AN ANALYSIS OF POTENTIAL HAZARD AND RISK FOR FLOOD AND LANDSLIDE AREAS (CASE STUDY IN WEST JAVA PROVINCE)

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ABSTRACT

West Java is one of the regim in the high potential occurrence of floods and landslides. This is due to the characteristics of its topography, as well as high population density which increase every year, causing pressure on the ecosystem. The purpose of this study was to build methodology in determining floods and landslides criteria, mapping of potential hazards and the risk of flooding, and landslides. Models of potential hazard and risk of flooding and landslides built through spatial analysis system with weighted and scoring of the 7 parameters used landuse, rainfall, slope, elevation, landform, soils and geology while the risk model to floods and landslides

used vulnerability parameters (consist of infrastructure, accessibility/road and land use), and element of risk parameters (consist of population density, emergency response and GDP). The results showed West Java has the high potential flood-prone of 460.204 ha (12.5%) and very high at 507.274 ha (13.8%), with distribution locations in Bekasi, Cirebon, Indramayu, Karawang, Majalengka, Subang, Bandung City, Banjar City, Bekasi City, Bogor City, Cirebon City, and Depok City. As for the high potential of landslide-prone of 141.855 ha (3.9%) and very high at 14.895 ha (0.4%), with distribution locations in Bandung dan Garut. Based on the results of field validation and recapitulation data of floods and landslides incidence in the field from BNPB (2010–2012), showing the results map accuracy of the analysis of hazard and risk potential of flooding and landslides are quite high. The frequency of floods in the field occurs 88 times as much as the moderate to very high class of flood hazard potential areas of with a total of 115 times the incidence of flooding, or by 76.5% of the total flood. While the frequency of landslides in the field occurs 86 times in the classes as moderate to very high landslide hazard potential with a total of 113 times the incidence of landslides, or 76.1% of the total landslide.

Keywords: Hazard, Risk, Floods, Landslides, Accuracy

1. INTRODUCTION

Trends disaster in Indonesia has increased from year to year. Hydrometeorological disasters such as floods, droughts, landslides, cyclones, and tidal waves are the dominant type of disaster in Indonesia. Hydrometeorological disasters occurred on average almost 70% of total disaster in Indonesia. Global climate change, land use change, and increasing population magnify the threat of further risk reduction in Indonesia (BNPB, 2011). Flooding is the inundation in the event of a flat area around the river as a result of the overflow of river water flow of the river can not be

accommodated. Flooding is the interaction between man and nature aspects arising from the process by which people try to use natural beneficial and avoid adverse nature (Rasyid H, 2010). Landslides are a product of the balance disorder that causes mass movement of soil and rock from a higher to a lower place. The movement is due to the style factor lies in the areas of uneven ground or called slope (Nicoll K, 2010).

Causes of landslides are naturally covers the earth's surface morphology, land use, lithology, structural of geology, rainfall, and earthquake. In addition to natural factors, landslides also caused by human activity factors that affect the landscape such as agricultural activities, the imposition of slope, slope cutting, and mining (Mathew J. *et al.* 2007). West Java is one area that has a high potential for the occurrence of landslides. This is in addition due to the topography of the hilly and mountainous regions, as well as high population density puts pressure on the ecosystem. Landslide prone areas of West Java province including in Bandung, Cianjur, Bogor, Sukabumi, Majalengka, Sumedang, Ciamis, Tasikmalaya, Kuningan, and Purwakarta. Judging from the demographic aspect, the area is a densely populated area (Directorate of Volcanology and Geological Hazard Mitigation, 2002).

One form of mitigation in order to deal with natural disasters and at the same time to reduce its impact is the availability of an early warning system. The absence of an early warning system that could save the people and the environment and the lack of understanding of the environment they live in, the cause of many fall victim to any of floods and landslides disaster (Gupta AK. *et al.* 2010). Application of Remote Sensing and GIS technology can help mitigate natural disasters by identifying the location and review of issues related to the impact of floods and landslides. Mitigation measures to reduce or minimize the impact of floods and landslides done by making a model of GIS, by combining several variables to obtain the most vulnerable to the hazard and risks of floods and landslides (Kabir A. *et al.* 2011).

