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THE INFLUENCE OF PRECIPITATION, STREAM DISCHARGE, AND PHYSIOGRAPHIC FACTORS ON FLOOD VULNERABILITY AT CIMANUK RIVER-WEST JAVA, INDONESIA

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Abstract: The study on the characteristics of precipitation, stream surface discharge, and physiographic factors in influencing flood vulnerability at Cimanuk Watershed, West Java is essential since Cimanuk Delta is one of the most growing river delta in West Java. Furthermore, regression based model between flood as dependant variable has been regarded as the most suitable approach. Highest rate of monthly, daily average, daily precipitations, and high stream discharge were focused in November to April. Therefore, higher probability of flood occurence in Cimanuk watershed may concentrated only in those months. Correlation between highest rate of stream discharge's occurence frequency and the occurence frequency of highest rate of monthly, daily average, and daily precipitations were 0.807, 0.960, 0.162 respectively. The highest rate of stream discharge can be determined by measuring the highest rate of monthly, daily average, and daily precipitations. However, it should be kept in mind that the highest rate of daily precipitation hold insignificant correlation with stream discharge. In all months of the year, the factors have positive effect on flood vulnerability are precipitation, soil type, and land cover, but the slope has negative effect.

KEYWORDS: flood vulnerabilty, precipitation, slope, land cover, discharge, regression

Introduction

Flood has been widely acknowledged as one of the most common disaster in Indonesia. This kind of disaster, may come from inland stream or sea water overflow. In general, areas affected by sea water overflow are commonly located across coastline. Whilst, the impact of inland stream overflow are usually limited only in areas along the correspending river stream. In West Java Province-Indonesia, areas that oftenly affected by stream overflow flood are the riversides of Cimanuk Watershed. This river is the largest river in the province with about 230 km in total length, about 3276 km^2 in the total extent of its water catchment area, and span trough four regencies in West Java Province, namely Garut, Sumedang, Majalengka, and Indramayu. Administratively, Cimanuk river's stream has been divided into three sub-streams, which are (a) Cimanuk upstream with approximately 145.677 ha total extent in Garut and Sumedang Regency, (b) Cimanuk middlestream with approximately 114.477 ha total extent in Sumedang and Majalengka Regency, and (c) Cimanuk downstream with approximately 81.299 ha total extent in Indramayu Regency.

There are four main influencing factors of flood disasters, such as precipitation intensity, land cover, slope, and surface flow/discharge. In line with this notion, Morita (2014) states that among any other factors that may have influence on flood, the most prominent are including precipitation rate, poorly managed drainage system, poorly distributed population. In addition, climate change has also been considered as one of key influencing factor, since it may trigger the unprecedented increase in flood frequency.

Hydrological factors cause rapid flood runoff and flood discharge grow with an increase in impervious areas. Concentrated population and assets are also important social aspects of flood risk. Climate change is now considered an important factor that increases flood risk, with an increase in the frequency and their intensity of torrential storms (Patrick *et al.,* 2007). Drainage basin area has a great effect on the floods generated at its outlet while other factors have less effect than the drainage area such as the slope and roughness. However, using regression techniques, maximum values can be calculated for such purpose that may depend on the meteorological (Elmoustafa, 2012). To reduce model bias and uncertainty, a weighted ensemble mean (WEM) is used for multimodel projections (Nohara *et al.,* 2006). Taking into account of those perspectives, it can be said that this study on the characteristics of precipitation, stream surface discharge, and physiographic factors in influencing flood vulnerability at Cimanuk River is essential. Furthermore, regression based model between flood as dependant variable has been regarded as the most suitable approach.

Materials and Methods

Data

This study was mainly conducted harnessing secondary data collected form The Ministry of Public Works and Housing, such as land use map, slope map, soil type map, and flood vulnerability map. In addition, daily precipitation data for 10 years (precipitation data from 2011 to 2015 for probability analysis, 2016 for regression model and discharge data from 2007 up to 2013, but 2007 is not complete) were also gathered from 12 climate stations (Table 1).

Tabel 1: Position of 12 climate stations.

