

Landslide Zonation at the Budong-Budong Watershed, Central Mamuju District of West Sulawesi Province

Muchtar S. Solle¹, Paharuddin², Asmita Ahmad¹, and Muh. Ansar¹

¹ Jurusan Ilmu Tanah Fakultas Pertanian Universitas Hasanuddin, Jl. Perintis Kemerdekaan KM 10 Makassar

² Program Studi Geofisika Fakultas MIPA Universitas Hasanuddin, Jl. Perintis Kemerdekaan KM 10 Makassar

e-mail: muchtarsolle@gmail.com

Abstract

The objectives of this study are as follows: first, to investigate the contributing parameters induced land sliding in the Budong-Budong watershed, and second, to construct landslide susceptibility zonation map. In this study, the analytical hierarchy process (AHP) based on Geographical Information System (GIS) methods was used to produce map of landslide susceptibility. In this study area, more than 50% of total area were classified high (H) to very high (VH) susceptibility landslide zone. Mean while, 12% of total area were classified as moderate (M) and remaining were classified as low (L) to very low (VL) susceptibility landslide zone. Almost area of Budong-Budong Watershed were classified as VH and H susceptibility landslide zone underlying by Talaya (Tmtv), Lamasi (Toml) and Latimojong (Kls) Formation on the steep slope land.

Keywords: AHP, GIS, Budong-Budong, landslide, watershed

Abstrak

Penelitian bertujuan untuk membangun peta kerentanan longsor di wilayah tersebut. Penelitian ini menggunakan metode Analytical Hierarchy Process (AHP) dan Sistem Informasi Geografis (SIG) untuk membangun peta kerentanan tanah longsor. Hasil penghitungan mengklasifikasikan Indeks kerentanan tanah longsor menjadi 5 kategori yaitu sangat rendah, rendah, sedang, tinggi dan sangat tinggi. Berdasarkan peta zona kerentanan tanah longsor di wilayah DAS Budong-Budong, terdapat zona kerentanan tanah longsor kategori tinggi sampai sangat tinggi mencapai luas 187.429 ha atau 59 persen dari total luas wilayah DAS Budong-Budong. Wilayah DAS Budong-Budong yang tercakup didalam zona kerentanan tanah longsor kategori tinggi sampai sangat tinggi terdiri dari Formasi Talaya (Tmtv), Lamasi (Toml) dan Latimojong (Kls) pada bentang lahan berlereng terjal.

Kata kunci: AHP, Budong-Budong, DAS, longsor, SIG

Introduction

Landslide is one of natural disasters which causes property damage, death and adversely affect on infrastructure and farmlands. In Indonesia, it is the third most extreme disaster after flood and storm (BNPB, 2012). In Sulawesi island, landslides happen every year in rainy season. On 18 November 2013, landslide happened in Budong Budong watershed, West Sulawesi. Mass movements reached the body of Le'bo river (tributary of Budong Budong river) and made some temporary barriers. When the rain came in abundant, they were collapsed and caused flood to the community situated in alluvial lands.

The landslide susceptibility at the upstream should become a concern particularly when it comes rainy season since it may cause negatif effect to the downstream (Miardini dan Harjadi, 2011). There should be a study about it to anticipate the same

disaster. With or without a flood, a landslide may cause hazardous effects not only to people's lives, but it also distracts economical and social stabilities as what had happened to the landslide and hazardous flood in Gowa Regency caused by the collapse of Mount Bawakaraeng's caldera (26 March 2004), the collapse of natural watershed in Way Ela river in Maluku (25 July 2013) and in Biring Ere, Sinjai Regency (20 Juni 2006), and several disasters in other regencies or provinces in Indonesia.

The Local Regulation No. 24 year 2007 about Disaster Mitigation has changed paradigm of disaster management that is from responsif way (centered to disaster preparadness and recovery) to preventif one (centered to disaster mitigation and readiness). However, it is a concern that only few programs which can run well.

A landslide with or without hazardous flood preceding it happens in an unpredictable and short time. The wide areas affected by landslides at the upstream of the watershed have become a challenge to reveal the landslide causes and any mitigation that should be done. Fell et al. (2008) and Priyono et al. (2008) stated that landslide susceptibility was because of slope steepness and the combination of the slopes, geology, climate, vegetation and antropogenic such as deforestation and other significant factors.

