Derivate Factor for Land Use Change to Landslide Occurrence Triggered by Rainfall at Ujung Loe Watersheds, Indonesia

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1. Introduction

In South Sulawesi, land use change has translated into numerous landslide incidents triggered by the intensity of rainfall compared to other factors such as active volcanoes and earthquakes.

Especially in Ujung Loe watershed, the topography is naturally very steep topography and mountainous (38.8% class slope >20 degree) and has a very high level of instability, especially during the rainy season (rainfall: 2.999 mm/year – 3.791 mm/year: Meteorology, climatology and geophysics Makassar, 2015).

The main occupation of social community in that area is farming. Most of them is located in mountainous area. It was difficult to avoid because this is people's culture for farming in mountainous areas and have made it hereditary. Rudiarto and Doppler (2013), said that in Indonesia, where many upland areas can be found, land use-cover change for the extension of agriculture activity is commonly occurred.

Based on these factors, research must be done to derivate factor by analysis of land use change to landslide occurrence. The specific objectives of the study are examine the land use change from the period 2004 to 2011 and establish the relationship between land use change, topographic parameters (slope) and the occurrence of landslide

2. Study Area

The study was conducted in the Upper of Ujung Loe Watersheds located in Bulukumba and Sinjai Regency, South Sulawesi, Indonesia. It extends from 119°55'42.34"E to 120° 8'43.12"E and 5°18'19.07"S to 5°24'43.33"S. it was provided area for cultivation and farming, and some area particularly at upstream part are covered by forests. The study area is located on elevation from 255 – 2860 m from sea level. According to Meteorology, climatology and geophysics Makassar (2015), rainfall was from 2.999 mm/year – 5.474 mm/year. The slope is around 38.8% with slope class >20 degree and area particularly at upstream part are very steep (>40 degree) (fig. 1).

3. Material and Method

This study utilized Landsat satellite images on scene path 114 row 064 of 2004 and 2011. Landsat 5 TM (date recorded September, 21th 2004) and landsat 7 ETM+ (date recorded October, 11th 2011) images, each with a 30 m resolution, and aster DEM 30m, are collected from United States Geological Survey (USGS) website, Earth Explorer (http://earthexplorer.usgs.gov/).

Landsat images have been registered and geo-corrected from the source. Atmospheric correction has been conducted with the use of vegetation delineation function through the ArcGIS software package version 10.3. In addition, radiometric correction has been carried out by using the Landsat calibration function within the tools of Arc GIS 10.3 software. Remote sensing and GIS techniques was adopted to classify land use. Unsupervised classification method is applied to classify land use into 15 class, then classify into 5 classes class i.e. No vegetation, Sparse vegetation, Medium Vegetation, High Vegetation and Dense Vegetation. The certified maps of land cover and use, which generated, classified and validated by using ground control points method in the same year of Landsat images and google earth pro imagery map, were used in order to measure the accuracy assessment. An overall accuracy values of 86%, 87% and Kappa values of 0.84, 0.88 were achieved for the unsupervised classified maps of 2004 and 2011, respectively. Land cover analysis: In this study, land cover analysis by using the Land use classification in five classes (i.e. No vegetation, Sparse vegetation, Medium Vegetation, High Vegetation and Dense Vegetation) is conducted. Slope class divide into 6 class i.e. 0 -10^0, 10-20^0, 20-30^0, 30-40^0, 40-50^0 and >50^0 by analysis slope in software ArcGIS 10.3 (Fig. 1). Historical landslide inventory was identified by delineated in google earth pro by using high resolution image time series from 2012 to 2014.

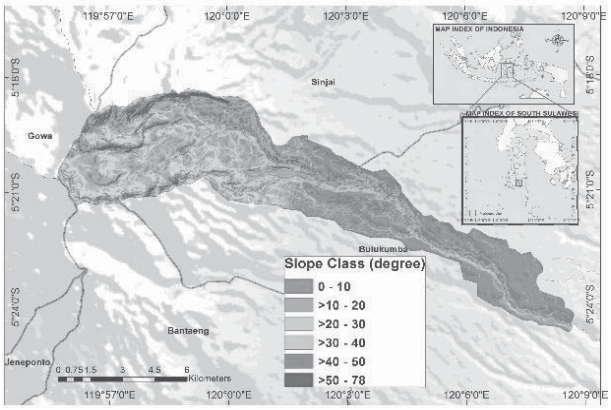

Fig. 1 Slope of study area

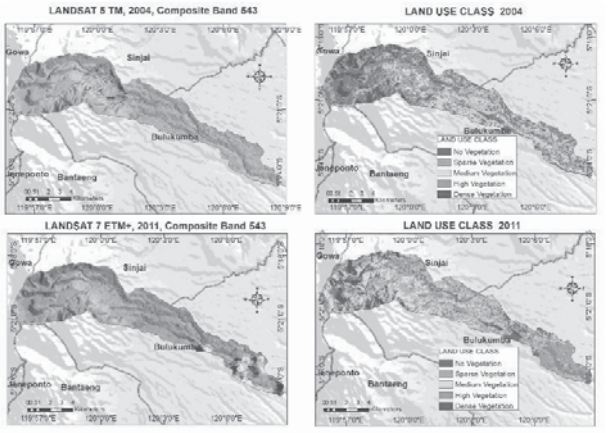

Fig. 2. Image Landsat and Land Use class from 2004 and 2011

Statistical analysis (Binary Logistic Regression) to see the correlation between Land Use Change, Slope and Landslide occurance were conducted.