No	Coordinate		Station	Subdistric	Distric
	South	East			
1	7º16'20,76"	107º 49'0,39"	Bayongbong	Bayongbong	Garut
2	6º50'15.28"	107º 47'35.25"	Cijambu	Tanjungan	Sumedang
3	7º20'47.24"	107º 48'5.30"	Cikajang	Cikajang	Garut
4	6º54'49.67"	108º 4'29.85"	Cibogo	Darmaraja	Sumedang
5	6º46'47.52"	108º 10'6.47"	Kamun	Kadipaten	Majalengka
6	06º 31' 46"	108º 20' 59"	Kertasemaya	Kertasemaya	Indramayu
7	07º 14' 41"	107º 52' 04"	Bojongloa	Bayombong	Garut
8	07º 12' 36"	107º 53' 52"	Leuwidaun	Kota Kulon	Garut
9	06º 46' 00"	108º 08' 00"	Tomo	Tomo	Sumedang
10	07º 06' 00"	107º 58' 00"	Leuwigoong	Leles	Garut
11	06º 39' 42"	108º 13' 26"	Monjot	Cibeureum	Majalengka
12	06º 57' 00"	108º 05' 00"	Wado	Wado	Sumedang

Smallest analysis unit

Smallest analysis unit in this study was District areas across Cimanuk watershed area that covered 4 regencies, such as Garut, Sumedang, Majalengka, and Indramayu Regencies (Figure 1). In total, there are 103 districts covered. Data was grouped into two categories. Firstly, static data, such as land cover, slope, and soil type. Secondly, dynamic data, such as precipitation for the duration of six years, discharge for the duration seven years (2007-2016).

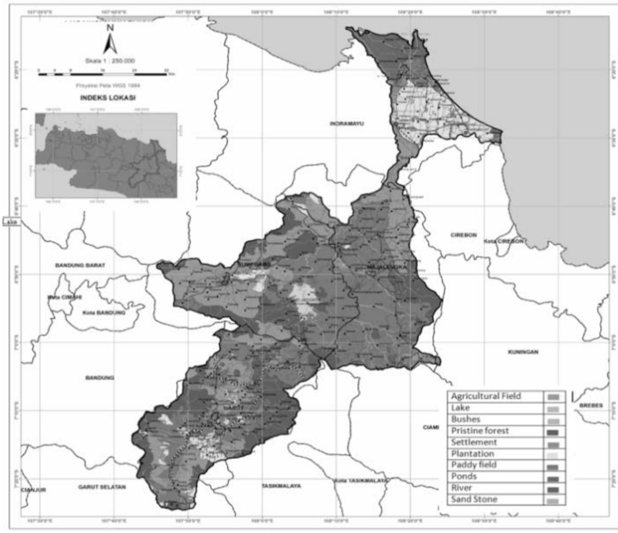


Figure 1: Location of the study.

Analysis

Initially, the maximum monthly and daily precipitation volume were analyzed. This is because those variabels are regarded as the main elements that may have an influence on flood (Bureau of Meteorology, 2018). Afterwards, the number of rainy days in a month was counted. This number was then used to calculate the probability of monthly precipitation rate, as well as daily maximum precipitation rate. The increase in precipitation rate was assumed to be directly related to the increase in stream discharge. Therefore, measurement on stream discharge is needed. Discharge is the volumetric flow rate of water that is transported through a given cross-sectional area. The equation implies that for any incompressible fluid, such as liquid water, the discharge (Q) is equal to the product of the stream's cross-sectional area (*A*) and its mean velocity *(u)*, and is written as: $Q = A u$ (Buchanan & Somers,1969; Dunne & Leopold, 1978; Govers, 1992); Where :

Q is the discharge ([L^3T^{-1}]; m^3/s or ft^3/s),
A is the cross-sectional area of the portion of the channel occupied by the flow ([L^2]; m^2 or ft^2), is the average flow velocity ([LT^{-1}]; m/s or ft/s)

Analysis on maximum precipitation and stream discharge occurence time is essential in order to estimate flood probability. Hence, precipitation and stream discharge data from the last 10 years were analyzed annually. Then, the correlation between precipitation and stream discharge was calculated. According to Walpole *et al.* (2012), Agresti *et al.* (2018), Mendenhall *et al.* (2013), Gashi *et al.* (2010) and Singh *et al.* (2000), correlation between two variables X and Y is estimated by the sample correlation coefficient r, where:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Where: x_i = frequency of highest stream discharge in month i, i = January,.., December; y_i = frequency of highest precipitation in month i, i = January,.., December; $\bar{y}$ = average frequency of highest stream discharge; $\bar{x}$ Average frequency of highest precipitation. Correlation is used since only to know linear relationship between frequency highest precipitation and freqeuncy of highest stream discharge each month. Coefficient determination (R^2) is used also for regression model which it explains how much percentage of model can explain of data.

$$R^2 = \frac{\sum_{i=1}^{n}(\tilde{y}_i - \bar{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} x\ 100\%$$

Where: $\tilde{y}_i$ = estimate data from regression model, y_i = original data, $\bar{y}$ = average of data.

