Characteristics of Landslide and Rainfall Areas in Majalengka Regency, West Java Province

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Abstract. Majalengka Regency is one of the districts with a high landslide hazard in West Java Province. They are mostly affected by heavy rainfall or prolonged rain. This study aims to classify landslide events in 2018-2019 based on physical factors consisting of slopes, soil types, lithology, land use, and vegetation density using the K-Means Clustering analysis method. To analyze the characteristics of rainfall that triggered landslides in 2018-2019 using the Thiessen polygon method. The results showed that the clustering of landslide events in 2018-2019 in Majalengka Regency was formed five clusters with the highest rainfall on the D-Day average in cluster 5, which is 49 mm/day. The highest average cumulative rainfall 3 days before the landslide events was in cluster 4, which is 80 mm/day. The highest average cumulative rainfall 5 days before the landslide events was in cluster 3 is 112 mm/day. The highest average cumulative rainfall 10 days before the landslide events was in cluster 1, which is 174 mm/day.

Keywords: K-Means Clustering, Landslide, Majalengka Regency, Physical Factors, Rainfall

1. Introduction

West Java Province nationally ranks first in terms of landslides. The Regional Disaster Management Agency of West Java Province noted that the most frequent disaster events were landslides. During February 2019, there were 119 landslides in West Java [1]. The Disaster Risk Index of Majalengka Regency is ranked seventh in West Java Province, and at the national level, it is ranked 16th out of 497 districts and cities in Indonesia [2].

Besides, Majalengka Regency is dominated by hilly and mountainous topography, which covers 71.3% of the total area of this district [3]. The topography is spread across the central and southern parts of this district. In the Majalengka Regency south part, there are mountains, namely Mount Ciremai (3,076 masl), which is the highest mountain in West Java Province. This is related to landslides that usually occur in mountainous areas, hills, steep slopes, and cliffs, so it is straightforward to support landslides. However, in most of the events landslides have a significant impact, namely heavy rainfall or prolonged rain.

Throughout 2018, Majalengka Regency was subjected to rain with the highest rainfall that occurred in January, which reached 705.8 mm with the number of rainy days 28, and the lowest was in August, which was 20.0 mm with the number of rainy days 1. One of them was a landslide in the Gunung Herang Landeluh Block, Sadasari Village, Argapura District, Majalengka Regency, which allegedly occurred due to continuous rain [4]. The Meteorology, Climatology, and Geophysics Agency of the Jatiwangi meteorological station explained that the peak of the rainy season in January and February 2019 is expected to be precise mid-January to mid-February. This has contributed to the increasing incidence of landslides in January and February. This is because the intensity of rainfall that occurs is in the high category, which is above 300 millimeters per month [5].
Thus, based on the occurrence of landslides that have occurred, this research is more emphasized to be able to classify landslide events based on physical factors such as soil type, lithology, slopes, land use, and vegetation density in 2018-2019 and can analyze the characteristics of trigger rainfall landslides are based on groups of landslides in the Majalengka Regency. This study analyzed during 2018-2019 in Majalengka Regency, due to a significant increase in the number of landslides.

2. Data and Method

2.1. Data

Data collection in this research consists of two stages: primary (field survey) and secondary (agency) data collection. The field survey in this study uses the application Avenza, work maps, digital cameras, and writing instruments. During the field survey, observations are made of the location of landslides in Majalengka Regency. The survey was conducted to determine the physical condition of the landslide events area. While other data are data on the distribution of landslides, distribution data of rainfall stations, daily rainfall data, National DEM (for slope maps), land use maps, vegetation density maps, soil type maps, and lithology maps.

2.2. Method

This study used the Thiessen Polygon method and the K-Means Clustering. For the characteristics of landslide-triggering rainfall using the Thiessen polygon method by applying the calculation of rainfall at the time of the landslide, three daily rainfall before the landslide, five daily rainfall before the landslide, and ten days of rainfall before the landslide based on the landslide event cluster in Majalengka Regency. While the characteristics of the landslide area use the K-Means Clustering method, which aims to classify landslide events based on physical factors consisting of soil type, lithology, slopes, land use, and vegetation density in Majalengka Regency to visualize the results of grouping landslide events.