Research Method

Objects of the research is Budong Budong watershed which administratively situated in Center Mamuju Regency, West Sulawesi Province. This watershed spreads from the northeast to the west with total area 317,514 ha.

This research is conducted by applying the analysis of geographical informative system including Overlaying, Buffering, and Network Analyzing based on multi-criteria analysis and Analytical Hierarchical Process (AHP). This AHP has been used by other researchers (Ayale et al., 2005; Komac, 2006; Intarawichian and Dasananda, 2010; Yalcin, 2008; Yalcin et al., 2011). For the process above, the maps or the layers of all factors/parameters in this research should be prepared first (Figure 1) and those are :

- elevation map from Aster DEM, 2009. Resolution 30m
- slope steepness map from Aster DEM, 2009. Resolution 30m
- slope aspect map from Aster DEM, 2009. Resolution 30m
- lithology map from the map of regional Geology of Sulawesi
- straightness map from the map of regional geology of Sulawesi
- map of proximity to river from the Indonesian Topographic Map with the scale of 1: 50.000
- map of proximity to road from the Indonesian Topographic Map with the scale of 1: 50.000
- isohyet map from the annual rainfall data of Kalumpang station, Karossa, Mamasa and Majene
- The Land cover map from citra landsat TM 7 year 2011
- The Soil Texture map from the report of RePProT

and RTSP Transmigration

The landslide susceptibility map of Budong Budong watershed is built with the AHP method and in this method, index of landslide susceptibility in every pixel is calculated by adding up the values of every factor causing landslide with the formula:

$$LSI = \sum (W_i * R_i) \quad (1)$$

Where : LSI is the index of landslide susceptibility in every pixel, R_i and W_i are the the value level and the value factor (1) which are from the result of AHP method. Since the basic of the calculation is in pixel, all maps or layers are in the form of vector data which is transformed into the raster form and then it is time to add the value of each layer which is resulted from the AHP process (Table 1). The ultimate process is the making of the landslide susceptibility map using formula (1), which is automatically calculated by weighted overlaying technique in the menu of program Arcgis 10.2. Using the natural breaks algorithm menu (Figure 3), the result of LSI value is divided into 5 categories of landslide susceptibility zones : 1. Very high, 2. High, 3. Medium, 4. Low, and 5. Very low (Table 2).

Result and Discussion

Based on the evaluation result to the 10 factors causing landslide (Table 1), there are three major factors which have the highest value as the causes of the landslide in Budong Budong watershed: lithology (0.237), land steepness (0.222) and rainfall (0.169). The annual rainfall is approximately 2900 mm/year with the maximum average 4386 mm/year and the minimum average 1710 mm/year with the steepness average of the land is >20%. Lithology which is on the steepness >20% is dominated by lithology from Talaya (Tmtv), Lamasi (Toml), and Latimojong Formations (Kls). Those formations generally are formed from materials or sediment particles and pyroclastic with soft particles (1/16 mm) which partly change into metamorphic rocks (in Latimojong formation/Kls). The activity of geology structure at Plio-Pleistosen (Calvert and Hall, 2007) has reduced the stability of the rocks from those three formations. This is just like what Ahmad and friends (2014) said that the landslide at sub Salo Lebo watershed which was part of Budong Budong watershed generally happened because of the movement of tuffa from the Lamasi and Talaya formation. That rocks has