Linear regression approach was then conducted in order to evaluate the most influencing factors of flood vulnerability, with independent variables such as soil type, land cover type, slope, and monthly precipitation. All of those independant variables were scored for each of District in Cimanuk watershed. Flood vulnerability level was calculated by multiplying score of independant variables and area extent. For example, in Cimalaka District with about 22.44 km^2 of total area extent with calculation score in Table 2.

Table 2: Calculation score of variables in Cimalaka District.

Characteristics	Calculation	Score
Cimalaka with Area 22.44 km^2		
Precipitation January such as 260-280 mm in an area of 18.89 km^2 and 280-380 mm in an area of 3.56	(3*18.89+3*3.56)/22.4	3.006
Soil such as Grey Regosol and Litosol= 17.72 km^2, Yellowish Brown Andosol = 0.09 km^2, Brown Latosol = 4.63 km^2.	((17.72*1)+(0.09 *2)+ (4.63 *3)) /22.44	1.417
Slope such as 0-2^0 = 4.00 km^2, 2-15^0 = 13.38 km^2, 15-25^0 = 3.17 km^2, 25-40^0 = 1.87 km^2, and > 40^0 = 0.00 km^2.	((4.00)*5) +(13.38)*4)+ (3.17*3)+ (1.87*2)+ (0.00*1))/22.44	3.870
Land cover, such as agricultural field =13.85 km^2, pristine forest = 4.32 km^2, settlement area =3.81 km^2, and plantation = 0.47 km^2.	((13.85 *2)+(4.32 *1)+ (3.81 *3)+(0.47 *2)) /22.44	1.98
Precipitation score towards flood vulnerability	((3.5 + ((1.98*0.175) + (3.87*0.35) + (1.417*0.175)))/3)	4.150

And soon so that values of all independent variables in all of 103 districts were calculated. From that point, multiple regression model calculations were conducted between flood vulnerability as dependant variable (flood vulnerability), while precipitation (X_1), soil type (X_2), land cover (X_3), slope (X_4) as independant variables. Model estimation was conducted monthly, so there are 12 regression models produced. This is because precipitation rate was changing every month. Meanwhile, independent variables were relatively constant. Multiple linear regression model, where there are 4 numbers of independant variables and a dependant variable can be written as:

$$y_i = \beta_0 + \beta_1 \, x_{i1} + \beta 2 \, x_{i2} + \beta_3 \, x_{i3} + \beta_4 \, x_{i4} + \varepsilon_i$$

where: x_{ij} is observation i on variable j. Residuals:

$$\varepsilon_i = y_i - (\beta_0 + \beta_1 \, x_{i1} + \beta 2 \, x_{i2} + \beta_3 \, x_{i3} + \beta_4 \, x_{i4})$$