The objectives of this research are (1) determine the criteria and parameters forming floods and landslides, (2) determine hazard and risk potential areas of floods and landslides in West Java Province.

2. DATA AND METHODS

2.1 Time and Research Site

The study was conducted from April 2011 to October 2012. Locations of research lies in West Java Province, while the processing and analysis of data is done in the Ministry of Environment, Jakarta as well as in the Spatial Information Laboratory Section, Department of Soil Science and Land Resources, Faculty of Agriculture, Bogor Agricultural University.

2.2 Research Design

This study was designed to collect secondary data and primary data to answer the question of how to determine the criteria and parameters forming floods and landslides, as well as determine the potential areas of hazard and risk of floods and landslides. The matrix design of the study are shown in Table 1, while the flow chart stages of research are presented in Figure 1.

2.3 Weighting and Scoring Method

In determining the weight and score of each parameter forming floods and landslides, the Analytical Hierarchy Process-AHP method is used which developed by Thomas L. Saaty, to organize information and expert opinion (judgment) in selecting the most preferred alternative. In the AHP process is done by making pairwise comparison matrices questionnaire of the parameters and variables to be determined weights and scores (Marimin, 2010).

Table 1. Research design matrix of hazard and risk potential for floods and landslides analysis

Objective	Types and Sources of Data	Data Collection Techniques	Data Analysis Techniques	Output
Determining the criteria and parameters forming floods and landslides	Landuse, Landform, Elevation, Slope, Rainfall, Geology, Type of Soil	- Study of Literature - Questionnaire - *Expert Judgement*	- *Analytical Hierarchy Process (AHP)* - Software Expert Choice - Descriptive	The criteria weights and scores of each parameter forming floods and landslides
Knowing the potential areas of hazard and risk for floods and landslides	Landuse, Landform, Elevation, Slope, Rainfall, Geology, Type of Soil	Extraction from satellite imagery, topographic maps, soil maps, rainfall data, geological and landsystems data	Spatial Analysis (Scoring and Weighting)	Map of the potentially area of hazard and risk floods and landslides

