ISBN: 978–602–361–072-3

MULTI-HAZARD RISK ASSESSMENT OF KULON PROGO REGENCY

’Azmiyatul ‘Arifati, Ratri Ma’rifatun Nisaa’, Azzuhfi Ilan Tinasar;
Student of Geoinformation for Spatial Planning and Disaster Risk Management, Universitas Gadjah Mada; Yogyakarta
E-mail: azmiyatul@gmail.com

ABSTRACT

Kulonprogo is one of the regency in Yogyakarta Special Region which hazardous and vulnerable. This research aims to map multi-hazard risk in Kulonprogo Regency. Perka BNPB 2/2012 is used as guideline for multi-hazard risk assessment. Hazard and vulnerability analysis are needed in risk mapping through a semi-quantitative approach, which uses weighting factors and index values. Hazards considered in Kulonprogo Regency are flood, landslide, and tsunami. Parameters to determine landslide and flood hazard potential are slope, rainfall, soil, and land use. While, tsunami hazard potential uses inundation height as its parameter. Multi-hazard map is obtained from overlying hazard maps using GIS tool. Vulnerability index is gained from social, economic, physical, and environmental components which are classified into three classes then deliver it through index 0 - 1. The result is risk index in range of 0.4 to 0.79, which indicates Wates, Kalibawang, and Kokap Sub-District as the highest on multi-hazard risk. Whereas, low risk stands to Lendah and Nanggulan Sub-District.

Keywords : Multi-hazard, Risk Assessment, Geographic Information System.

INTRODUCTION

Background

Kulon Progo is a regency in Yogyakarta Special Province which has variety of landforms such as marine, alluvial, and structural denudational. Data from BNPB (Indonesia National Board of Disaster Management) depicts information about disasters that occur since 1998 in Kulon Progo. There have been 12 floods, abrasion, earthquake in 2006, 6 droughts, 7 hurricanes, and 10 landslides.

The research related to disasters in Kulon Progo has been conducted by Widyawati (2013), which resulted some classes of vulnerability in the coastal area of Kulon Progo based on tsunami hazard. More than 70% of total coastal area in Kulon Progo consists of high and medium vulnerability. Geographycally, it is caused by geographical position which directly opposite the Indian Ocean and the meeting place of two tectonic plates, The Eurasian plate and the Indo-Australian plate. Baskoro (2015) mentioned high level of risk zone in Samigaluh which is one of a sub-district in Kulon Progo Regency is distributed in four villages such as Purwoharjo, Sidoharjo, Ngargoharjo, and Pagerharjo. Multi-hazard risk in Temon Sub-District of Kulon Progo Regency represents some hazards such as tsunami, earthquake, flood, hidrometeorology phenomena which collaborate to treat the people living in

Temon District (Mardiatno, 2016). A research which discusses multi-hazard risk in Kulon Progo has been conducted. Therefore, this research aims to map multi-hazard risk in Kulon Progo Regency which will be focused on three disasters: landslide, flood, and tsunami. The benefit of this research is to give information of places which are hazardous and vulnerable and categorized into multi-hazard risk classes: low, medium, and high risk.