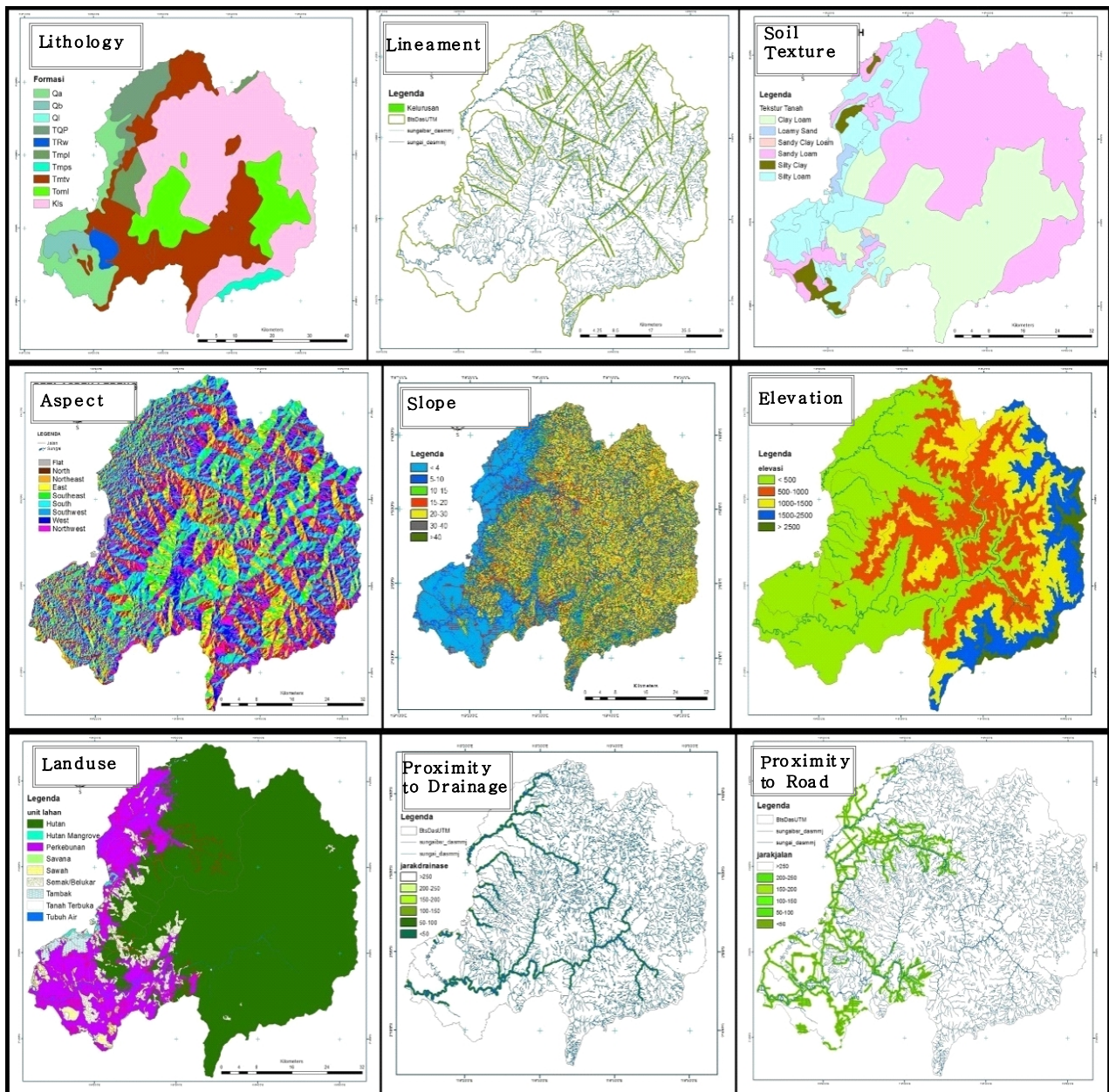


Figure 1. Thematic/layer map which is used to build the map of landslide susceptibility of Budong Budong

experienced a decline of shear strength. Significant amount of fissions in tufa may cause in the decline of stone stability which becomes so low mainly due to the intensif weathering process of the stone surface and the internal stone resulted from fission. The materials making up the tufa are soft and they may fasten the decline of rock stability (Comegna, et al., 2013; Regmi et al., 2013). This texture has mineral crystal surface so that the chemical and physics reactions due to the interaction with subversive water result in the increase of shear stress.

The value of landslide susceptibility index (LSI) is calculated by using the formula (2). From the result it is known that the LSI has a minimum value of 0.03

and maximum value of 0.25 with the average value of 0.14 and deviation standar 0.05. LSI is mainly a relative susceptibility of landslide. Therefore, the higher index that an area has, the higher susceptibility of area to experience landslide. For further process, the index value is divided into five levels based on the Natural Breaks method (see Figure 2) which represent five different zones of landslide susceptibility. Finally, those zones are classified into five levels: very high (VH), High (H), Medium (M), Low (L), Very Low (VL) and they are described in the map of landslide susceptibility (Figure 3). In addition, their percentages are shown in Table 2.