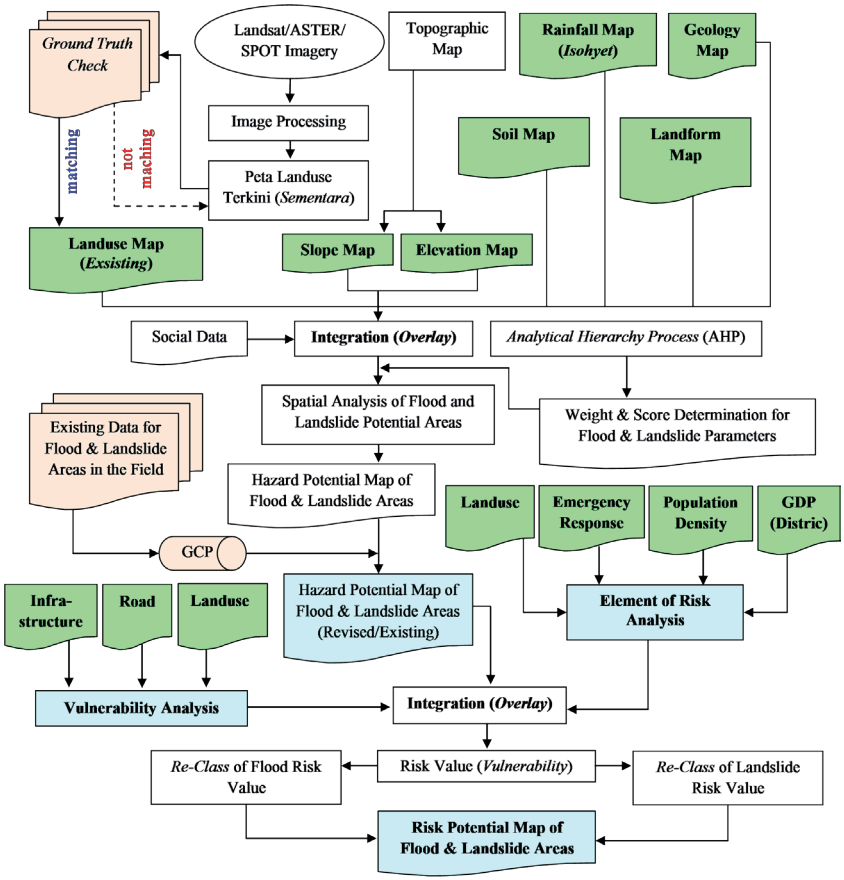

Figure 1. Flowchart stages of research

Respondents involved in the AHP process is a 6 (six) people, who represent expertise in the areas of flooding and landslides, soil physical, geological, land suitability, environmental mitigation, as well as modeling and Geographic Information Systems (GIS). Data processing is carried out using a questionnaire AHP software Expert Choice 2000. The weight indicates the magnitude or degree of the value of each parameter indicated by the range of scores 0–1, while the score indicates the value of each variable on each of

the parameters indicated by the range of values 0–100. AHP analysis result for the weight of each parameter forming floods and landslides are shown in Table 2, while the weight and score of each parameter and variable-forming floods and landslides are shown in Appendix 1 and Appendix 2.

Table 2. The weight of each parameter forming floods and landslides

No.	Parameters	Weight	
		Flood	Landslide
1	Landform	0,277	0,167
2	Rainfall	0,108	0,067
3	Elevation	0,126	0,280
4	Geology	0,026	0,109
5	Soil	0,036	0,031
6	Slope	0,377	0,310
7	Landuse	0,049	0,038

Source: result of AHP analisis, 2013

2.4 Analysis of Floods and Landslides Hazard Level

Value of floods and landslides hazard areas are determined from the total sum of the multiplication of the weights and scores from 7 (seven) parameters that influence flooding and landslides above. Determination of the hazard level as much as done by dividing the values of the hazard level with the same number of intervals class; class intervals determined by the equation **i = R / n**; where **i**: width inteval, **R**: difference between the maximum and minimum scores, **n**: number of vulnerability classes.

2.5 Analysis of Floods and Landslides Risk Level

Risk potential map of flooding and landslides derived from floods and landslides hazard which then integrated (overlay) with the results of the analysis of vulnerability. Analysis of the vulnerability it self is combine

between vulnerability parameters (consist of infrastructure, road/ accessibility and landuse) and element of risk (consist of population density, emergency response, and gross domestic product/GDP). Integration map results with the criteria of vulnerability analysis resulted in a final value that has been reclassified, based on the value of the matrix reclassification risk of flooding and landslides.

3. RESULT

Biophysical Condition of West Java Province

Geographically located in the West Java province at 5°50'-7°50' latitude and $104^0$48' -$108^0$48' BT where north is bordered by Java Sea and Jakarta, east to Central Java Province, south of the Indonesian Ocean, and west by the province of Banten. Extensive land area is 3,680,951 hectares with a coastline of 724.85 km. The population in 2011 are 46,497,175 million people, spread over 26 regencies/cities, 625 districts and 5,899 Village. Based on the Koppen classification system that bases the relationship between climate and vegetation growth, West Java Province including **Afa** into climate types (where: **A** is the tropical rainy climate with the coldest month temperature >18°C; **f** is always wet with rain every month >60 mm, and **a** is the average temperature of the warmest month >22.2°C).

Flat to gentle slope dominates the vast percentage of 24.3% in the form of land with a flat slope (<2%), and 23.9% in the form of land with gentle slopes (2-8%). Landform is dominated by Plains (30.4%), Hills (19.8%), Mountains (19.4%) and Alluvial Plains (15.6%) of the total area of West Java Province. Landuse in 2012 was dominated by vast paddy fields with 1,323,822 ha (35.7%), mixed garden covering 972,747 ha (26.2%), settlement area of 453 044 ha (12.2%) and dryland agriculture area of 313 026 ha (8.4 %) of the total area of West Java Province.