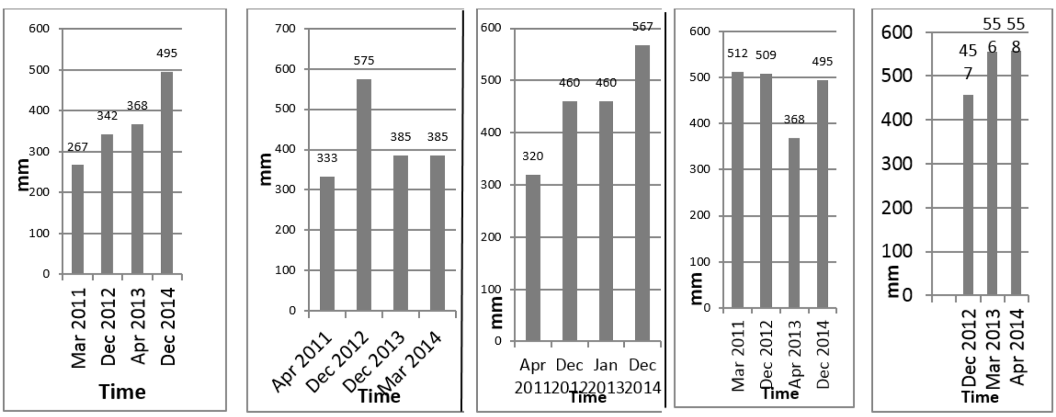
A normal equation in a matrix notation can then be written as: $(\boldsymbol{X'} \boldsymbol{X}) \tilde{\boldsymbol{\beta}} = \boldsymbol{X'Y}$, where: X is observation matrix sized n x 4, with the first column value of 1, **Y** is a matrix sized n x 1 and $\tilde{\boldsymbol{\beta}}$ sized 5 x 1. So that the regression solution is: $\tilde{\boldsymbol{\beta}} = (\boldsymbol{X'} \boldsymbol{X})^{-1} (\boldsymbol{X'} \boldsymbol{Y})$, (Wagenaar *et al.,* 2017; Long, 2009; Tofallis, 2009; Good and Hardin, 2009; Chiang, 2003; (Steel & Torrie, 1960; Fotheringham & Wong, 1991; Chiang, 2003; Aldrich, 2005; Freedman, 2005; Willem *et al.,* 2008; Good & Hardin, 2009; Long, 2009; Tofallis, 2009; Amstrong, 2012; Wagenaar *et al.,* 2017).

Results and Discussion

Highest precipitation rate

At village of Bayongbong, Bayongbong Sub-District, Garut, highest of monthly precipitation rate was recorded about 267 mm in March 2011, increased to 342 mm In December 2012, slightly rose to 368 mm in April 2013, and increased to 495 mm in December 2014. Meanwhile, average of daily highest precipitation rate in March 2011 was about 8.61 mm, then increased to about 11.03 mm in December 2012, 11.27 mm in April 2013, 15.97 mm in December 2014. Highest daily precipitation rate in 2011 was recorded on 6 April with about 84 mm, 106 mm on 28 February 2012, 77 mm on 12 April 2013, 68 mm on 14 December 2014.

At the village of Cijambu, Tanjungan Sub-District, Sumedang, highest of monthly precipitation rate which recorded in April 2011, December 2012, December 2013, and March 2014 respectiverly were 333 mm, 575 mm, 385 mm 385 mm. Meanwhile, average of daily highest precipitation rate in April 2011 was about 11.10 mm, 18.15 mm in December 2012, 12.42 mm in December 2013, and 14.55 mm in December 2014. Highest value of daily precipitation rate in 2011 was recorded on 22 December with about 50 mm. In 2012 recorded on 12 November with approximately 94 mm. In 2013 recorded on 15 November with about 110 mm. Lastly, in 2014 recorded on 14 March with about 80 mm.

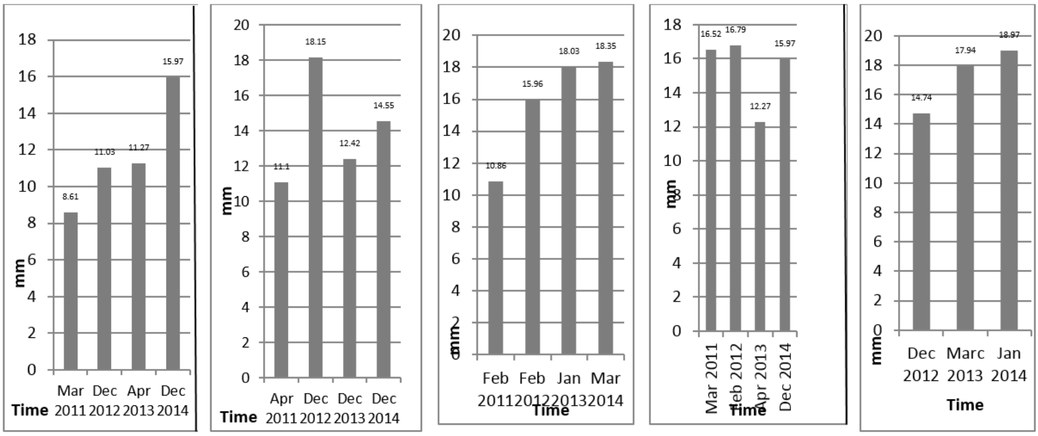


a.At Bayongbong b. At Cijambu c. At Cikajang d. At Cibogo e. At Kamun

Figure 2: Highest monthly precipitation rate.

