TEMPORAL AND SPATIAL ANALYSIS OF EXTREME RAINFALL ON THE SLOPE AREA OF MT. MERAPI

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ABSTRACT

Rainfall has temporal and spatial characteristics with certain pattern which are affected by topographic variations and climatology of an area. The intensity of extreme rainfall is one of important characteristics related to the trigger factors for debris flow. This research will discuss the result of analysis on short duration rainfall data in the south and west slope of Mt. Merapi. Measured hourly rainfall data in 14 rainfall stations for the last 27 years were used as analysis input. The rainfall intensity-duration-frequency relationship (IDF) was derived using empirical formula of Sherman, Kimijima, Haspers, and Mononobe method. The analysis on the characteristics of extreme rainfall intensity was performed by conducting spatial interpolation using Inverse Distance Weighted (IDW) method.

Result of analysis shows that IDF of rainfall in the research area fits to Sherman's formula. Besides, the spatial distribution pattern of maximum rainfall intensity was assessed on the basis of area rainfall. Furthermore, the difference on the result of spatial map for one hour extreme rainfall based on isolated event and non-isolated event method can be evaluated. The result of this preliminary research is expected to be inputs in the establishment of debris flow early warning in Mt. Merapi slope area.

Keywords: *Rainfall intensity, spatial distribution pattern, isolated event, non-isolated event*

1 INTRODUCTION

The eruption of Mt. Merapi on 2010 has caused the casualties. In addition, it also left the large volume of deposit sediment material. Its material deposit of the sediment is a potential secondary hazard; such as lahar flow or debris flow that could cause the casualties and damage of public infrastructure. One of the trigger factors of the lahar flow or debris flow on the slopes of Mt. Merapi is the extreme rainfall, which influenced by the air movement globally and locally that make up the diverse mechanisms of the air. Therefore, the rainfall characteristics will vary from the spatial and temporal point of view.

The characteristics of rainfall are affected by the topographic and climatology variations of an area. The distribution of extreme rainfall in the slopes area of Mt. Merapi can be investigated by doing the analysis on the available data of the recorded extreme rainfall. Rainfall distribution is analyzed by comparing the characteristics of rainfall at various elevation of rain gauge. These rainfall characters include the amount of extreme annual rainfall, number of rainy days as well as intensity, duration and frequency of rainfall.

On the slope area of Mt. Merapi, which is an active volcano, the amount of rainfall is the significant factor that triggers the lahar flow caused by the slide material that deposited on the river system. It has the high speed and ability to affect massive damage. Accurate information about the characteristics of extreme rainfall on the slopes of Mt. Merapi can be used for the analysis of sediment associated with disaster mitigation and warning systems of lahar flow hazard.

2 LITERATURE REVIEW

2.1 Rainfall Process

Rainfall is influenced by the geographical of an area. Rainfall in Indonesia has a very high level of diversity in spatial and temporal. This situation caused by the geographic position of Indonesia, which crossed by the equator and lay between two continents and two oceans. Indonesia is also an archipelago country that has many islands with diverse topography that can also lead to higher rainfall variability (As-Syakur AR, 2011).

Rainfall is the event of water falling from the atmosphere to the earth's surface which can occur at any place. There are two factors that influence the rainfall occurrence, i.e. presence of moist air mass and meteorological condition that could lift the mass of air to condense (Sri Harto, 2000).

2.2 Rainfall Intensity

The amounts of rainfall per unit time referred as the intensity of rainfall that commonly is expressed in mm/hr. Therefore, the intensity of rainfall means the amount of precipitation/rainfall in a relatively short time (usually within 2 hours). According Sosrodarsono and Takeda, 1985, rainfall can be classified based on its intensity. The classification of rainfall intensity is shown in Table 1.

Table 1. Rainfall intensity classification

Rainfall Type	Rainfall Intensity (mm)	
	1 hour	24 hour
Very light rainfall	< 1	< 5
Light rainfall	1 – 5	5 – 20
Normal rainfall	5 – 10	20 – 50
Heavy rainfall	10 – 20	50 – 100
Extreme rainfall	> 20	> 100

The analysis of relationship between two important parameters in the form of rainfall intensity and duration can be associated statistically with a frequency of occurrence that the results are presented as intensity-duration-frequency (IDF) graph (Joesron Loebis, 1992).