Flood and Landslide Hazard Potential Areas

Based on the analysis of the flood and landslide hazard potential maps, can be seen that the West Java Province is dominated by the low flood-prone potential at 37.8%; while the high and very high flood-prone potential areas only 12.5% and 13.8%. Landslide hazard potential areas is dominated by low landslide-prone class by 42.5% and 31.6% safe areas; whereas high and very high landslide-prone potential areas only by 3.9% and 0.4% of the total area of West Java province (Table 3).

Distribution of potential areas for occurrence of floods per distric/city with a high and very high flood-prone classes are in Bekasi (25.8% and 57.2%), Cirebon (38.8% and 36.6%), Indramayu (32.7% and 62.4%), Karawang (12.4% and 67.8%), Majalengka (31.3% and 10.1%), Subang (22.8% and 31.6%), Bandung City (58.3% and 0.0%), Banjar City (15.4% and 30.4%), Bekasi City (57.4% and 22.8%), Bogor City (50.7 % and 16.9%), Cirebon City (50.2% and 28.4%), and Depok City (56.5% and 19.0%). While the potential distribution area of the landslide by distric/city with high and very high landslide-prone classes are in Bandung District (21.8% and 2.7%) and Garut (12.5% and 1.0%). Distribution of floods and landslides hazard potential per distric/city, and map of floods and landslides hazard potential areas shown in Figure 2 and Figure 3.

Flood and Landslide Risk Potential Areas

Based on the analysis of floods and landslides risk potential areas can be seen that the West Java Province is dominated by low flood-risk potential areas of 93.0% whereas moderate and high flood-risk potential areas only by 5.2% and 1.8%. The risk potential of landslides in West Java Province is dominated by the low landslide-risk areas of 98.2% whereas moderate and high landslide-risk areas only 1.7% and 0.1% (Table 4).

Distribution of the area that has the potential for the occurrence of flood risk by districts/ cities with high flood-risk class are in Bandung City (42.4%),

Bekasi City (44.1%), Bogor City (24.4%), Cimahi City (19.2%), Cirebon City (28.2%), and Depok City (24.9%). While the risk potential distribution area of the landslide by district/city with high landslide-risk class, only in Bandung Distric (0.2%) and Garut Distric (0.5%). Distribution of flood and landslide risk potential areas by district/city, and map of floods and landslides risk potential areas shown in Figure 4 and Figure 5.

Table 3. Range value and flood-prone and landslide-prone areas in West Java Province

No.	Prone Classes	Flood-Prone Potential			Landslide-Prone Potential		
		Range Value	Areas		Range Value	Areas	
			Ha	%		Ha	%
1	Safety Area	4,82 - 8,69	653.871	17,8	3,34 - 7,39	1.164.444	31,6
2	Low-Prone	8,69 - 12,56	1.393.211	37,8	7,39 - 11,44	1.564.541	42,5
3	Moderate-Prone	12,56 - 16,43	666.389	18,1	11,44 - 15,49	795.215	21,6
4	High-Prone	16,43 - 20,30	460.204	12,5	15,49 - 19,54	141.855	3,9
5	Very High-Prone	20,30 - 24,17	507.274	13,8	19,54 - 23,62	14.895	0,4
Total			**3.680.951**	**100,0**		**3.680.951**	**100,0**

Source : result of analysis, 2013

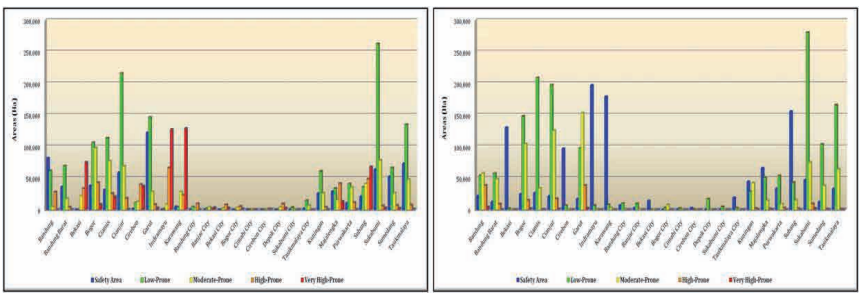

Figure 2. Graph of the distribution of potential flood and landslide prone by district/city

