Comparison landslide-triggering rainfall threshold using satellite data: TRMM and GPM in South Bandung area

Gian Nanda Pratama¹, Rusmawan Suwarman²,³, I Dewa Gede Agung Junnaedhi², Edi Riawan², Aan Anugrah⁴
¹ Undergraduate of Department of Meteorology, Bandung Institute of Technology
² Research Group of Sains Atmosphere, Bandung Institute of Technology
³ Department of Magister of Hydrogeology Engineering, Bandung Institute of Technology
⁴ Non government organisations, Garda Caah, Majalaya
Email: giannandapratama@gmail.com/giannanda@students.itb.ac.id

Abstract: The number of landslides events in Bandung ranked fourth in Indonesia. The landslide is affected not only by the geographical character, but also by the rainfall intensity and duration. Thus, the information of the threshold of landslide triggering rainfall is important to be obtained. This study is aim to determine the threshold of rainfall in South Bandung using rainfall data provided by TRMM and GPM satellites. The satellite data is corrected by ground-observation data in three sites. The empirical method used in this study performs the relationship between the rainfall intensity and duration to the landslide event and the threshold curve obtained by lowering the regression line intensity-duration (ID) to lowest point rainfall in causing the landslide. The relationship of rainfall ID for landslide threshold is expressed in $I = 2.3e^{-0.03*D}$ for TRMM data, while $I = 7.20e^{-0.09*D}$ for GPM data. The result shows that the GPM data better than TRMM data and the analysis of measurement data showed a pattern corresponding to the observed values.

Keywords: Threshold, GPM, rainfall trigger landslide, observations, landslide, TRMM

1. Introduction
Geology Agency, Center for Volcanology and Geological Disaster Mitigation [1], states the potential for ground movement occurs in Bandung District fall into the category of medium to height. That's because region of Southern Bandung have a 235.213 Ha with slope <4° and then 451.913 Ha with slope >4°[2].

Hong [3] used satellite Tropical Rainfall Measuring Mission (TRMM) data to determine for global events landslides-triggering rainfall threshold. Muttaqin [4] evaluate threshold Hong for West Java, but not have been able to cover all historical landslides data, especially in West Java.

Fauziah [5] conduct research determines the intensity-duration for West Java use satellite data Tropical Rainfall Measuring Mission (TRMM) with a coarse scale. Presently, NASA have two satellites rainfall: Tropical Rainfall Measuring Mission (TRMM) with a coarse scale (0.25°x0.25°) and Global Precipitation Measurement (GPM) with a higher scale (0.1°x0.1°). A minimum rainfall threshold is defined as the lowest level below which a process of landslide triggered by rainfall always occurs. The threshold rainfall has two methods, physical and empirical method. The
physical model requires a lot of supporting data as it combines spatial analysis, soil type, lithology, morphology, and slope. This information is difficult to be collected accurately and must have a great resource.

Furthermore, empirical method is used by applying analysis historical of rainfall events resulted in the landslides. This empirical threshold can be defined global, regional or local and independent of soil type, lithology, morphology, and land-use condition. The combination of rainfall to determine the threshold triggering landslides are divided into four subcategories: intensity-duration (ID) thresholds, thresholds based on the total event rainfall, rainfall event-duration (ED) thresholds, and rainfall event-intensity (EI) thresholds.

Intensity – duration (ID) thresholds is the most common and are widely used in proposed preceding study [3]. This threshold uses a model known as an ID curve. The general equation of this ID curve is

\[ I = c + \alpha D^\beta \quad \text{(1)} \]

where \( I \) is rainfall intensity, \( D \) is rainfall duration, and \( c \geq 0 \). \( \alpha \) and \( \beta \) are parameters obtained empirically. Based on previous researches, \( \beta \) value is ranging from -2.0 to -0.19 and \( \alpha \) value is ranging from 4.0 to 176.44 [3].

Information rainfall observation in-situ is importance to research. And then, December 2015, KK - Atmospheric Sciences – Faculty of Earth Science and Technology (FITB) ITB cooperation with PT. Reasuransi Maipark Indonesia and Garda Caaah for the community service by installing rain gauges at some point in South Bandung area (Figure 1).

![Figure 1. Area study and observations points AWS](image)

Therefore, the area of South Bandung as one of landslides-prone needs to have a rainfall threshold equation. Rainfall Information Satelit Data TRMM has a coarse scale but long history data and then the data GPM which has a detail scale and short history data. This paper, we aim to determine and to compare threshold landslide-triggering rainfall based on the calculation of the intensity-
duration of rainfall with empirical methods and analyze the relationship between the rainfall threshold and slopes in South Bandung.

