the study area were used in this study. For the creation of landuse data and spatial validation, data set of Landsat 7 acquired in September 2002 and 5 sets of SAR images of ALOS PALSAR 1 level 1 acquired in 2007, 2008, 2009, 2010 and 2011 were used for the differential interferometry processing data pairs.

Landslides causal factors parameters of vector data were delineated from geological data and land use database of local government bodies. Acquisition of statistic incidents of the landslide ranging 2004 until to 2014 taken from the provision of google earth data.

2.2 METHODOLOGY

InSAR interferometry (InSAR), the phase data of SAR images are analyzed to derive the local topography (original InSAR) or detect and quantify the ground displacement that has occurred in the slant-range direction between the two acquisitions data called Differential-InSAR, (Agustan et.al, 2010). This technique has been used since 1995 to monitor surface displacement related to volcanic activity (Cascini, et al, 2009). The result of this process is generally called D-InSAR, which estimates the ground displacement in the slant-range direction (Bayuaji, et.al, 2010).

This study also applies of frequency ratio model to create a landslide susceptibility map at Lompobattang mountain in Indonesia. In susceptibility mapping, we have to assume that future landslide occurs in the same condition that caused the past landslide. Landslide data was used as a dependent variable, and eight landslide causal factors including slope, curvature, aspect, distance from fault, distance from road, and distance from river, lithology and then land use were selected as independent variables for landslide susceptibility mapping.

Landslide inventories are essential and are important factor to predict future landslide by using probabilistic method. Landslide inventory data were collected from 2004 until 2014 google earth image interpretations of Lompobattang Mountain with highest altitude range between 700 m and highest of 2833 m above sea level. From this a total of 158 landslide were identified, which covered an area of 3.44 km2. Most of the landslides are shallow landslides with minimum and maximum landslide area 708 m2 and 512,765 m2 (0.51 km2) respectively. By using google earth historical imagery tools, we have limited the study area to an altitude 500m as no landslides data were found below this point. Before applying the landslide data in GIS analysis, we have to digitize the time series data from google earth image interpretation, step carps of noticeable landscape modification exist. Then these files are saved as GIS compatible (kml) format and the data is again subsequently changed into shapefile and then raster format for spatial analysis.

3. RESULT AND DISCUSSION

Using the Geographic Information Systems (GIS) data processing software, visual delineation of Landsat image overlaid with vector data shows that an area of approximately 647 ha has been affected at the upper part of River Jeneberang, with indications of significant mass movement prior to the landslide. On the other hand, the SAR processing using GMTSAR software have yielded coherence images for each level 0 ALOS PALSAR data. Generating DInSAR images require a pair of different acquisition images. We have processed 3 new pairs that showed reasonable good coherence namely the pair images of 200909/201009 and 200809/200909 (Figure 4). Based on the theory, coherence in DInSAR images are partly caused by the baseline of the two different acquisition time of the satellites. Other than this baseline factor, the coherence is also influenced by the atmospheric condition when the image acquired such as heavy rainfall, effect of scattering, etc.

The DInSAR image pair of 200809/200909 showed some indications of surface displacement. One linear movement of 5 cm around the landslide area, suggesting the occurrence of cracks/gaps related to subsidence before the landslide event (Figure 4). Ground validation using high resolution differential GPS from the field also supports this interpretation of the DInSAR image. From project report of Jeneberang Sabo Dam, we managed to obtain the GPS location of the cracks that occurred before and after the landslides. Overlaying this points allow us to confirm the throne and the head of the landslides. The image analysis shows us there is a slight deformation along the slope of the potential landslide.

The landslide susceptibility map in Figure. 5 was produced from the classification of landslide susceptibility index map, and it's classified into five classes by using natural breaks classification method or Jenks optimization method. The five classes include very low, low, moderate, high and very high describing the level of landslide susceptibility (proneness) in this study area This classification method has been used widely especially for planners and its designed to determine the best arrangement of values into different classes. This is because this method maximizes the variance between classes and reduces the variance within classes. For verification, a susceptibility map was verified by overlaying with landslide validation data. The percentages of landslides which fall in high to very high, moderate, and very low to low comprises of 83.94%, 4.08 %, and 11.98% respectively.