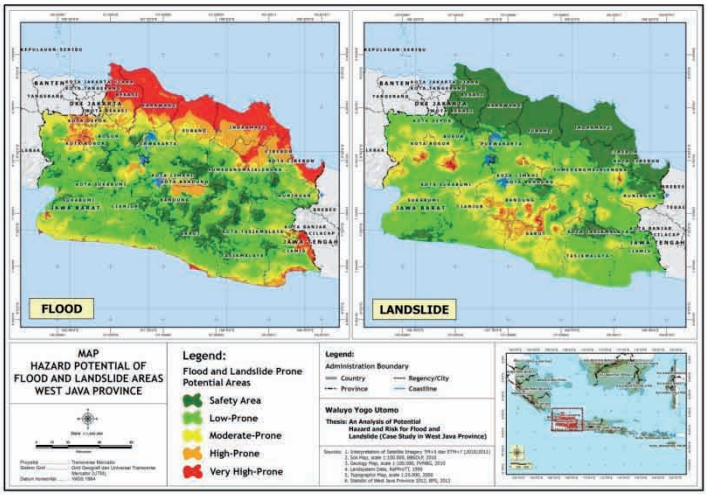

Figure 3. Map of flood and landslide hazard potential areas in West Java Province

Table 4. Risk potential of flood and landslide areas in West Java Province

No.	Risk Potential	Flood-Risk Potential Areas		Landslide-Risk Potential Areas	
		Ha	%	Ha	%
1	Rendah	3.422.677	93,0	3.616.460	98,2
2	Sedang	190.671	5,2	61.836	1,7
3	Tinggi	67.603	1,8	2.655	0,1
Total		**3.680.951**	**100,0**	**3.680.951**	**100,0**

Source : Result of analysis, 2013

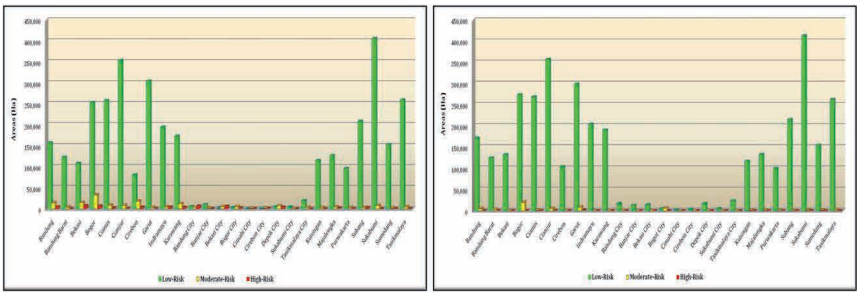

Figure 4. Graph of the distribution of potential risk of flooding and landslides per district/city

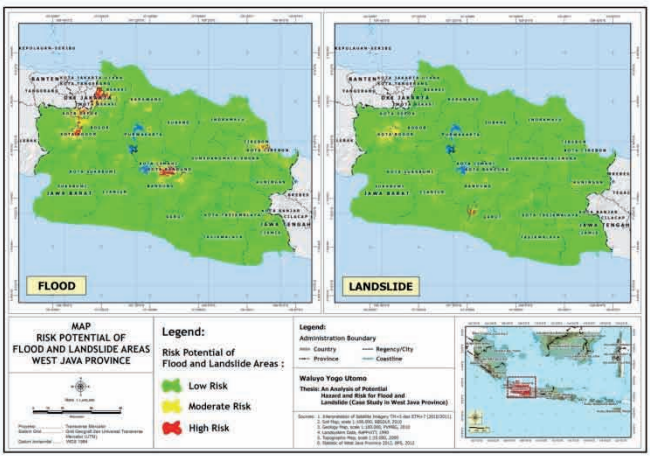

Figure 5. Map of flood and landslide risk potential areas in West Java Province

Level of Accuracy Based on Field Validation

Based on the results of field validation and summary incidence data of floods and landslides in the field from National Disaster Management Agency (BNPB) on 2010–2012, shows the degree of accuracy of maps results and an analysis of potential flood-prone and landslide-prone are quite high.