METHOD

Study Area

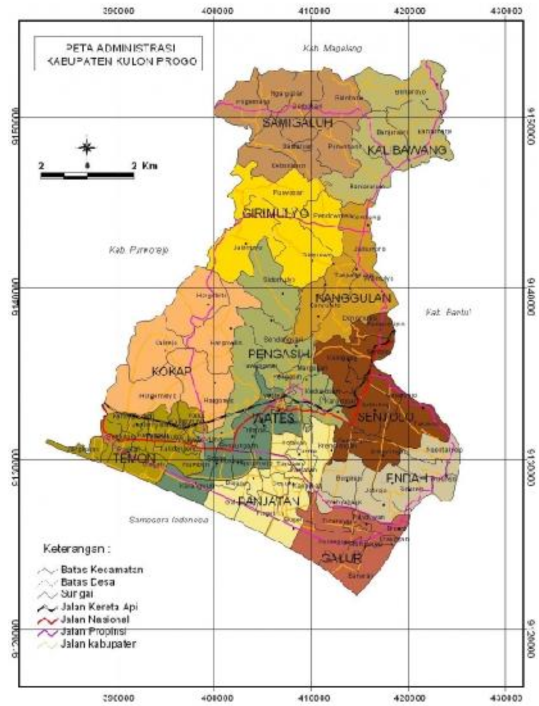

Figure 1. Administration Map of Kulon Progo Regency

Kulon Progo Regency is located in the western part of Yogyakarta Special Region and Wates is the capital of Kulon Progo. Astronomically, Kulon Progo Regency is situated between 7^{o} 38' 42''- 7^{o} 59'3'' south latitude, and between 110^{o} 1' 37''-110^{o} 16' 26'' east longitude. It has 586,28 km^{2} which consists of 12 sub-districts, 87 villages, 1 urban, and 917 hamlets. Based on topography, Kulon Progo Regency includes lowland, upland, and hilly areas. In specific, Kulon Progo landscape is divided into five major groups. 17,58% of the region are less than 7 m above sea level. 15,20% of the region are between 8-25 m above sea level. 22,84% are between 26-100 m above sea level, while 33% area are between 101-500 m above sea level. 11,37% of the region are more than 500 m above sea level (BPS, 2016). In the north part, it is highland of Menoreh Hill with an altitude of 500-1000 meters above sea level, covering Girimulyo, Kokap, Samigaluh, and Kalibawang Sub-District. Land use of this highland is designed as a conservation cultivation area and is prone to landslide. In the middle side, it is hilly area with an altitude of between 100 and 500 meters above sea level, covering Nanggulan, Sentolo, Pengasih, and mostly Lendah. Moreover, in the south part, it is a lowland with a height of 0-100 meters above sea level, including Temon, Wates, Panjatan, Galur, and Lendah. Based on the slope condition, coastal area along 24,9 km is in 0-2% slope which in the rainy season is prone to flood (kulonprogokab.go.id).

Method in this research use guidelines from Perka BNPB 2/2012 on disaster risk assessment. To do risk analysis, hazard and vulnerability components are needed with Sub-District as unit of analysis. This risk mapping analysis uses a semi- quantitative approach, which uses weighting factors and index values. The result will be an index value with a range of 0-1.

Hazard Potential Analysis

Landslide and Flood Hazard Potential

The producing of landslide and flood potential maps is using a qualitative approach (knowledge driven) by giving a score on each parameter. Parameters used are similar for both landslide and flood hazard potential assessment, among other slope from DEM TerraSAR 9m resolution, rainfall from BMKG (metrological agency), soil map, and landuse from topographic map (RBI).

Table 1. Parameters to determine landslide and flood hazard potential

No	Parameters	Classification	Landslide Score	Flood Score
1.	Slope	0 – 3 %	1	5
		3 – 8 %	1	5
		8 – 15 %	2	4
		15 – 25 %	3	3
		25 – 40 %	4	2
		> 40 %	5	1
2.	Rainfall (mm/year)	>2500	5	5
		2000 – 2500	4	4
		1500 – 2000	3	3
		1000 – 1500	2	2
		<1000	1	1
3.	Soil	Regosol	1	5
		Latosol	3	3
		Kambisol	2	4
		Grumusol	4	2
4.	Landuse	Shrub	3	2
		Farm	2	2
		Sand land	1	5
		Sand beach	1	5
		Settlement	3	3
		Grass	3	3
		Paddy field	1	4
		Rainfed paddy fields	3	2
		Dry-field	3	2
		Water body	1	3
		Reservoir	2	3

Souce: (Data processing, 2017)

Spatial analysis in GIS is used to overlay all parameters. Then, total score will be calculated and divided into three classes: high, moderate, and low potential hazard. Next, attempt to quantify the landslide and flood classification into hazard index value (0-1) based on Perka BNPB 02/2012 (table 2).

Table 2. Scoring for each class of landslide and flood hazard potential

Class	Value	Weight %	Score
High	1	100	0.33
Moderate	2		0.66
High	3		1

Source: Perka BNPB 2/2012

Tsunami Hazard Potential

The making of tsunami hazard potential map is based on Tsunami Risk Assessment Guideline (TRA) in Perka BNPB 2/2012. Input data for tsunami hazard mapping is DEM TerraSAR with spatial resolution 9 m. Query builder is needed to divide hazard class into three classes based on the DEM height value (table 3).

Table 3. Scoring for each class of tsunami hazard potential

Classification	Tsunami inundation heights	Class	Weight (%)	Score
High	< 1 m	1	100	0.33
Moderate	1 – 3 m	2		0.66
Low	>3m	3		1

Source: Perka BNPB 2/2012

Vulnerability Analysis

The vulnerability index is obtained from social, economic, physical, and environmental components. Those data can be gained through Kulonprogo Regency and Kecamatan in figure, land use map, and protected area map.