To enhance the LSM produced after the validation, we overlaid with the DInSAR image produced and it is confirmed the landslides incidences falls on the surface displacement indications of the images (Figure 5).

4. CONCLUSION

Susceptibility mapping is an essential tool to delineate areas prone to landslide, and it has become an important information for decision makers and government. Creating an accurate and reliable Landslide Susceptibility Maps is not easy. This study has shown with frequency model analysis we could create the maps and even enhanced by the combination of satellite images and specific Differential Interfrometric SAR processing. Three pairs of ALOS PALSAR-1 pair's images have shown good coherence image which therefore will give better result on the DInSAR images. Integrating optical satellite image (Landsat) with SAR image processing can complement the change detection analysis and Differential Interferometric SAR (DInSAR) is proven to be one of the effective methods in mapping surface displacement especially for landslides. Integration of remote sensing and GIS processing such as statistic model of landslides frequency ratios of incidences have given us a possibility to create the map from raster image processing. Overlaying the two image result so far can enhance the validation.

Besides validation, in this research, we describe the level of accuracy of prospective landslide prediction by overlying landslide susceptibility map with landslide inventories that were used for validation. The results showed that about 84% of the landslide fall in high to very high susceptibility classes, while 16% landslides fall in the very low to moderate classes. The value ratio in frequency ratio showed the strong relationship within class of causal factors and coefficients on variable (Z) of causal factors in the logistic model showed the strong correlation between all causal factors to landslide occurrence.

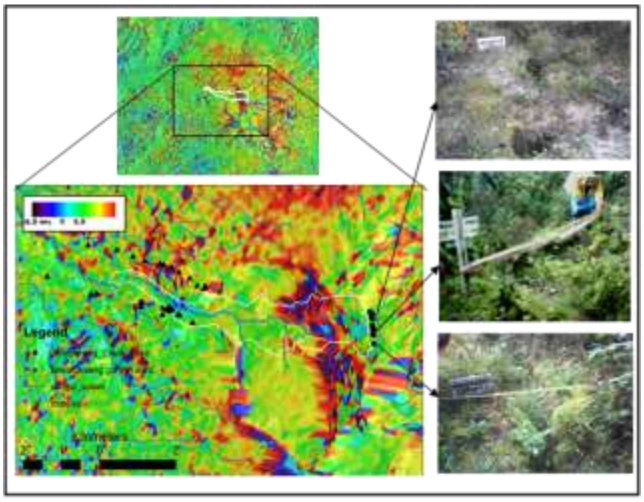

Figure 2. DInSAR image with crack locations and GPS positions from the field survey