The frequency of floods in the field occurs 88 times as much as the class of potential flood-prone moderate to very high with a total of 115 times of flood events, or by 76.5% of the total flood. While the frequency of landslides in the field occurs as much as 86 times in a class of potential landslide prone moderate to very high with a total of 113 times the occurrence of landslides, or 76.1% of total landslides (Table 5 and Figure 6).

Table 5. The occurrence frequency of floods and landslides in the field (existing)

Disaster	Flood and Landslide occurrence frequency					Total
	Safety Area	Low-Prone	Moderate-Prone	High-Prone	Very High-Prone	
Flood	6	21	7	50	31	**115**
Landslide	4	23	8	51	27	**113**
Total	**10**	**44**	**15**	**101**	**58**	**228**

Source : Result of analysis, 2013

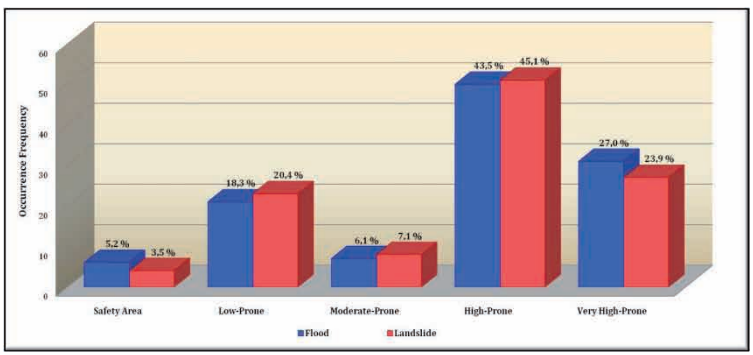

Figure 6. Graphs and percentage frequency of floods and landslides occurrence in the field to map flood-prone and landslide potential analysis results

4. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The main parameters and weight values that contribute to flood-prone is rainfall (0.324), slope (0.212), elevation (0,158), landform (0,146), geology (0,056), land use (0.055), and the type of soil (0,049). While the main parameters and the weights that contribute to landslide-prone is rainfall (0.274), elevation (0,254), landform (0.135), land use (0,095), geology (0,094), the type of soil (0.091), and slope (0.057).

West Java Province is dominated by the low potential flood-prone at 37.8%, while the high and very high potential of flood-prone only 12.5% and 13.8% with a wide distribution area per district/city with high and very high flood-prone class are in Bekasi (25.8% and 57.2%), Cirebon (38.8% and 36.6%), Indramayu (32.7% and 62.4%), Karawang (12.4% and 67.8%), Majalengka (31.3% and 10.1%), Subang (22.8% and 31.6%), Bandung City (58.3% and 0.0%), Banjar City (15.4% and 30.4%), Bekasi City (57.4% and 22.8%), Bogor City (50.7% and 16.9%), Cirebon City (50.2% and 28.4%) and Depok City (56.5% and 19.0%). Landslide-prone potential is dominated by low-prone class by 42.5% and 31.6% safety areas whereas the high and very high landslide-prone potential only by 3.9% and 0.4% of the total area of West Java Province with a wide distribution area per district/city with high and very high landslide-prone classes are in Bandung District (21.8% and 2.7%) and Garut District (12.5% and 1.0%).

Based on the results of field validation and summary incidence data of floods and landslides in the field from National Disaster Management Agency (BNPB) on 2010–2012, shows the degree of accuracy of maps results and an analysis of potential flood-prone and landslide-prone are quite high, amounting to 76.5% of total flood and 76.1% of the total landslide in West Java Province.

Recommendations

It is recommended in further studies, to be able to enter the parameters of economic values in the stages of disaster vulnerability analysis environment (floods and landslides), so it can be calculated how much potential losses.

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Appendix 1. Results AHP weights and scores forming parameters flood