Landslide susceptibility Zone which includes high to

Table 1 (continued)

Distance to lineament										0.052
(1) 0 – 50	1	4	6	7	8	8				0.497
(2) 50 – 100		1	4	5	6	7				0.250
(3) 100 – 150			1	4	4	4				0.122
(4) 150 – 200				1	2	3				0.059
(5) 200 – 250					1	2				0.041
(6) >250						1				0.031
Inconsistency = 0.08										
Distance to drainage (m)										0.039
(1) 0 – 50	1	5	6	7	8	9				0.561
(2) 50 – 100		1	1	2	2	3				0.131
(3) 100 – 150			1	1	2	2				0.105
(4) 150 – 200				1	2	2				0.092
(5) 200 – 250					1	2				0.064
(6) >250						1				0.046
Inconsistency = 0.02										
Slope aspect										0.034
(1) Flat	1	1/7	1/3	1/2	1/6	1/7	1/7	1/5	1/8	0.019
(2) North		1	1	3	1	1/2	1/2	1	1/2	0.091
(3) Northeast			1	2	1/2	1/6	1/2	1	1/2	0.064
(4) East				1	1/5	1/8	1/4	1/3	1/4	0.030
(5) Southeast					1	1/6	3	1	1/3	0.112
(6) South							1	7	1	0.291
(7) Southwest							1	1	1/3	0.093
(8) West								1	1/3	0.116
(9) Northwest									1	0.182
Inconsistency = 0,07										
Elevation (m)										0.030
(1) 500 – 1000	1	1/4	1/5	1/6	1/7	1/8				0.980
(2) 1000 – 1500		1	1	1/2	1/3	1/4				0.129
(3) 1500 – 2000			1	1/6	1/6	1/8				0.179
(4) 2000 – 2500				1	1/4	1/6				0.247
(5) >2500					1	1/7				0.318
Inconsistency = 0,02										1
Distance to road (m)										0.017
(1) 0 – 50	1	4	5	6	7	8				0.475
(2) 50 – 100		1	4	5	6	7				0.259
(3) 100 – 150			1	4	4	4				0.129
(4) 150 – 200				1	2	3				0.062
(5) 200 – 250					1	2				0.043
(6) >250						1				0.031
Inconsistency = 0,02										