2. Data and Method

2.1. Data

To determine the rainfall threshold, we need historical event landslides data, rainfall data and topographic data to analyze the relationship between threshold and the degree slope:

- The history of landslide is provided by The Centre of Volcanology and Mitigation of Geological Disaster (PVMBG) and National Disaster Management Agency (BNPB) for South Bandung from 2009 to 2016.
- Rainfall intensity is obtained from rainfall TRMM and GPM, which can be downloaded at (ftp://pmm.nasa.gov and ftp://disc2.nascom.nasa.gov). The spatial resolution is 0.25º x 0.25º and 0.10º x 0.10º.
- Rainfall data observations Weather and Climate Prediction Laboratory (WCPL) which can be downloaded at www.weather.meteo.itb.ac.id
- The topography data obtained from Digital Elevation Model (DEM), with a resolution of 30 x 30 m, can be downloaded at (http://gdem.ersdac.jspacesystems.or.jp/)

To get a landslide triggered by rainfall (not triggered by other causes, such as earthquake or human interference). Landslide occurrence data obtained from PVMBG and BNPB to do filtering. The number of events recorded landslide is as much as 88 events. Filtering methods landslide occurrence in this study:

1. Double data case
2. Undefined Coordinate
3. Slope <4°
4. No description of the place
5. Rainless (No rain consecutive 24 hours before the incident)

From a total of 88 landslides that meet the criteria for filtering results by 26% or 23 events, double data case 24%, undefined coordinate 21%, slope <4° 11%, no description of the place 7% and rainless 11% (Figure 2).

![FILTERING DATA PROFILE](image)

**Figure 2.** Filtering data landslides

2.2. Method
Method to get a rainfall threshold in this study using empirical method ID because the availability of the data support the use of this method, other than that methods of empirical ID produce better results when adding rainfall data that does not resulted landslides. The method of this study is described on point 2.2.1 Verification of satellite data, 2.2.2 Comparison of thresholds TRMM and GPM, 2.2.3 Classification Slopes:

2.2.1 Verification of satellite data
TRMM, GPM and observations have a different grid and temporal resolutions, then for validation data TRMM and GPM with observational data should be equated temporal resolution and view the observation point in the grid. There are two points observation located in one grid (Figure 3 and Figure 4), the observation data should be used as one entity similar to the method of rainfall region.

\[ R = \frac{(R_1 + R_2)}{n} \]  

where \( R \) is rainfall intensity, \( R_1 \) observation (1), \( R_2 \) observation (2), and \( n \) is total stations.

Validation data and comparison of data quality in this study using Spearman Rank Correlation is the ranking method, in this research, ranking ranging from the largest to the smallest.

\[ r_s = 1 - \frac{6 \sum d^2}{n(n^2-1)} \]  

\[ z = r_s \sqrt{n - 1} \]

where \( r_s \) is coefficient correlation spearman, \( \sum d^2 \) is Total square of the difference between ranking, \( n \) is total sample and \( z \) is \( z \) count. For data \( \leq 30 \) use (equation 3), if data\( >30 \) use (equation 4).

Figure 3. Observation point AWS in grid GPM
2.2.2 Comparison of thresholds TRMM and GPM
To compare of thresholds use the regression line of data intensity-duration, most suitable in this method is exponential regression because can describe the landslide events and lowered it to the limited landslide events to get a rainfall thresholds.

Figure 4. Observation point AWS in grid TRMM

Figure 5. Distribution of Landslides
2.2.3 Classification Slopes

The slope is one of the factors supporting the occurrence of landslides. From the results of filtering landslide (23 events), classified according to the classes slope Zuidam [6]. Distribution of landslides data that used in this study the results of slope classification and filtering data (Figure 5).

3. Result and Discussion

3.1. Verification of satellite data

By using a confidence interval of 0.02 or 98% can be seen in (Table 1) showed that the Z count > Z table, but the Spearman correlation coefficient GPM is still better than the TRMM although GPM has been reduced resolution.

| Table 1. Correlation observations and satellite (mm/3 hrs) with Z count and Z table |
|---------------------------------|----------------------|----------------------|
|                                 | AWS and TRMM         | AWS and GPM          |
| Correlation                     | 0.44                 | 0.59                 |
| Z Count                         | 2.99                 | 4.06                 |
| Z Table                         | -2.33 and 2.33       | -2.33 and 2.33       |

The results of the analysis showed that of a significant positive relationship between the variables X and Y but GPM more like observational data seen from GPM Spearmann Correlation Coefficient is greater than the TRMM Spearmann Correlation Coefficient.

