Flood Risk Mapping Based on Land Physical Characters Case Study at Kudus Regency, Central Java, Indonesia

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1. Introduction

Flooding has become a significant urban problem in Indonesia within this past decade. Bakornas data in **Fig. 1** shows that flood was dominating the occurrences of natural disaster in Indonesia from 2003 to 2008. Some regency in Central Java Province, such as Kudus, Cilacap, Semarang and Surakarta were suffered by flood during this period[1]. This study focuses in Kudus Regency due to four main reasons: 1) There are two main rivers that contributes to the flood event in Kudus Regency, i.e. Juwana River and Wulan River. The hydrological and sedimentation process in these rivers cause siltation and obstruct its flow. 2) Kudus Regency is dominated by flat area, 3) Kudus Regency is dominated by intermountain basin. This basin covers Kudus Regency, Jepara Regency, Pati Regency, and Demak Regency, and 4) The type of soil in south part basin area in Kudus Regency is alluvial. The structure of alluvial soil has appropriately 50% of clay material, which means it has very slow permeability and obstructing the infiltration process. These land-physical characters create complex situation, in which all of them give important role on the causes of flooding in Kudus Regency. Usually, this complex situation is occurred at downstream river or coastal area. Interestingly, Kudus Regency is located at intermountain basin. Spatial data are commonly used as a reference set by various local planning authorities for hazard mitigations. However, Kudus Regency does not have spatial data with regards to flood disaster. Due to this reason, it is necessary to conduct flood mapping in order to identify the distribution of flood hazardous area in Kudus Regency. The aims of this study are to generate the spatial distribution of potential flood hazards and to analyse the cause of flood hazard in Kudus Regency. Spatial data of flood disaster are generated base on the land physical characteristics, which are: 1) slope class, 2) soil classes (soil infiltration factor), 3) landuse (coefficient runoff), and 4) rainfall (isohyet map). This study applied Geography Information System (GIS) to determine the distribution of hazardous area due to flood disaster by overlay those parameter characteristic layers[2].

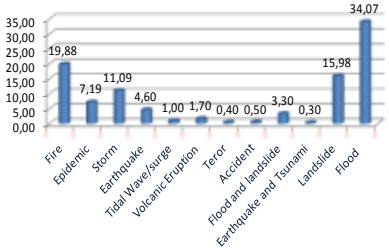

Figure 1 : The Occurence of Natural Disaster in Indonesia from 2003 – 2008 (BNPB,2009)

2. Study Location

Kudus Regency, as seen in **Fig. 2**, is located in $110^0$36'-$110^0$50'47" East Longitude and $6^0$51-$7^0$16' South Latitude. It has total area of 42,516 Ha, which consists of 9 districts with 123 villages and 9 urban villages.

Kudus Regency is bounded by Muria Mountain in north part and Rembang Hills in the south part. Moreover, it is dominated by intermountain basin in the south area (Undaan, Mejobo and Jati District). Kudus Regency located at an altitude of 5-1.600 m above sea level as shown in **Fig. 3**. The lowest elevation is Undaan District, which is 5 meters above sea level. The area with the highest elevation is Dawe District, which is a plateau with an altitude of 1.600 meters above sea level. As seen in **Fig. 3**, the majority of land slope elevation in Kudus Regency is plain with 0 – 8% inclination. This condition is suitable for agriculture, but in the other hand it has potential risk for flood hazards.

This area is composed by alluvium material, volcanic rocks and tufaan sand. The geomorphological process continuously produces alluvial soil[2]. Therefore, the majority of soil type in Kudus Regency is Alluvial. This type of soil has several characteristics, as follow: 1) colour is grey or brown, 2) texture is clay with levels 50%, and 3) this soil have low organic matter, but high nutrient, less water absorption and easily eroded.

Table 1 shows the landuse categories in Kudus Regency. Landuse in Kudus Regency is dominated by rice field for more than 50% total area. Unfortunately, forest coverage, as the retention area, just 1.051 Ha or around 2% of total area in Kudus Regency. Each landuse has the coefficient runoff (*C*), which relates with soil infiltration capability. Larger coefficient runoff means less infiltration and more surface runoff. Settlement area and hard land-cover has large coefficient runoff, therefore increasing number of these areas may reduce the capacity to absorb water and increase the surface runoff water, and consequently causes flooding in some area at Kudus Regency.