Based on the data that has been collected, processed using ArcGIS 10.4 software, Microsoft Excel, and SPSS software. The stages of the processing process are as follows:

2.2.1. Regional Physical Data Processing

The physical factors of the area in this study consisted of soil type, lithology, slope, land use, and vegetation density. The stages in processing regional physical factor data are using ArcGIS 10.4 software. Soil type maps, lithology maps, land use maps, and slope maps are categorized based on classifications in Majalengka Regency, meanwhile, for vegetation density maps using the results of Sentinel 2 Image processing which is processed using the NDVI algorithm which is adjusted to the results of the validation in the field and adjusted to Google Earth and land use maps from the National Defense Agency. Furthermore, each map of the physical factors is extracted to each landslide events point to produce a map of the distribution of landslide events based on physical factors.

2.2.2. Landslide Events Data Processing

Landslide location data for 2018-2019 is input into the physical factor map of the area consisting of soil type maps, lithology maps, slope maps, land use maps, and vegetation density maps in the Majalengka Regency. Furthermore, to find out the characteristics of the landslide area, the data on the location of landslide events for 2018-2019 in the tabular format is arranged based on the sequence of the date of the event according to the location and time of occurrence.

After that, the coding process was carried out with SPSS software using cluster analysis (K-Means Clustering) to classify the characteristics of landslide areas based on physical factors by scoring the five factors, according to their level of influence on the hazard of landslides. In this study, groups or clusters of landslide events were adjusted based on five physical factors, so that five groups or clusters of landslide events were formed in Majalengka Regency.

2.2.3. Rainfall Data Processing

Spatially and temporally, the rainfall station data is made by dividing the area by the Thiessen polygon. The rainfall data is divided into rainfall on the D-day landslide events, rainfall 3 days before the landslide events, rainfall 5 days before the landslide events, and rainfall 10 days before the landslide events. In determining the cumulative amount of rainfall that triggers landslides, it is done by summing the daily

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rainfall data at the nearest rain gauge station from the location of the landslide events. This is done through overlapping between the time of the landslide and the rain gauge station.

3. Result and Discussion

3.1. Distribution of Landslide Events in Majalengka Regency

3.1.1 Distribution of Landslide Events Based on Slope

Based on Figure 1, it is known that the occurrence of landslides in Majalengka Regency mostly occurred in the steep slope classification (8-16°), namely 29 events with a proportion of 35.37%. Then, the classification of slightly steep slopes (4-8°) has a total of 23 events with a proportion of 28.05%, the classification of ramps slopes (2-4°) has a total of 19 events with a proportion of 23.17%, the classification of slopes is flat (0-2°) has a total of 9 events with a proportion of 10.98%, the classification of slopes is slightly abrupt (16-35°) which is 2 events with a proportion of 2.44%. So it can be seen that Majalengka Regency is dominated by steep slopes and has the highest number of landslides by comparison to other slopes.

3.1.2 Distribution of Landslide Events Based on Type of Soil

Based on Figure 2, it can be seen that the frequency of landslides by soil type in the Majalengka Regency, West Java Province is in six classifications of soil types. Based on the six classifications of soil types, the most landslide occurrences are latosol soil types, which dominate the Majalengka Regency area with 41 landslides with a percentage of 50%. For the distribution of landslides according to other soil types, namely regosol soil types, there were 20 landslides with a percentage of 24.39%. Then, andosol soil types were 9 landslides with a percentage of 10.98%, grumusol soil types were 6 landslides with a percentage of 7.32%, litosol soil types were 5 landslides with a percentage of 6.10%, and 1 alluvial soil types with a percentage of 1.22%. This can be seen in the spatial distribution in Figure 2.
3.1.3 Distribution of Landslide Events Based on Lithology

Based on Figure 3 it can be seen that the frequency of landslides according to the lithology of Majalengka Regency, there are five lithological classifications. Of the five lithological classifications, landslides in Majalengka Regency are only in three lithological classifications, namely volcanic rocks, loose sediments, and solid sediments.
Most landslides occurred in the Majalengka Regency, namely in volcanic rocks as many as 40 landslides with a percentage of 48.78% supported by the lithological area of the volcanic products in Majalengka Regency which dominates compared to other lithological classifications. Meanwhile, for the distribution of landslides, according to other lithologies, solid sediments were 26 landslides with a percentage of 31.71%. Furthermore, in loose sediments, there were 16 landslides with a percentage of 48.78%.