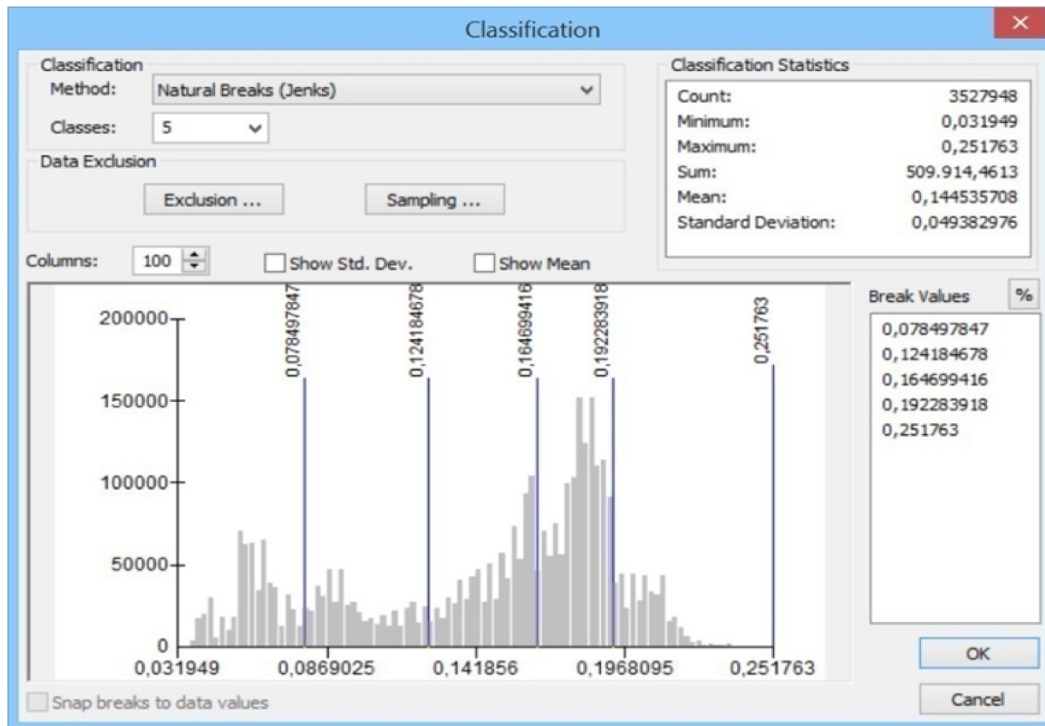


Figure 2. Diagram of LSI classification

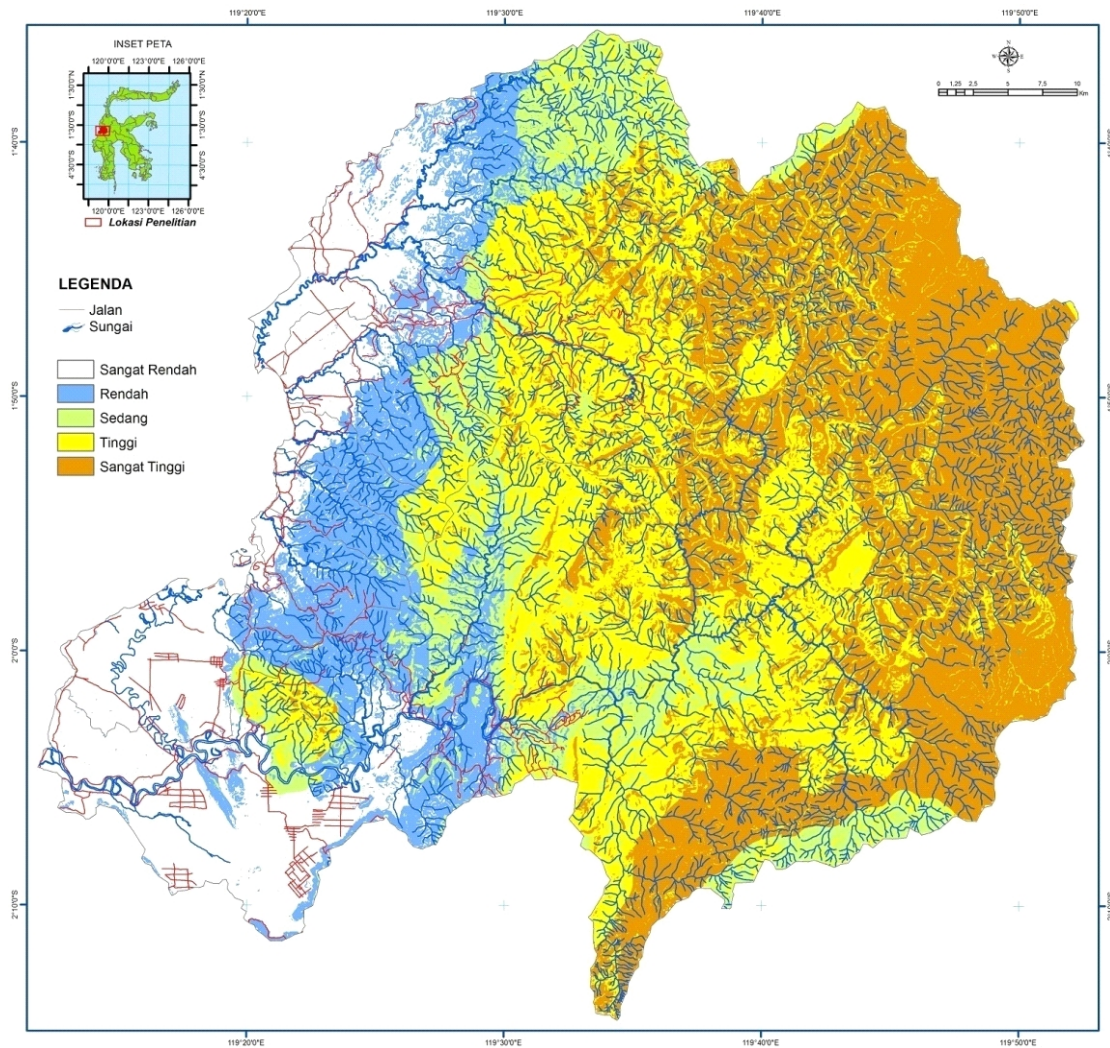


Figure 3. Map of Landslide susceptibility Zone of Budong Budong watershed

Table 2. Landslide susceptibility levels of Budong Budong watershed

No	Number of pixel	Level	Area (Ha)	Percentage (%)
1	586,236	Very Low	52,761.24	16.62
2	447,920	Low	40,312.80	12.70
3	411,232	Medium	37,010.88	11.66
4	964,846	High	86,836.14	27.35
5	1,117,708	Very High	100,593.72	31.68
Total			317,514.78	100.00

very high level has the area 187,429 ha or 59% of the total area of Budong Budong watershed while the zone which includes the medium level has the area 37,010 ha or 27.35% of Budong Budong watershed. Since it is relatively wide, the government center development at the downstream of Budong Budong watershed should have a precise estimation and intergrated plan with the development at the upstream.