4. Results and Discussion

The significant changes of land use/cover change in the study area as shown in Table 1 and fig. 2 and fig.3. Results of the land use/cover analysis confirmed the increase of the Medium-vegetation class from 2.017 ha in 2004 to 2.931 ha in 2011 (increasing was 5.66% per year) because of the increased rates of farming areas. This rising rate can be attributed to the increasing population in need of agricultural land in the study area based on data from Central Bureau of Statistics of South Sulawesi (2013). The increasing rate population was 1.15% mainly with agriculture worker. On the other hand, the class of dense vegetation decreased from 1.685 ha in 2004 to 914 ha in 2011 or decreased 96.27 ha per year because of open land for farming and ilegal logging in dense forest areas.

Table 1. Changes in the Land use densities between 2004 and 2011

Land Use Density Class	2004 Land Use Density Class area			2011 Land Use Density Class area			Change between 2004 to 2011		Average rate of change	
	cells	ha	%	cells	ha	%	ha	%	ha/year	%
No Vegetation	15470	1392	17.41	6081	547	6.84	-845	-60.69	-105.63	-7.59
Sparse Vegetation	25021	2252	28.15	29794	2681	33.52	430	19.08	53.70	2.38
Medium Vegetation	22416	2017	25.22	32568	2931	36.64	914	45.29	114.21	5.66
High Vegetation	7255	653	8.16	10276	925	11.56	272	41.64	33.99	5.21
Dense Vegetation	18717	1685	21.06	10160	914	11.43	-770	-45.72	- 96.27	-5.71
Grand Total	88879	7999	100.00	88879	7999	100.00				

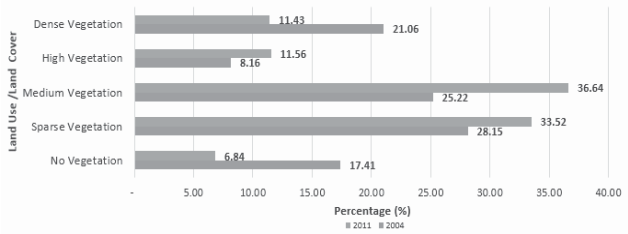

Fig. 3. Histogram of land use change from 2004 to 2011

The Landslides occurrence has occurred 128 times at 2012 comparing with 2014. The highest lanslides was in 2013 with 93 times. It was happen with heavy rainfall with 5474 mm/year and intensity 27.8 mm/day in 2013 (Meteorology, climatology and geophysics Makassar, 2015).

The significant derivate factor of land use/cover change to landslides in the study area as shown in (Fig. 4a). Results of the land use/cover to landslides occurance analysis confirmed the highest of land use change from high vegetation to medium vegetation on the slope >30^0 with 82 landslides occurance. It happens because decrease in the vegetation can make negative influence to the stability slope as Kubota et. all. (2007) that land with forest by the root system will be reinforce the soil strength and stabilizes the slope.

Statistical analysis indicates that land use change (from the dense vegetation to high vegetation, high vegetation to medium high vegetation respectively, and so on) has influence on landslide occurrences. Further statistical analysis showed that in term of influence to landslide occurences, slope showed greater influence (B-intercept: 0.672) compared to individual land use change(B-intercept: -0.007)(Fig. 4b). However, general land use changes (B-intercept: 0.312) along with the slope (B-intercept: 0.662), influence the landslide occur occurrences (Fig. 4c). It was like as Begueria (2005), that land use change has effect with the landslide occurrences.

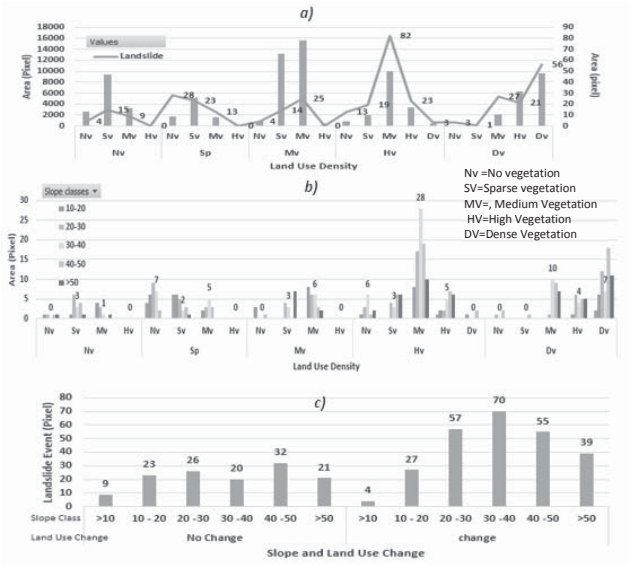

Fig. 4. Analysis land use change, slope and Landslide; a) Land Use change and landslide, b) Land Use Change by individual, slope and landslide; c) Land Use change occurence, slope and landslide

5. Conclusion

The significant land use change from 2004 to 2011 is observed at Ujung Loe watersheds in no vegetation and dense vegetation class. The higher increased ones were medium vegetation and high vegetation class. Landslides has occurred 128 times between 2012 to 2014 and the most frequent is in 2013. The general land use change in Ujung Loe watershed indicates significant effect to landslides occurrence and slope instability.

Acknowledgements

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