3.1.4 Distribution of Landslide Events Based on Land Use
The distribution of landslide events based on land use shows that residential land is a land-use classification with the highest number of landslide events, namely 39 events with a percentage of 47.56%. Then, shrubs and built land have the same number of landslide occurrences, namely 11 events with a percentage of 13.41%, moor land having 7 landslide occurrences (8.54% percentage), irrigation rice fields having 5 landslide events (percentage 6.10%), plantations had 4 landslide events (4.88% percentage), water bodies had 3 landslide occurrences (3.66% percentage), and forests had 2 landslide events (percentage 2.44%). The spatial distribution of landslides based on land use in Majalengka Regency can be seen in Figure 4.

![Landslide Distribution Map of Land Use in Majalengka Regency](image)

**Figure 4.** Landslide Distribution Map of Land Use in Majalengka Regency

3.1.5 Distribution of Landslide Events Based on Vegetation Density
Based on Figure 5a, it is known that the distribution of landslide events in 2018 with a value of >0.5 (high density) has the largest number of landslides, namely 10 events with a percentage of 33.33%. Vegetation density with a value of <0.2 (non-vegetation) and a value of 0.3-0.5 (medium density) had the same number of landslide events, namely 8 events with a percentage of 26.67%. Vegetation density with a value of 0.2-0.3 (low density) has a number of landslide events of 4 incidents with a percentage of 13.33%. The distribution of landslide event points based on vegetation density in 2018 is centralized in the eastern part of Majalengka Regency which is an area with high density (Figure 5a).

Based on 5b, it is known that the distribution of landslides in 2019 vegetation density with a value of <0.2 (non-vegetation) has the highest number of landslide events, namely 17 events with a percentage of 32.69%. Low density with a value of 0.2-0.3 has a total of 16 landslide events with a percentage of 30.77%. Medium density with a value of 0.3-0.5 has the number of landslide events of 11 events with a percentage of 21.15%. The density is high with a value >0.5, the number of landslide events is 8 with a percentage of 15.38%. The distribution of landslide event points based on vegetation density in 2019 is scattered in the southern part of Majalengka Regency (Figure 5b).
Figure 5. (a) Landslide Distribution Map Based on Vegetation Density 2018 in Majalengka Regency; (b) Landslide Distribution Map Based on Vegetation Density 2019 in Majalengka Regency

3.2. Landslide Occurrences Classification Based on Physical Factors in Majalengka Regency

Table 1. Physical Characteristics of Each Cluster

| Cluster | Slope                  | Type of Soil            | Lithology                              | Land Use                              | Vegetation Density  |
|---------|------------------------|-------------------------|----------------------------------------|---------------------------------------|---------------------|
| 1       | Flat, Ramps, and Slightly Steep | Latosol, Lithosol, and Grumosol | Volcanic Rock, Loose Sediment, and Solid Sediment | Water Bodies and Shrubs                  | Non-Vegetation and Low Density |
| 2       | Ramps, Slightly Steep, Steep, and Slightly Abrupt | Latosol, Regosol, Lithosol, and Andosol | Volcanic Rock and Solid Sediment | Built Land, Settlements, and Moor | Non-Vegetation, Low Density, and Medium Density |
| 3       | Flat, Ramps, Slightly Steep, and Slightly Steep | Latosol, Regosol, Andosol, Grumosol, and Lithosol | Volcanic Rock, Loose Sediment, and Solid Sediment | Built Land, Settlements, Plantation, Irrigation Rice Fields, and Moor | Non-Vegetation, Low Density, Medium Density, and High Density |
| 4       | Flat                    | Alluvial                | Loose Sediment                        | Irrigation Rice Fields                | Non-Vegetation       |
| 5       | Ramps and Steep             | Latosol, Regosol, and Andosol | Loose Sediment, Solid Sediment, and Volcanic Rock | Shrubs, Forest, Plantation, and Water Bodies | Non-Vegetation, Medium Density and High Density |