Conclusion

1. Based on the evaluation result of landslide causes, there are three main factors causing the landslide in Budong Budong watershed: lithology (0.237), land steepness (0.222) and rainfall (0.169).

2. The category of Landslide susceptibility zone at Budong Budong watershed is high and even very high with the total area 187,429 ha or 59% of the total area of Budong Budong watershed. Its distribution mainly extents from the middle to upstream of Budong Budong watershed particularly at Talaya formation, Lamasi and Latimojong.

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References

- Ahmad, A., Solle, M.S., Paharuddin. 2014. Hubungan antara Faktor Litologi dengan Tipe dan Pola Longsoran di Sub Das Salo Lebbo, DAS Budong-Budong, Kabupaten Mamuju Tengah, Provinsi Sulawesi Barat. Makalah dipresentasikan pada Seminar Nasional Pengelolaan Das Terpadu Untuk Kesejahteraan Masyarakat 2014.
- Ayalew, L., Yamagishi, H., Marui, H., Kanno, T. 2005. Landslides in Sado Island of Japan: Part II. GIS-based susceptibility mapping with comparisons of results from two methods and verifications. *Engineering Geology Journal* 81. 432– 445.
- Calvert, S.J., R. Hall. 2007. Cenozoic evolution of the Lariang ang Karama regions, North Makassar basin, western Sulawesi, Indonesia. *Petroleum Geosciences Journal*. Vol.3. pp. 353-368.
- Comegna, L., L. Picarelli, E. Bucchignani, P. Mercogliano. 2013. Potential effects of incoming changes on the behavior of slow active landslides in clay. *Journal of the International Consortium on Landslides*. Springer. Vol.10. No.4.
- Fell, R., Corominas, J., Bonnard, C., Cascini, L. Leroi, E., Savage, W.Z. 2008. Guidelines for landslide susceptibility, hazard and risk zoning for land use planning. *Engineering Geology Journa* 102. 85–98
- Intarawichian, N. and Dasananda, S. 2010. Analytical hierarchy process for landslide susceptibility mapping in lower Mae Chaem watershed, Northern Thailand. *Suranaree Journal of Science and Technology* 17 (3) : 277-292
- Komac, M. 2006. A landslide susceptibility model using the Analytical Hierarchy Process method and multivariate

statistics in perialpine Slovenia. *Geomorphology Journal* 74. 17-28.

- Miardini, A., B. Harjadi. 2011. Aplikasi penginderaan jauh dan SIG dalam penilaian potensi erosi permukaan secara kualitatif di daerah tangkapan waduk Kedung Ombo. *Jurnal Forum Geografi*. Vol.25. No.2. Hal. 152-163.
- Priyono, Kuswaji Dwi. 2008. Analisis morfometri dan morfostruktur lereng kejadian longsor di Kecamatan Banjarmangu Kabupaten Banjarnegara. *Jurnal Forum Geografi*. Vol.22. No.1 Juli. Hal. 53-69.
- Regmi, A.D., K. Yoshida, M.R. Dhital, K. Devkota. 2013. Effect of rock weathering, clay mineralogy, and geological structures in the formation of large landslides, a case study from Dumre Besei landslides, Lesser Himalaya Nepal. *Landslides Journal*. Springer-Verlag.
- Republika, 2013 Banjir bandang, 3 desa di Mamuju terendam. www.republika.co.id/
- Yalcin, A. 2008. GIS-based landslide susceptibility mapping using analytical hierarchy process and bivariate statistics in Ardesen (Turkey): Comparisons of results and confirmations. *Catena Journal* 72. 1-12.
- Yalcin, A., Reis, S., Aydinoglu, A.C. and Yomralioglu, T. 2011. A GIS-based comparative study of frequency ratio, analytical hierarchy process, bivariate statistics and logistics regression methods for landslide susceptibility mapping in Trabzon, NE Turkey. *Catena* 85. 274-287.