2.3 Rainfall and Topography

Rainfall, both the intensity and the period is influenced by physical and dynamic processes in the atmosphere (Ina, et al, 2006). Meanwhile, one of the factors that affect the physical processes and the dynamic atmosphere is a form of surface or in other words its topography.

There are three processes correlate rainfall and topography:

a) adiabatic process because of the obstructions such as buildings and mountains, in which artificial and natural barriers would keep the air mass moving horizontally, then forcing the air rises to the top,
b) horizontal convergence process, because of the pressure differential causes air masses accumulate on the surface and then rises to the top that has a lower air temperature,
c) convective processes, heat emitted by the earth's surface, both land and sea of warm air mass will then ascend to a place that has a low temperature (Aldrian, et al, 2011).

2.4 Spatial Interpolation of Rainfall

Interpolation is a method to obtain data based on some other recorded or observed data (Wikipedia, 2012). In order to produce a thematic map, the rainfall data observed in several locations has to be analyzed through spatial interpolation process. Spatial interpolation is a method that can be used to estimate information on an area with a predetermined location based on the information contained in other areas. One of the interpolation method is inverse square distance weighted (IDW), which a simple deterministic method that taking into account the data of the surrounding points (NCGIA, 2007). IDW interpolation equation is as follows:

$$z_0 = \left(\sum_{i=1}^{n} z_i \times \frac{1}{L_i^2} \right) \Bigg/ \left(\sum_{i=1}^{n} \frac{1}{L_i^2} \right)$$

where:
z_0 = the estimated rainfall at point 0,
z_i = the observed rainfall at point/station i,
L_i = the horizontal distance between point 0 and i,
n = the number of rainfall stations.

3 RESEARCH METHODOLOGY

3.1 Research Area

Research location is the area around the slopes of Mt. Merapi. In this research, data taken from 14 rainfall stations, namely Babadan, Deles, Mt.Maron, Ngandong, Batur, Argomulyo, Ngepos, Girikerto, Plosokerep, Pucanganom, Pakem, Sukorini, Sorasan and Randugunting station. The observed data from each station is short duration rainfall (hourly) during the last 30 years (1981-2010).

3.2 Procedures of Analysis

In general, the stages of research activity can be shown in Figure 1.

4 RESULT AND DISCUSSION

4.1 Analysis of IDF Curves

The comparison of the mean deviation for each analyzed rainfall intensity by using Sherman, Kimijima, Mononobe, and Hasper method shows that the Sherman’s formula performs the best result as can be seen in Table 2. Example of graph drawing 5 years return period of IDF curves obtained by applying the empirical formulas and analytical method for the station of Babadan can be seen in Figure 2.

4.2 Spatial Distribution Pattern of Isolated Event Rainfall

Result of spatial interpolation of rainfall data using the methods based on rainfall events with a uniform duration of time (isolated event) produces a variation of rainfall intensity that range from no rain conditions (zero) to a maximum value of 61 mm/hr which spreads the area with radius 250 m to 5 km as shown in Figure 3. The distribution pattern of rainfall that occurred in January for 30 years (1981-2010) also showed that 60% of rainfall events have a tendency trend occurred in the west and southwest slopes of Mt. Merapi. This can happen because of the monsoon is influenced by factors that are potentially forming the western region of convergence in the form of a belt of rain clouds.

Table 2. Comparison of the accuracy of the rainfall intensity formulas

Rainfall Station	Mean Deviation			
	Sherman	*Kimijima*	*Haspers*	*Mononobe*
Argomulyo	0.1	5.3	0.8	0.4
Babadan	0.2	1.0	0.9	0.5
Batur	0.1	1.9	1.9	1.5
Deles	0.1	1.1	2.5	2.1
Girikerto	0.3	0.7	0.3	0.6
Gn. Maron	0.3	3.0	0.2	0.4
Ngandong	0.3	0.9	0.9	0.6
Ngepos	0.3	0.9	0.5	0.8
Pakem	0.1	0.3	1.0	0.7
Plosokerep	0.1	1.1	3.7	3.3
Pucanganom	0.0	0.5	0.9	1.3
Randugunting	0.1	1.0	1.7	1.3
Sorasan	0.1	0.3	0.6	0.2
Sukorini	0.2	0.9	1.7	2.0