3.2. Comparison Thresholds TRMM and GPM

From the results of the threshold (Figure 6 and Figure 7) the most suitable is use exponential regression, because it could cover all the historical landslide and shown in (Table 2), showed the value of R-Square of the fitting rather well 0.4.

![Figure 6. TRMM threshold with exponential regression and event landslides](image)
Figure 7. GPM threshold with exponential regression and event landslides

Figure 8. GPM threshold with gradient slope

Table 2. Comparison Threshold TRMM and GPM with $R^2$ and RMSE

|        | Threshold               | $R^2$ | RMSE |
|--------|-------------------------|-------|------|
| GPM    | I = 7.2 e\(^{-0.01 D}\) | 0.59  | 3.9  |
| TRMM   | I = 2.3 e\(^{-0.05 D}\) | 0.42  | 4.8  |

From the results fitting data (Table 2) RMSE of GPM data smaller than TRMM data is 3.9, it shows that the GPM more similar observation data because it has a small error. Landslide caused by
some factor not only by rainfall, can be seen in (Figure 6 and Figure 7) exponential regression line (blue) and threshold (red) produces different distances between TRMM and GPM. The distance between (blue and red) GPM smaller than the TRMM, it shows that the threshold GPM interference from other factors such as lithology, soil type, land cover, and etc was considered almost equal. Therefore, GPM can describe the threshold of rainfall triggers landslide

3.3. Relationship Between Thresholds with Slope
Slope is one of the important factors of the landslide besides rainfall. This sub-chapter explains only GPM data because this is a better threshold to describe landslide event (Figure 8). Slope with a higher than 6 degree is more contrast than the other classes. The possible things explain this condition because of the lower degrees faster to be saturated rather than steeper degrees. The threshold value on every slope is different class of GPM (Table 3).

| Slope     | Thresholds GPM       |
|-----------|----------------------|
| 4° - 8°   | I=5.14 e^{(-0.14 D)}|
| 8° - 16°  | I=9.4 e^{(-0.14 D)}  |
| 16° - 35° | I=14.95 e^{(-0.06 D)}|

4. Conclusion
Based on the analysis of the relationship rainfall intensity and duration on landslides events studied over South Bandung Area, obtained the following conclusions:

- The obtained threshold from 23 landslide event occurrences in South Bandung Area with GPM data is \( I= 7.2 e^{(-0.09 D)} \) and with TRMM data is \( I= 2.3 e^{(-0.03 D)} \)
- Global Precipitation Measurement (GPM) data more like observational data because correlation GPM is greater than Tropical Rainfall Measuring Mission (TRMM)
- Relationship between slope and threshold landslide-triggering rainfall line shows that the steeper needs to have higher intensity of rainfall and longer duration than flatter slope.

5. Acknowledgements
This research was supported by KK-Atmospheric Sciences FITB-ITB, PT. Reasuransi Maipark Indonesia and Garda Caah for getting rainfall observation data. The Centre of Volcanology and Mitigation of Geological Disaster (PVMBG), National Disaster Management Agency (BNPB) for getting Landslide Inventory Database Indonesia (LIDIA).

6. References
[1] Center for Volcanology and Geological Disaster Mitigation 2008.
[2] Andri N Ardiansyah 2011 Landslide Disaster Risk Areas in Bandung Area. University of Indonesia.
[3] Y. Hong, R.F. Adler, A. Negri, G.J. Huffman 2007 Flood and Landslide Applications of Near Real-time Satellite Rainfall Products. NASA Goddard Space Flight Center.
[4] Imam Muttaqin 2015 Evaluation Threshold I-D Hong 2006 Events for Landslide in West Java. Bandung Institute of Technology.
[5] Selma Nurul Fauziah 2015 The Determination of Rainfall Threshold Triggering Landslide in West Java Using TRMM Satellite Data. Bandung Institute of Technology.
[6] Zuidam, R.A. & Zuidam Cancelado, F.I., 1979 and 1985, Terrain Analysis and Classification Using Areal Photographs, A Geomorphological Approach, Netherland, Enschede: ITC.

[7] F. Guzzeti, S. Peruccacci, M. Rossi, and C.P Stark 2007 Rainfall Thresholds for the initiation of landslides in Central and Southern Europe. Meteorol Atmos Phys 98,. 239-267. The Netherlands.

[8] M. D. Syaifullah 2014 Validasi dan Koreksi Data Satelit TRMM pada Tiga Pola Hujan di Indonesia. Badan Meteorologi Klimatologi dan Geofisika. Jakarta.