During 2011, in the village of Cikajang, Cikajang Sub-District, Garut, highest value of monthly precipitation rate was recorded in April with about 320 mm. In December 2012 the value increased to 460 mm. The value then remain steady at 460 mm in January 2013. In December 2014, the value increased to 567 mm. Meanwhile, average value of daily highest precipitation rate in February 2011 was about 10.86 mm. The value was then increased to about 15.96 mm in February 2012. In January 2013, there was a slightly increase to about 18.03 mm, whilst in March 2014 there was a slight increase to about 18.35 mm. Highest value of daily precipitation rate in 2011 was recorded on 25 December with about 75 mm. In 2012 recorded on 19 November with approximately 92 mm. In 2013 recorded on 24 January with about 113 mm. Lastly, in 2014 recorded on 20 February with about 80 mm.

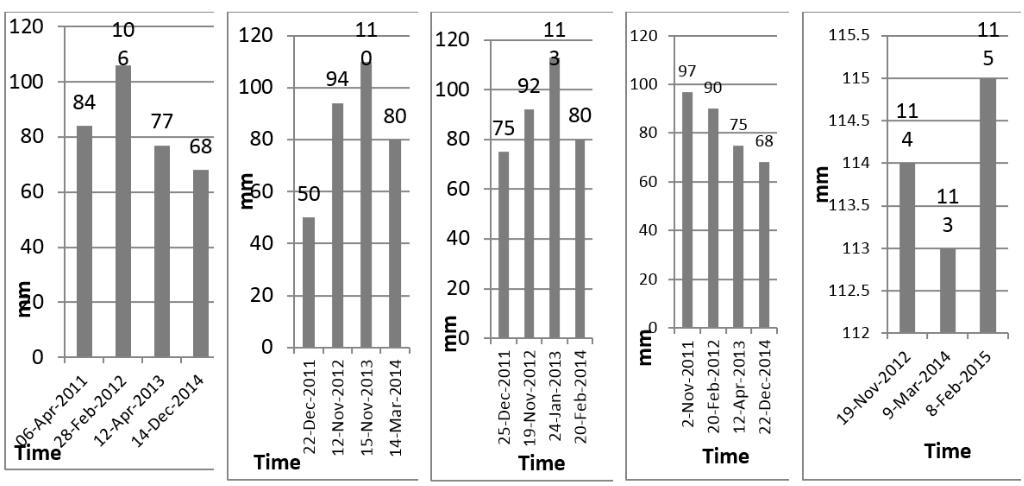
During 2011, in the village of Cibogo, Darmaraja Sub-District, Sumedang, highest value of monthly precipitation rate was recorded in March with about 512 mm. In December 2012 the value decreased to 509 mm. The value then decreased to 368 mm in April 2013. In December 2014, the value increased to 495 mm. Meanwhile, average value of daily highest precipitation rate in March 2011 was about 16.52 mm. The value was then increased to about 16.79 mm in February 2012. In April 2013, there was a slightly decrease to about 12.27 mm, whilst in December 2014 there was a slight increase to about 15.97 mm. Highest value of daily precipitation rate in 2 November 2011 was about 97 mm. In 20 February 2012 with approximately 90 mm. In 12 April 2013 with about 75 mm. Lastly, in 22 December 2014 with about 68 mm.



a.AtBayongbong b. At Cijambu c. At Cikajang d. At Cibogo e. At Kamun

Figure 3: Average value of daily highest precipitation rate.

During 2012, in the village of Kamun, Kadipaten Sub-District, Majalengka, highest value of monthly precipitation rate was recorded in December with about 457 mm. The value then increased to 556 mm in March 2013. In April 2014, the value increased to 558 mm. Meanwhile, average value of daily highest precipitation rate in December 2012 was about 14.74 mm. In March 2013, there was a slightly increase to about 17.94 mm, whilst in January 2014 there was a slight increase to about 18.97 mm. Highest value of daily precipitation rate in 2012 was recorded on 19 November with about 114 mm. In 2014 recorded on 9 March with about 113 mm. Lastly, in 2015 recorded on 8 February with about 115 mm.



a.At Bayongbong b. At Cijambu c. At Cikajang d. At Cibogo e. At Kamun

Figure 4: Highest value of daily precipitation rate.