In Table 1, it is known that the characteristics of landslide areas processed using cluster analysis (K-Means Clustering) in Majalengka Regency are divided into five clusters or groups of landslide events adjusted based on the five physical factors of the area. The clustering technique has wide use and tends
to increase along with the growing amount of data. K-Means is a simple technique in clustering analysis that aims to find the best division of entities "n" into groups of "k" or what can be called clusters so that the total distance between group members and centroids is appropriate [6].

In cluster 1, the number of members is 5 landslide event points, cluster 2 has 28 landslide event points, and cluster 3 has 36 landslide event points, cluster 4 has 1 landslide event point member, and cluster 5 has a total membership of 12 landslide event points. The factors that cause the increasing incidence of landslides are soil type, slope morphology, rainfall, and human activities. Most landslides are triggered by high rainfall [7].

Based on Table 1, it can be seen that each cluster is based on physical factors consisting of slopes, soil types, lithology, land use, and vegetation density. The following is an explanation of the physical characteristics of the cluster, as follows:

1. Physical Characteristics of Cluster 1
   In cluster 1, the dominant slope is a ramps slope (2-4°), which is 3 landslide events. Furthermore, soil type is dominated by latosol soil namely 2 events and lithosol soil namely 2 landslide events. For the lithology classification, it is dominated by volcanic rocks namely 2 events and loose sediments, namely 2 landslide events. If the land use was dominated by shrubs, namely 4 landslide events. Meanwhile, the vegetation density was dominated by non-vegetation with a value of <0.2, namely 4 landslide events.

2. Physical Characteristics of Cluster 2
   In cluster 2, the predominant slope is steep (8-16°) with 14 occurrences. It is also known that the steeper the slopes will increase the potential for landslides [8]. The soil type in cluster 2 is dominated by latosol soil, which is 16 landslide events. For lithology, it is dominated by volcanic rocks, which are as many as 21 landslide events. For land use, it is dominated by settlements, namely 18 landslide events. Meanwhile, vegetation density was dominated by non-vegetation classification (value <0.2), which was 14 landslide events.

3. Physical Characteristics of Cluster 3
   In cluster 3, the dominant slope is a slightly steep slope (4-8°), which is 13 landslide events. Soil type is dominated by latosol soil, which is 15 events. For lithology, it is dominated by volcanic rocks, which are 16 landslide events. Sedimentary rock types are rocks formed from the consolidation of sediment, as loose material, which is transported to the deposition site by wind, water, gravitational landslides, and landslides [9]. If land use is dominated by settlements, there are 21 landslide events. Furthermore, the vegetation density in cluster 3 is dominated by high density (value> 0.5), which is 12 landslide events.

4. Physical Characteristics of Cluster 4
   In cluster 4, it is known that this cluster only has a number of members, namely 1 landslide event point in Majalengka Regency. Because the landslide events point is located in the northern part of Majalengka Regency, it is different from the other landslide event points which are scattered and close to each other, the distance between each landslide event point. Cluster 4 has physical characteristics only on flat slopes (0-2°). The soil type classification only consists of alluvial soils and the lithological classification only consists of solid or undifferentiated sediments. Meanwhile, the land use classification only consists of irrigation rice fields. Furthermore, for the classification of vegetation density, it only consists of non-vegetation which has a value of <0.2.