Social Vulnerability

Social vulnerability uses two indicators, namely population density and vulnerable group. Vulnerable group consists of sex ratio, poverty ratio, disabled ratio, and age group ratio. Those data are classified into three classes according to Perka BNPB (table 4). Then, the score can be calculated by dividing classes into the number of classes. At the end, weight is used as a score multiplier. Index of social vulnerability is obtained subsequently.

Table 4. Parameters of Social Vulnerability

Parameters	*Weight (%)*	*Class*		
		Low (1)	Medium (2)	High (3)
Population density	60	<500 persons/km^2	500-1000 persons/km^2	>1000 persons/km^2
Vulnerable group	40	<20%	20-40%	>40%

Source : Perka BNPB 2/2012

 ISBN: 978–602–361–072-3

Economic Vulnerability

Economic vulnerability uses productive land as indicator. Productive land area can be obtained from land use map. The areas which have potential on giving economic value are categorized as productive land. Table 5 is the classification for each economic value of productive land.

Table 5. Parameters of Economic Vulnerability

Parameter	*Weight (%)*	*Class*		
		Low (1)	Medium (2)	High (3)
Productive land	100	< 50 million	50-200 million	>200 million

Source : modified from Perka BNPB 2/2012

Physical Vulnerability

Physical vulnerability is determined from public facilities indicator. Public facilities that used are hospitals, schools, and worship place. Table 6 is the classification for each economic value of public facilities.

Table 6. Parameters of Physical Vulnerability

Parameter	*Weight (%)*	*Class*		
		Low (1)	Medium (2)	High (3)
Public facilities	100	< 500 million	500million-1 billion	>1 million

Source : modified from Perka BNPB 2/2012

Environmental Vulnerability

Environmental vulnerability indicator uses protected forest and natural forest. These data are obtained from protected area map and classified into three classes (table 7). Then, the score can be calculated by dividing classes into the number of classes. At the end, weight is used as a score multiplier. Index of environmental vulnerability is obtained subsequently.

Table 7. Parameters of Environmental Vulnerability

Parameter	*Weight (%)*	*Class*		
		Low (1)	Medium (2)	High (3)
Forest	100	< 20 ha	20-50 ha	>50 ha

Source : modified from Perka BNPB 2/2012

Total Vulnerability

According to Perka BNPB, different hazard has different vulnerability. For flood, landslide, and tsunami hazards, the weight for each vulnerability has the same formula, so that vulnerability in this research use the formula as follows:
Vulnerability = (0.4 x social vulnerability) + (0.25 x economical vulnerability) + (0.25 x physical vulnerability) + (0.1 x environmental vulnerability).

Multi-Hazards Risk Potential Analysis

Analytical Hierarchy Process (AHP) is widely used for risk analysis. In this case, before creating risk map, multi-hazards map is produced by using AHP to produce weight for landslide, flood, and tsunami potential hazards. Then, multi-hazards risk assessment is created by applying following formula into GIS raster calculator:

$R_t = \sum_i^n H_i \times V_i$, where:

Rt = Risk total

H = Hazard

V = Vulnerability

Lastly, output of risk map has a range between 0 and 1, which 0 means no risk, and 1 means high risk.

RESULT AND DISCUSSION

Hazard Potential Analysis

Kulon Progo Regency has index 0,33 – 1 for landslide and flood potential hazard and 0 – 1 for tsunami potential hazard (figure 1). Value 0 means no hazardous, while value 1 means very dangerous. The most hazardous area for landslide are in Samigaluh, Girimulyo, and Kokap Sub-district, the western part of Kulonprogo Regency. See from the side of the slope, this area has a steep slope (25-40%) to very steep (> 40%). Whereas, for flood potential hazard, the most hazardous area is in Temon, Panjatan, and Galur Sub-district, which located in the southern part of the regency. This area has slope steepness about 0 – 8 % or flat and undulating relief. Then, the southern part of Kulon Progo Regency has a tsunami hazard potential which the highest index is located in Temon, Panjatan, and Galur Regency. Sub-districts adjacent to the coastline, have a very dangerous area against the tsunami.