Variability precipitation over months per year at Cimanuk river is like variability precipitation over Indonesia. Indonesia consists of more than 1700 islands, is located between Australian and Asian Continents and Indian and Pacific Oceans. This situation, indonesia is affected by large-scale climatic phenomena such as El Ni˜no–southern oscillation (Kirono *et al.,* 1999) and monsoon (Sukanto, 1969; McBride, 1999; Haylock & McBride, 2001).

Highest stream discharge rate

The highest stream discharge rate in Cimanuk watershed, in the village of Kertasemaya, Kertasemaya Sub-District, Indramayu was recorded in December 2008 with about 578.5 m^3/sec. In February 2009, the value decreased to 418 m^3/sec. In February 2010 there was a slight decrease to 402 m^3/sec. In March 2011 the value was slightly increase to 478.1 m^3/sec. In December 2012, the value dropped to 239.20 m^3/sec. In December 2013, the value rocketed to 766.50 m^3/sec. The highest stream discharge rate in Cimanuk watershed, in the village of Bojongloa, Bayombong Sub-District, Garut was recorded in December 2008 with about 7.04 m^3/sec. In December 2009, the value decreased to 7.00 m^3/sec. In February 2010 there was a slightly increase to 20.19 m^3/sec. In March 2011 the value was relatively steady with about 19.15 m^3/sec. In January 2012, the value dropped to 9.92 m^3/sec. In April 2013, the value rocketed to 15.27 m^3/sec.

The highest stream discharge rate in Cimanuk watershed, in the village of Leuwidaun, Kuta Kulon Sub-District, Garut was recorded in March 2008 with about 25.17 m^3/sec. In November 2009, the value increased to 59.4 m^3/sec. In December 2010 there was a slightly decrease to 35.68 m^3/sec. In April 2011 the value surged to 40.30 m^3/sec. In December 2012, the value rocketed to 78.53 m^3/sec. In April 2013, the value dropped to 47.14 m^3/sec.

The highest stream discharge rate in Cimanuk watershed, in the village of Tomo, Tomo Sub-District, Sumedang was recorded in December 2008 with about 187.50 m^3/sec. In March 2009, the value decreased to 130 m^3/sec. In February 2010 there was a slight decrease to 127.40 m^3/sec. In December 2011 the value surged to 339.70 m^3/sec. In January 2012, the value rose to 387.1 m^3/sec. In January 2013, the value dropped to 327.3 m^3/sec. The highest stream discharge rate in the village of Bayongbong, Bayongbong Sub-District, Garut was recorded in April 2011 with about 7.513 m^3/sec. In November 2012, the value increased to 8.54 m^3/sec. In April 2013 there increased to 10.92 m^3/sec.

The highest stream discharge rate in the village of Leuwigoong, Leles Sub-District, Sumedang was recorded in December 2010 with about 53.58 m^3/sec. In December 2011, the value increased to 62.94 m^3/sec. In December 2012 there was a slightly increase to 198.64 m^3/sec. In December 2013 the value surged to 304.9 m^3/sec. The highest stream discharge rate in the village of Monyot, Cibeureum Sub-District, Majalengka was recorded in December 2008 with about 41.57 m^3/sec. In February 2009, the value decreased to 33.50 m^3/sec. In February 2010 there was a slightly increase to 351.20 m^3/sec. In December 2011 the value dropped to 262.1 m^3/sec. In December 2012 the value surged to 325.90 m^3/sec. The highest stream discharge rate in the village of Wado, Wado Sub-District, Sumedang was recorded in February 2009 with about 95.40 m^3/sec. In April 2011, the value decreased to 57.28 m^3/sec. In January 2012 the value relatively steady at 54.69 m^3/sec.

Analysis of highest rate of monthly precipitation, daily average precipitation, daily precipitation and stream discharge

During a 4-year period of measurement across Cimanuk watershed, there were no occurences of highest rate of monthly precipitation, daily average precipitation, and daily precipitation in the month of May, June, July, August, September, and October. On the otherhand, highest rate of monthly precipitation, daily average precipitation, and daily precipitation were focused in November, December, January, February, March, and April, since it is rainy season. Other season, it is dry season such at

May, June, July, August and October, highest rate of monthly precipitation, daily average precipitation, and daily precipitation were never found. Law and Jong (2006) also said Terengganu River estuary during Northeast Monsoon season (between November and March) receives a very heavy load of monsoon rains. When the season move toward inter-monsoon and Southwest Monsoon season, it is dry season. Fadzil *et al.* (2011) said the water characteristics along the Johor Coast follow the common pattern of monsoon South China Sea (SCS).