5. Physical Characteristics of Cluster 5
   In cluster 5, the slopes are dominated by the steep classification (8–16°), which is 11 landslide events. If an area has an increasingly steep slope, the potential for landslides to occur in that area will be even higher. Slopes with a steep slope require soil cover in the form of plants that have strong roots so that the soil on the slope does not experience landslides. Furthermore, for the classification of soil types, latosol soil is dominated by as many as 8 landslide events. If the lithology classification is dominated by loose sediments, there are as many as 8 landslide events. For the classification of land use, it was dominated by shrubs, which were 6 landslide events. Meanwhile, the classification of vegetation density was dominated by high density (value> 0.5), which was 6 landslide events.

Based on Figure 6, it is known that cluster 1 is scattered in the West, East, and South parts of Panyingkiran District, Maja District, Cikijing District, Sindangwangi District, and Leuwimunding District. Cluster 2 is scattered in the East, Central, and South parts of Malausma District, Lemahsugih
District, Cikijing District, Bantarujeg District, Cingambul District, Sindang District, Sindangwangi District, and Argapura District. Cluster 3 is scattered in the West, Central, East, and Southern parts of Majalengka Regency, which are in Kadipaten District, Cigasong District, Argapura District, Rajagaluh District, Sindang District, Sindangwangi District, Leuwimunding District, Panyikingran District, Bantarujeg District, Lemahsugih District, Banjaran District, Cikijing District, Majalengka District, Maja District, Sumberjaya District, and Malausma District. Cluster 4 is located in the northern part of Dawuan District. Cluster 5 is scattered in the Central, Eastern, and Southern parts of Majalengka Regency, which are in Sukahaji District, Argapura District, Banjaran District, Sindangwangi District, and Rajagaluh District.

Figure 6. Landslide Events Cluster Map in Majalengka Regency

3.3 Characteristics of Landslide Trigger Rainfall Based on Landslide Events Groups
Landslides often occur in Majalengka Regency along with the arrival of the rainy season and occur after heavy rains or prolonged rains. When the rainy season arrives there is an increase in the amount of infiltration water which affects the soil, therefore soil pores are easily destroyed and soil aggregation becomes very weak so that the soil shear resistance decreases [10]. Data and information obtained from secondary data state that landslides that occurred in the 2018-2019 period in Majalengka Regency hit 20 sub-districts. As one of the significant natural hazards, landslides cause causalities and tremendous property losses in mountainous areas [11].

3.3.1 Characteristics of Rainfall During the Rainy Season Month
Based on the graph of the average monthly rainfall for 2018-2019 in Figure 7, it is known that the peak of the rainy season generally occurs in March, while the beginning of the rainy season occurs in November. Besides, the highest number of landslides also occurred in February to March as shown in Table 3. At the beginning and peak of the rainy season, the high intensity of rain causes the water content in the soil to fill in a short time and cause landslides through the cracked soil, water will enter and accumulate at the bottom of the slope. The rainfall-induced landslides rely principally on the increased
pore pressure in the soil, which reduced effective normal stress to a critical level [12]. Landslides caused by heavy rainfall events and earthquakes are major natural disasters in many countries and on a global scale [13].

Then, in the January period, the rainfall in Majalengka Regency increases (rainy season period). Meanwhile, in the period from June to October, the rainfall was relatively low (dry season) so that there were no landslides. This situation is evidenced by the difference seen between the number of landslides occurring in the rainy and dry seasons. The number of landslides occurring at the beginning of the rainy season, from January to May, was 82 landslide events, while the number of landslides in the dry season did not have landslides.

![Figure 7. Average Monthly Rainfall for 2018-2019](image)

### 3.3.2 Characteristics of Rainfall in the Landslide Event Groups

Based on Table 2, the characteristics of rainfall based on each cluster in Majalengka Regency, it can be seen that the highest average rainfall on the D-day landslide events is in cluster 5, which is 49 mm/day, while the lowest is in cluster 4, which is 5 mm/day. For the average rainfall for 3 days before the landslide events, the highest was in cluster 1 and cluster 3, which is 29 mm/day, while the average rainfall for 3 days before the lowest landslide events was in cluster 5, which was 25 mm/day.