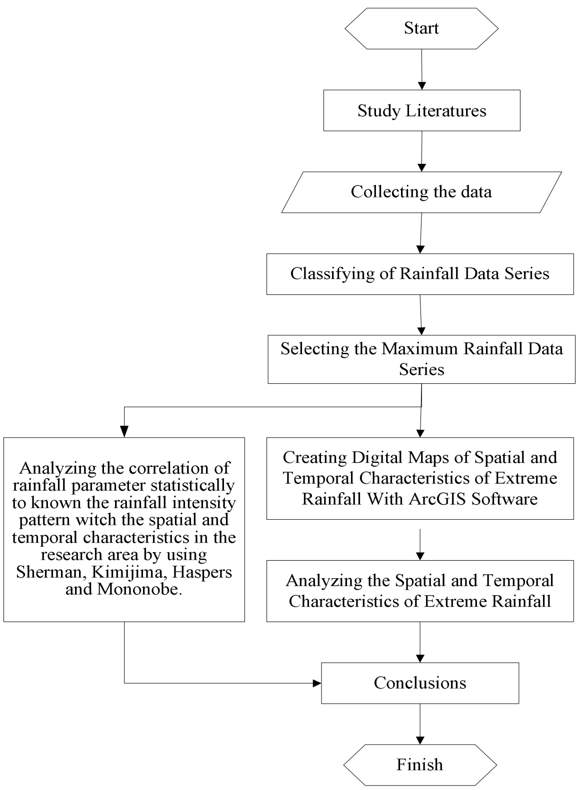

Figure 1. Flowchart of research activities

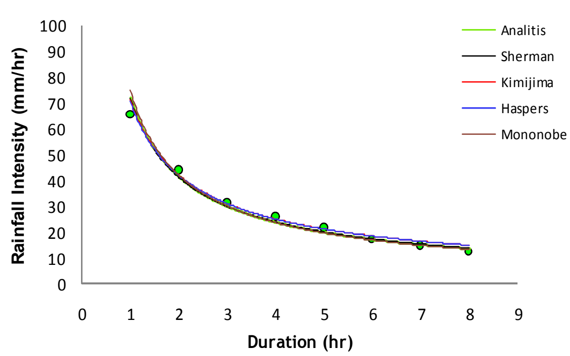

Figure 2. IDF curves Babadan station with 5-year return period.

4.3 Spatial Distribution Pattern of Non-isolated Event Rainfall

Mapping results from the review on spatial distribution pattern of rainfall using the method based on rainfall events with a non-uniform duration of time (non-isolated event) in the event hourly rainfall to have the relatively higher rainfall and predominantly occurs in March, as can be seen in Figure 4. Movement patterns of rainfall in March 2010 also indicate that the rain is influenced by the movement of west monsoon winds which generally started in the month of October to April. In this period the wind movement towards to the east direction as explained in Figure 5, which illustrates the distribution pattern of rainfall that occurred on March 22, 2010 with a maximum rainfall depth of 69.5 mm.

4.4 The Temporal Pattern of Rainfall

The results of analysis by the method of isolated event rain indicates that the extreme intensity (> 20 mm/h) often occurs in the afternoon and evening between 12:00 am and 18:00 pm. The analysis also shows that high intensity rainfall usually occurs in short duration, i.e. 1 hour, 2 hours and 3 hours. Examples of extreme rainfall in the temporal plot for duration of 1 hour and 2 hours in isolated event are depicted in Figure 6 and Figure 7.