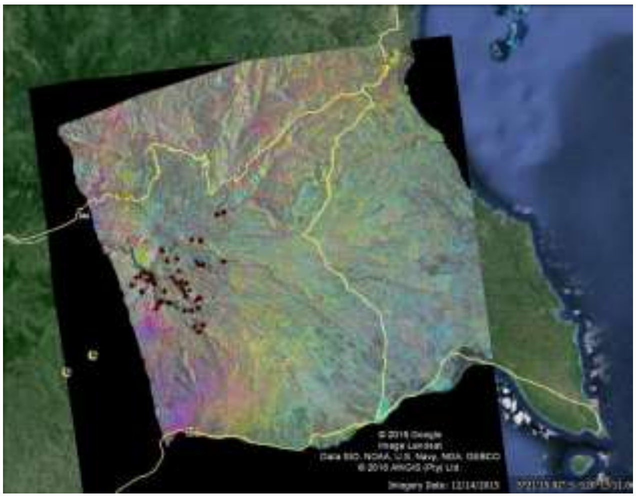

Figure 3. DInSAR Image overlaid with Google earth

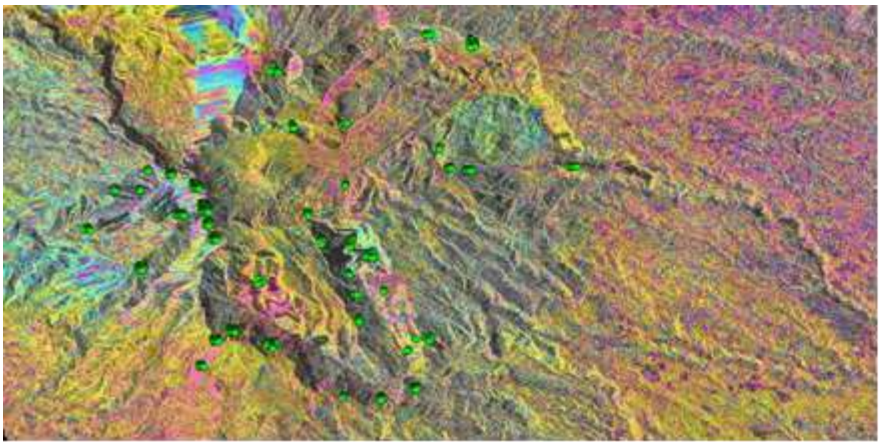

Figure 4. The Differential Inteferometry Image pair of 200809/200909

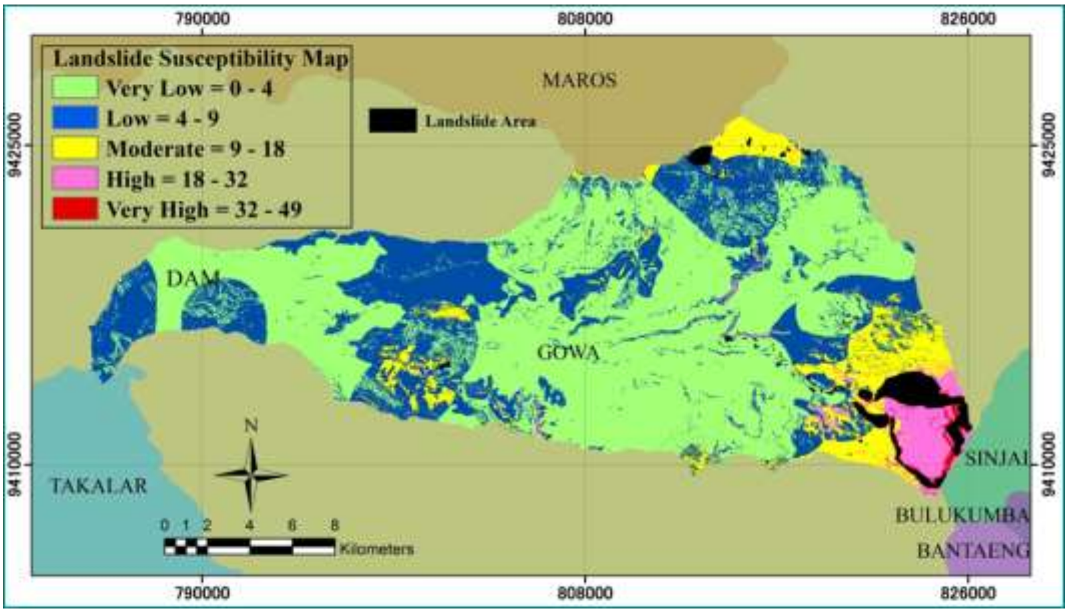

Figure 5. Landslide Susceptibility Map cre**ated from the frequency ratio model analysis**

References

Agustan, Kimata. F, Abidin. H.Z, and Pamitro. Y.E, 2010. Measuring ground deformation of the tropical volcano, Ibu, using ALOSPALSAR data. Remote Sensing Letters, 1 (1), pp. 37–44,

Bayuaji, L., Sri Sumantyo, J.T. and Kuze, H., 2010, ALOS PALSAR D-InSAR for land subsidence mapping in Jakarta, Indonesia. Can. J. Remote Sensing, 36(1) pp.1–8.

Cascini. L., Fornaro, G. and Peduto, D., 2009, Analysis at medium scale of low-resolution DInSAR data in slow-moving landslide-affected areas, ISPRS Journal of Photogrammetry and Remote Sensing, 64, pp. 598-611.

Tsuchiya.S, Sasahara, K., Shuin, S. and Ozono,S 2009, The large-scale landslide on the flank of caldera in South Sulawesi, Indonesia, Landslides, 6: 83-88.

Westen, C.J., Castellanos, E., and Kuriakose, S.L., 2008, Spatial data for landslide susceptibility, hazard, and Vulnerability assessment; Engineering Geology, 102, pp. 112-131.