Therefore, higher probability of flood occurence in Cimanuk watershed may concentrated only in those months. The highest rate of monthly precipitation often occured in December, and followed respectively by the month of bulan April, March, February, and January. Therefore, it can be estimated that according to the highest rate of monthly precipitation, the probability of flood occurence in December was 0.37, followed by April with about 0.26, March with about 0.21, February with about 0.11, and lastly January with about 0.05. The highest rate of daily average precipitation often occured in December, and followed respectively by the month of bulan April, March, February, and January. Therefore, it can be estimated that the probability of flood occurence in December was 0.44, followed by April with about 0.17, March with about 0.17, February with about 0.17, and lastly January with about 0.11. The highest rate of daily precipitation often occured in November, and followed respectively by the month of bulan December, April, March, February, and January. Therefore, it can be estimated that the probability of flood occurence in November was 0.26, followed by December with about 0.21, April with about 0.21, February with about 0.11, and lastly January with about 0.05.

Occurence pattern of highest rate of montly and daily average precipitation were seem to be more stable than daily precipitation. Therefore, it can be said that the highest flood probability in Cimanuk watershed was in December, followed respectively by April, March, February, and January. However, November should also be waryed since in this month there still a chance in the occurence of highest rate of daily precipitation that may cause flood.

Highest rate of stream discharge

Every year in May, June, July, August, and September there were no high stream discharge at all. Similarly, highest rate of monthly precipitation, daily average precipitation, and daily precipitation never be recorded in those months. Hence, it is estimated that in those months, there were no flood occured in Cimanuk watershed. Highest rate of stream discharge often recorded in December, followed by February, April, March, January and November. According to the highest rate of stream discharge, flood occurence probabilities for each corresponding month were 0.34, 0.20, 0.17, 0.11, 0.11, and 0.06 respectively. Flood occurences in Cimanuk watershed were caused by the stream discharge that exceding the river's capacity. So that, it can be said that the most significant indicator to estimate flood probability is stream discharge. Additionally, December may be regarded as the month with the highest propability of flood, since highest rate of stream discharge often recorded in this month.Correlation between highest rate of stream discharge's occurence frequency and the occurence frequency of highest rate of monthly precipitation, daily average precipitation, and daily precipitation were 0.807, 0.960, 0.162 respectively. Hence, highest rate of stream discharge can be determined by measuring the highest rate of monthly precipitation, daily average precipitation, and daily precipitation. However, it should be kept in mind that the highest rate of daily precipitation hold insignificant correlation with stream discharge.

Physiographic factors

Precipitation data were taken in 2016. According to this data, precipitation rates in Cimanuk watershed in Januari were ranging from 80-500 mm. In February, the values increased to 100-700 mm. Then in March, precipitation range decreased to 140-600 mm. In April, the lower and upper limit of precipitation values usually dropped compared to the previous month to about 40-500 mm. In May, this decreasing trend were generally remain stable, with precipitation range about 0-180 mm. In June, July, August, and September the trend remained steadily decreased with about 0-60 mm (June) and 0-20 mm (July, August, September). Afterwards, in October, November, and December, the trend started to increase with about 0-140 mm (October), 40-500 mm (November), and 20-600 mm (December).

Soil type in the upstream was dominated by association between Andosol and Regosol along with some insertion of Latosol. Regosol was characterized by greyish brown colour, and usually found on middle and deeper soil layers. Its texture was loam or sandy loam. Meanwhile, in regard to Andosol, this type of soil could be identified by its brownis colour, usually found on deeper layer, and its loamy texture. Soil type in middle stream of Cimanuk watershed was dominated by Latosol, which made up to 70% of total soil type in the area. Differently, on riverside area, the type of soil was dominated by greyish aluvial with loamy texture. Other types of soil commonly found on this area were including Latosol, Regosol, and Andosol. On the other hand, in lower stream area, the soil was composed of Gley, Alluvial, Mediteran and Podzolik.