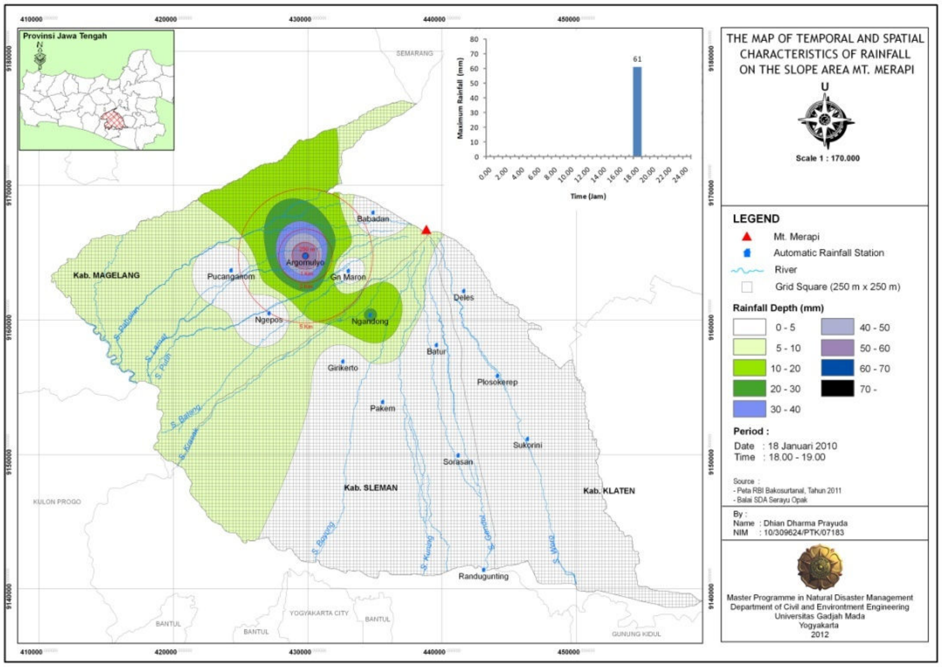

Figure 3. Map of rainfall spatial distribution dated January 18, 2010

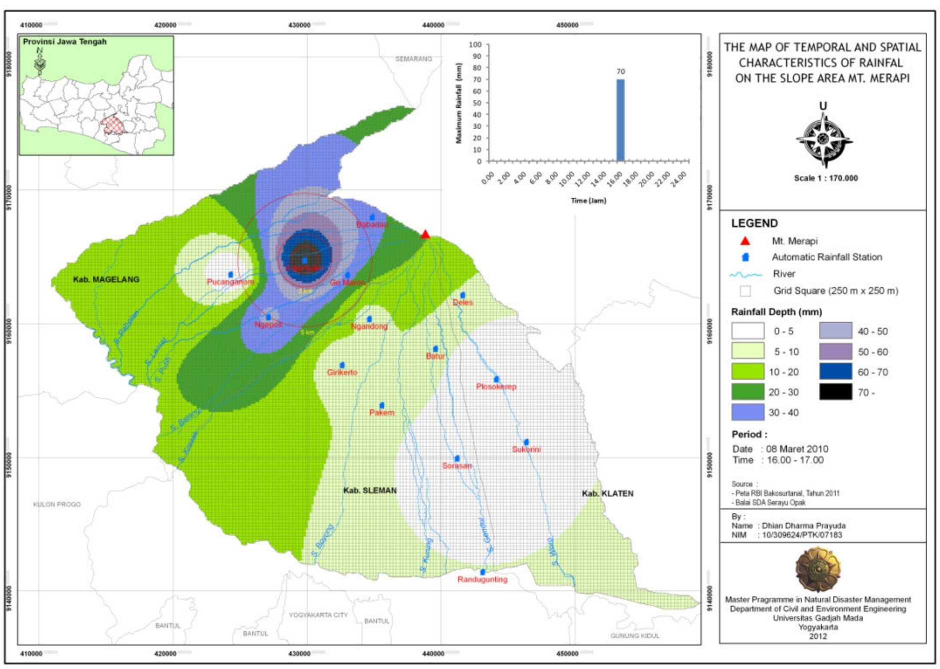

Figure 4. Map of rainfall spatial distribution dated March 8, 2010

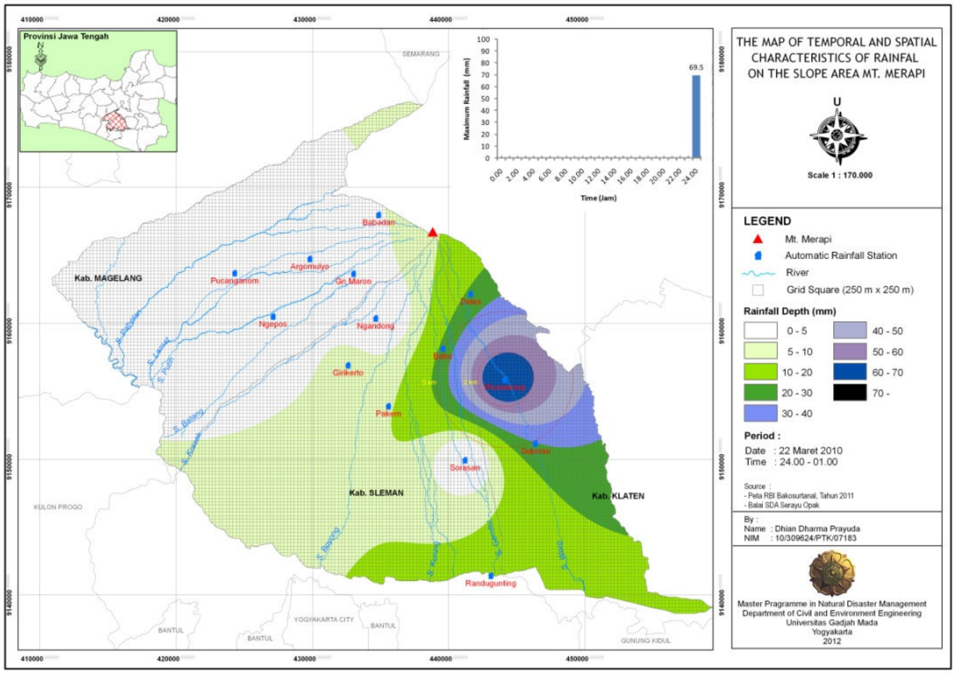

Figure 5. Map of rainfall spatial distribution dated March 22, 2010

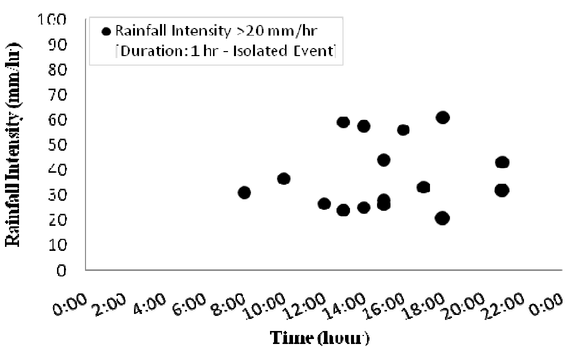

Figure 6. Temporal distribution of one hour rainfall in January 1981-2010

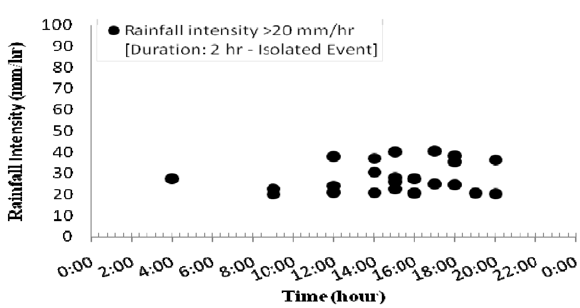

Figure 7. Temporal distribution of two hours rainfall in January 1981-2010

5 CONCLUSION

a) The Sherman's formula performs good result to develop rainfall IDF curve in the research area.
b) Spatial mapping results by using the data in isolated event rainfall of 1 hour duration indicates that rainfall intensity ranges from zero to a maximum value of 61 mm/hr which spreads the area with radius 250 m to 5 km.
c) In case of non-isolated event, the amount of one hour rainfall is relatively higher than the isolated event that often occurs in March.
d) Characteristics of one hour rainfall are influenced by western monsoon winds, in which the maximum rainfall frequently occurs in the west and northwest slopes of Mt. Merapi.
e) The isolated event of extreme rainfall intensity (>20 mm/h) often occurs in the afternoon and evening between 12:00 am and 18:00 pm.

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