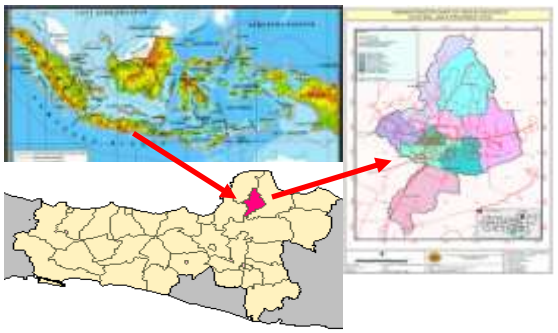

Fig. 2. Kudus Regency position in Indonesian Map

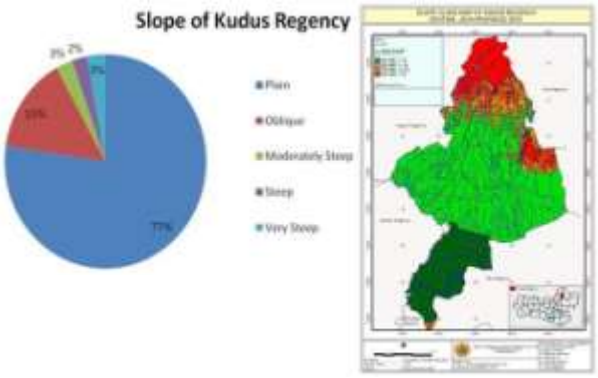

Fig. 3. Slope Class of Kudus Regency

No.	Landuse	Area	Percentage
1	Grass	1.263,49	2,97%
2	Public Fasilities	284,44	0,67%
3	Forest	1.051,54	2,47%
4	Mix field (Private Property)	4.052,52	9,53%
5	Open landscape	83,11	0,20%
6	Agricultural Area	2.167,72	5,10%
7	Settlement	7.833,21	18,42%
8	Rice field	25.382,14	59,70%
9	River (body water)	397,84	0,94%
	Total Area	42.516,00	100,00%

Table 1. Landuse in Kudus regency

3. Analysis and Result

In order to get flood hazards risk map, Kingma (at Mayasih Wigati, 2009)[1] recommended four land physical factor to be considered, i.e. slope class, soil, landuse and rainfall (Isohyet Map). These four physical factors were converted into layers with assigned weighting score and overlaid by using GIS technique. This study emphasized on land characteristic, therefore land factors (slope and soil) have the biggest scoring in weighting scale, as shown in the **Table 2**. After this scoring analysis, the flood prone area can be categorized by Sturgess formula, as described in Agus JP, 2008[3] :

$$Ci = \frac{Xmax - Xmin}{N}$$

where Ci = class interval,

$Xmax$ = the highest of total score data,

$Xmin$ = the lowest of total score data,

N = number of flood prone classification (5)

therefore $Ci = \frac{5{,}0-1{,}0}{5} = \frac{4{,}0}{5} = 0.8$

Table 2 : Scoring for Physical Parameter (Kingma, with modification)

No	Physical Parameter	Class Parameter				
1	Slope Class	0 - 2%	Highly Prone Area	5	30%	1,5
		2% - 8%	Prone Area	4		1,2
		8% - 25%	Rather Prone Area	3		0,9
		25% - 40%	Safety Area	2		0,6
		> 40%	Highly Safety Area	1		0,3
2	Soil Classification	Delicate aggregate	Highly Prone Area	5	30%	1,5
		Soft aggregate	Prone Area	4		1,2
		Fair aggregate	Rather Prone Area	3		0,9
		Coarse aggregate	Safety Area	2		0,6
		Very coarse aggregate	Highly Safety Area	1		0,3
3	Landuse Classification	Open landscape,swamp,body water	Highly Prone Area	5	20%	1,0
		Settlement, Mix field,building,hard cover	Prone Area	4		0,8
		Rice field, agriculture area	Rather Prone Area	3		0,6
		Plantation, grass	Safety Area	2		0,4
		Forest	Highly Safety Area	1		0,2
4	Rainfall (Isohyet)	> 3500 mm	Highly Prone Area	5	20%	1,0
		3000 - 3500 mm	Prone Area	4		0,8
		2500 - 3000 mm	Rather Prone Area	3		0,6
		2000 - 2500 mm	Safety Area	2		0,4
		< 2000 mm	Highly Safety Area	1		0,2