Prior to create multi-hazard map, Analytical Hierarchy Process (AHP) is applied to obtain the weight of each hazard. The first step of AHP is to create a pairwise comparative into matrix containing intensity of importance. From the calculation of consistency ratio in this study it is known that the pair comparison process is quite consistent with the value of consistency Ratio (CR) of 0 for the hazards. The weight for landslides and floods is 0.44, while for the tsunami is 0.11.

Lastly, multi-hazards potential map coming from three overlapping hazard maps by assigning weight to each of these hazards. The range of values is from 0.2904 to 0.7304. The most hazardous area is in western and southern part of Kulonprogo Regency, while the lowest hazardous area is in eastern part including Lendah and Sentolo Sub-District.

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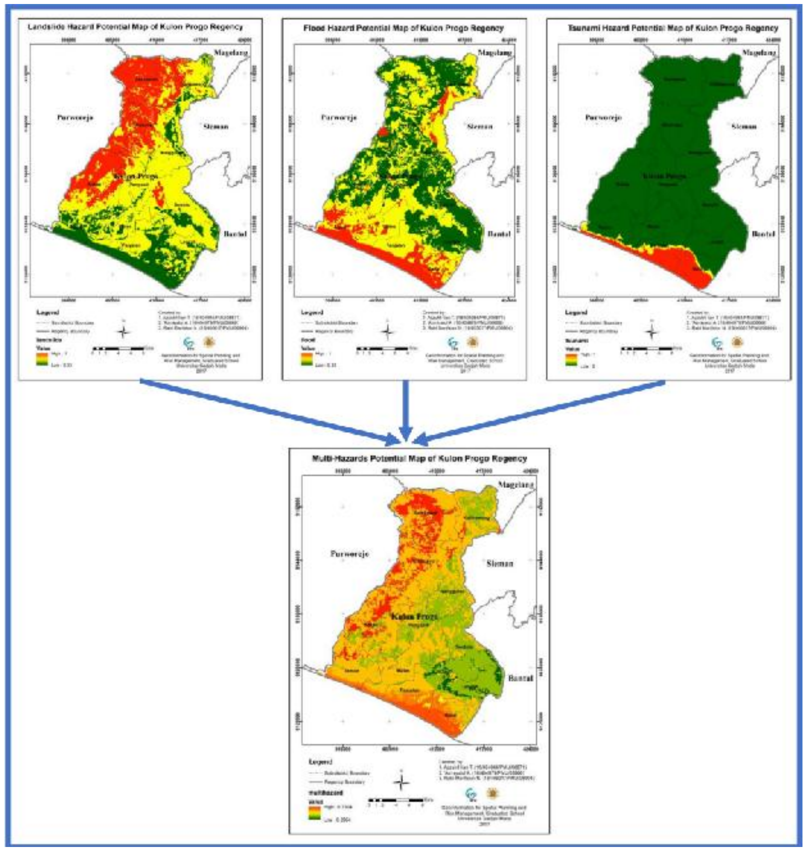
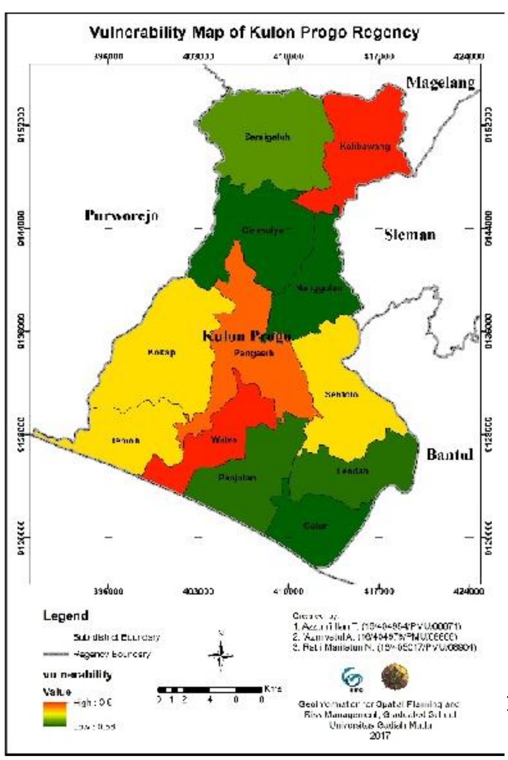


Figure 2. Landslide, Flood, Tsunami Potential Hazard and Multi Hazard Potential Map

Vulnerability Analysis



The map in figure 2 shows the vulnerability distribution in Kulonprogo Regency. The vulnerability index is in range of 0.58 to 0.9. A value 0.58 indicates a low damage and 0.9 indicates a high damage. Wates Sub-District has the highest damage potential, followed by Kalibawang Sub-District in the northern part of Kulonprogo Regency. Conversely, Girimulyo and Nanggulan Sub-District that located in the middle area of Kulonprogo have the lowest damage potential.