Slope throughout Cimanuk watershed are very diverse. In upstream area, slope class relatively moderate to steep (25-45^o) with strong litological association originated from volcano sediments. In middlestream area, the slope generally flat to moderate (0-25^o). Meanwhile, in lowerstream area, the slope commonly low (0-2^o)associated with vast swamp and flood sediment areas. Land cover and land use across Cimanuk watershed can be divided into 10 classes, covering agricultural field, lake, bushes, pristine forest, settlement, plantation, paddy field, ponds, river, and sand dune. Paddy field dominates this land use classes with aboutn 1217.43 km^2 total extent (33%), followed by agricultural field with about 851.32 km^2 (23%), and pristine forest with about 789.32 km^2 (22 %).

Table 3: Estimated parameters of linear regression models.

Month	Flood vulnerability					Coefficient of Determination (R2) (%)
	Intercept	Precipitation	Soil type	Land cover	Slope	
January	+2.004	0.07465**	0.06159**	0.55252**	-0.08332*	95.6
February	+2.858	0.04776**	0.02415ns	0.70952**	-0.10684**	96.1
March	-0.156	0.12974**	0.02183^{ns}	0.68994**	-0.44890**	97.2
April	+1.777	0.09611**	0.05485**	0.74398**	-0.37700**	96.8
May	+1.307	0.09321*	0.12365**	0.80016**	-0.08609^{ns}	93.4
June	+0.005	0.01215	0.09471**	0.74227**	-0.10763**	95.4
July	-2.331	2.13310**	0.02820*	0.21937**	-0.28441**	98.2
August	-0.096	0.96800**	0.07743**	0.45234**	-0.06973^{ns}	96.5
September	-2.070	2.09250**	0.01371^{ns}	0.22468**	-0.40743**	97.4
October	-0.109	0.05115^{ns}	0.08290**	0.82615**	-0.03845^{ns}	96.1
November	+2.389	0.01403^{ns}	0.14319**	0.72343**	-0.09825^{ns}	91.0
December	+0.502	0.08401**	0.08183**	0.50201**	-0.08836**	96.2

* significant, ** very significant, ns is not significant.

In December and January the most influential factors on flood vulnerability in Cimanuk watershed are monthly precipitation, soil type, land cover, Slope. Precipitation, soil type and land cover imply positive influence on flood vulnerability, while Slope implies negative influence on flood vulnerability. Flood vulnerability regression model in December can be expressed as: Flood vulnerability = 0.502 + 0.08401 X_1 + 0.08183 X_2 + 0.50201 X_3 - 0.08836 X_4, whlist in January: Flood vulnerability = 2.004 + 0.07465 X_1 + 0.06159 X_2 + 0.55252 X_3 -0.08332 X_4. Those equations show that if there is a change in land cover (X_3) from vegetated land to other uncovered class, then there will be an increase in flood vulnerability. Similarly, if there is a change in soil type (X_2) that originally porous to hardened soil layer, then there will be increase in flood vulnerability. Inline with this notion, a steeper slope class implies a lower flood vulnerability (X_4). Meanwhile, an increase in precipitation rate (X_1) may also imply to an increase in flood vunerability. Then it can be said that, the higher flood vulnerability, the greater probability of flood occurence. Determinantion coefficient for flood vulnerability model in December and January, are 96.2 % and 95.6 % respectively. In February, April, May, June, July, August, September, and November, the factors have positive effect to flood vulnerability are precipitation (X_1), soil type(X_2), and land cover (X_3). While the factor that negatively affect flood vulnerability is the slope (X_4). The coefficient of determination models in those months are greater than 90%. It means more than 90% of data can be explained by the models.

Conclusion

During rainy season (December, January, February, March, and April), the area study has high precipitation (monthly precipitation, average of daily precipitation, daily precipitation). Local goverment should be carrefull at those months, since it has high probability of flood occurence.

In all months of the year, the factors that have positive effect on flood vulnerability are precipitation, soil type and land cover. While the factors that negatively affect flood vulnerability is the slope. Those equations show that if there is a change in land cover from vegetated land to other uncovered class, then there will be an increase in flood vulnerability. Similarly, if there is a change in soil type that originally porous to hardened soil layer, then there will be increase in flood vulnerability. Inline with this notion, a steeper slope class implies a lower flood vulnerability. Therefore, the government should prohibit people from changing land use from agriculture to non-agriculture and transforming hilly land into flat land. It is advisable to reforest the land.

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