Table 3. Location of Flood Hazard and Area in Hectares

No.	Flood Classification	Hectares	Location (District)
1	Highly Prone Areas (7.050,63 ha)	16,58%	Undaan, Mejobo, Jati, Jekulo
2	Prone Areas (2.325,46 ha)	5,47%	Gebog, Dawe, Jekulo
3	Rather Prone Areas (14.670,26 ha)	34,51%	Kaliwungu, Jati, Gebog, Jekulo, Bae
4	Safety Area (8.063,64 ha)	18,97%	Gebog, Dawe, Jekulo, Kota, Kaliwungu
5	Very Safety Area (10.406,01 ha)	24,48%	Jati, Kota, Dawe, Gebog
	Total	100,00%	--

The result in **Table 3** shows that the safer area against flood risk is around 43% of total area or 18.469,65 ha, which scatter in the north part of Kudus Regency at mountains and hills landscape. In the contrary, more than 50% of total area in Kudus regency has the potential of flood hazards. Among, this area, 7 Ha is located at the highly prone areas that scatter at southern part of Kudus Regency, as seen as yellow colour in **Fig. 4**. Further, most of Undaan District, some part of Mejobo District and small part of Jati and Jekulo District are located on the high risk of flood disaster due to its slope, soil and landuse factor are the major factors that influence the flood hazard. The slope elevation in the southern area of Kudus Regency is mostly plain with 0-2% inclinations. In addition, this area is located at intermountain basin. Therefore, when the rain occurs, surface runoff flows down and gathers in this area for some period. Second factor is the soil condition. The domination of alluvial landform causes the permeability and infiltration process becomes very slow, and as consequences, river and rainfall runoff inundate floodplain for longer period[4]. Land use in Kudus Regency was dominated by rice field area. An open landscape such as body water (river, lake, and swamp), settlement, and rice field has larger coefficient value of runoff than other landuse (such as forest, grass, plantation, etc). Therefore, in settlement and rice field, rainfall cannot infiltrate into soil and goes directly as surface runoff, which may cause floods. In order to mitigate the flood disaster, the most appropriate flood control systems are constructing flood retention and embankment, and also implementing river improvement program. The landuse on highly prone area can be change into retention area in order to reduce the inundation period. Second solution is by frequently conduct river improvement program in the Juwana and Wulan River. Other solution is to strengthen the embankment at Undaan District.

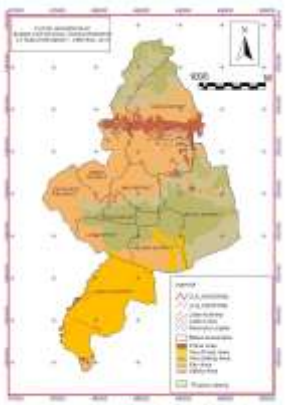

Figure 4 : Flood Risk Map of Kudus Regency

4. Conclusion

This study generated the spatial distribution of potential flood hazards at Kudus Regency by conducting scoring analysis, which considered 4 land physical characteristics, i.e. slope class, soil, landuse and rainfall, through GIS method. The result shows that more than 50% of total areas in Kudus Regency is vulnerable against flood disaster due to its slope, soil and landuse conditions. Most of this area is located at the south part of Kudus Regency, which has land physical characteristic of plain areas with 50% of clay material soil and used as rice field. These land physical characters cause longer process of soil infiltration and consequently cause higher surface runoff depth for longer period. However this flood hazards can be mitigated by constructing some retention areas in the highly prone areas, such as in Karangrowo Villages at Undaan District, Jetis Kapuan village at Jati District, and Kirig Village at Mejobo District. Other solutions are to restore Wulan and Juwana River frequently and strengthen the Undaan embankment.

References ;

1. Mayasih Wigati, Improving Flood Hazard and Vulnerability Assessment Based on Social Assessment in Bogowonto River, UGM-ITC, 2008.
2. Sukresno, 2005, Petunjuk Operasional Penentuan Kekritisan DAS, Ministry of Forestry, Surakarta, 2005;
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