Social vulnerability plays an important role of vulnerability index in Wates Sub-District. This location has high index, especially related to

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population density. Different with Lendah Sub-District which has the highest social vulnerability index, the vulnerability total does not depict that this area has high vulnerability because physical and environmental vulnerability is quite low.

Multi-Hazard Risk Potential Analysis

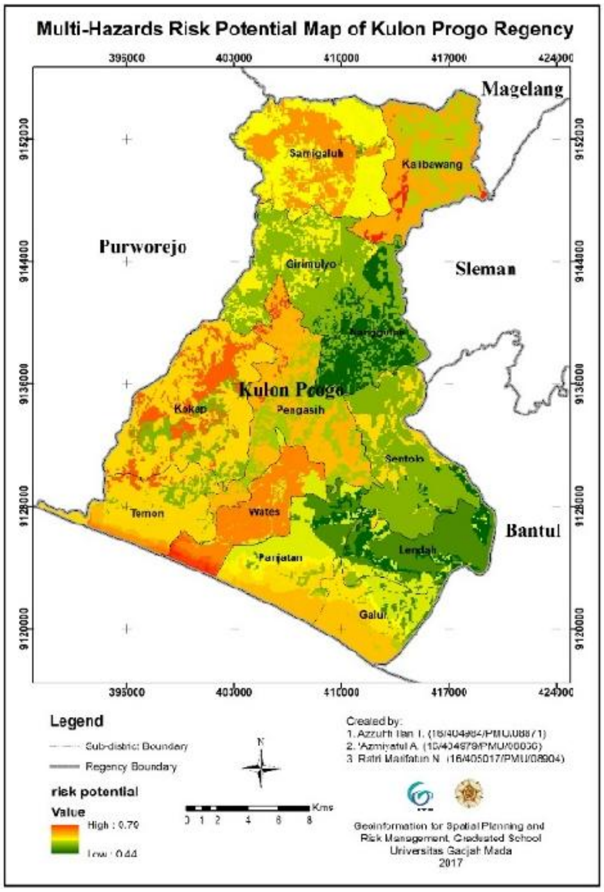

Figure 4. Multi-Hazards Risk Potential Map

The risk map is derived from overlaying multi-hazards map and vulnerability map. The risk index is in the range of 0.4 to 0.79. A value of 0.4 indicates a low risk and increasingly toward 0.79 indicates a high risk. Figure 3. shows the highest is located in Wates Sub-District, followed by Kalibawang and Kokap Sub-District. Whereas, low risk is stand to Lendah and Nanggulan Sub-district, the eastern part of Kulonprogo Regency.

In this case, Wates is found has high risk potential. Look at the detail, the vulnerability level in this sub-district is high, mainly social vulnerability. In addition, Wates also quite hazardous seen from multi-hazard map. Even though landslide hazard is tend to be low, flood and tsunami hazard in this area is high enough. Hence, Wates is inferred to has high risk potential. On the contrary, Lendah Sub-District is determined as low risk. Based on multi-hazard map, this area is less hazardous, either flood, landslide, or tsunami hazard. Though, seen from vulnerability aspect, Lendah is determined has low damage.

CONCLUSION

Multi-hazard risk assessment generally produce three kind of maps and study, these are multi- hazard potential map, vulnerability map, and multi-hazard potential risk map. From multi-hazards potential map of Kulonprogo Regency can be generalized the level of hazardous area, with index value between values 0.29 and 0.73. The most hazardous area is in western and southern part of Kulonprogo Regency, while the lowest hazardous area is in eastern part.

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Moreover, vulnerability map shows that Wates Sub-District has the highest damage potential. Eventually, risk index indicates the potential risk from multi-hazard and vulnerability analysis in range of 0.4 to 0.79. This research needs to be improved, mainly related to the vulnerability data availability. Not all the parameters based on Perka BNPB are used because of lack of data, such as GDRP, buildings, and crisis facilities. However, the existing data have already been used are able to depict the value of risk.

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