Furthermore, the highest average rainfall for 5 days before the landslide events was in cluster 1, which was 31 mm/day, and the lowest average rainfall for 5 days before the landslide events was in cluster 5, which was 22 mm/day. Then, the average rainfall for 10 days before the occurrence of the highest landslide was in cluster 3, which was 26 mm/day, and the lowest average rainfall for 10 days before the landslide was in cluster 4, which was 14 mm/day.

At the average cumulative rainfall 3 days before the landslide, the highest was in cluster 4, which was 80 mm/day and the lowest was in cluster 5, which was 54 mm/day. The highest mean cumulative rainfall for 5 days before the landslide events was in cluster 3, which is 112 mm/day and the lowest was in cluster 5, which was 71 mm/day. The highest average cumulative rainfall for 10 days before the landslide events was in cluster 1, which is 174 mm/day and the lowest was in cluster 4, which was 115 mm/day.

For the average rainfall intensity on D-day, the highest landslide events were in cluster 5, which was 62 mm/hour and the lowest was in cluster 4, which was 2 mm/hour. The highest average rainfall intensity for 3 days before the landslide events was in cluster 3, which was 48 mm/hour and the lowest was in cluster 1, which was 7 mm/hour. The average rainfall intensity for 5 days before the landslide events was the highest in cluster 2, which is 28 mm/hour, and the lowest in cluster 4, which was no measurement at the rainfall station. Meanwhile, the highest average rainfall intensity for 10 days before the landslide events was in cluster 2 and cluster 3, which was 30 mm/hour, and the lowest was in cluster 4, which is 1 mm/hour.

In Table 2 it can be concluded that the average rainfall for each cluster with cumulative rainfall 3 days before the landslide events, rainfall 5 days before the landslide events, and rainfall 10 days before the landslide events always has rainfall of >50 mm/day, where the rainfall is included in the category
heavy rain. Meanwhile, the average rainfall intensity based on each cluster is also included in the large rainfall category, because it has a rainfall intensity of >10 mm/hour. This is supported by the Meteorology, Climatology, and Geophysics Agency which states that indicators of heavy to very heavy rain can trigger landslides. The indicator of major rainfall is rainfall with an intensity of >50 mm/day and intensity of >10 mm/hour [14].

In general, there are two characteristics of landslide-triggering rain, which is the type of heavy rain with rainfall reaching 70 mm/hour or >100 mm/day and the normal type of rain with <20 mm/day but lasting a long time. The type of rain is normal but lasts a long time in Majalengka Regency, which is included in the five clusters of landslides. This type of heavy rain is only effective in triggering landslides on slopes where the soil has water-absorbing properties, such as sandy loam. Meanwhile, the normal type of rain if it lasts for several weeks can also trigger landslides on slopes composed of more impermeable soil, such as clay [15]. Besides, it is known that landslides do not only occur during heavy rain but when the rain stops or drizzle for some time (hours) it can cause landslide event in Majalengka Regency, West Java Province.

| Clusters | A (mm/day) | B (mm/day) | C (mm/day) | D (mm/day) | E (mm/day) | F (mm/day) | G (mm/day) | H (mm/hour) | I (mm/hour) | J (mm/hour) | K (mm/hour) |
|----------|------------|------------|------------|------------|------------|------------|------------|-------------|-------------|-------------|-------------|
| Cluster 1 | 27         | 29         | 31         | 25         | 70         | 97         | 174        | 23          | 7           | 16          | 8           |
| Cluster 2 | 43         | 28         | 25         | 25         | 69         | 98         | 168        | 48          | 26          | 28          | 30          |
| Cluster 3 | 37         | 29         | 30         | 26         | 74         | 112        | 170        | 48          | 48          | 23          | 30          |
| Cluster 4 | 5          | 27         | 27         | 14         | 80         | 80         | 115        | 2           | 10          | -           | 1           |
| Cluster 5 | 49         | 25         | 22         | 23         | 54         | 71         | 146        | 62          | 25          | 10          | 7           |

Information:
A = Average rainfall on the day landslide events (mm/day)
B = Average rainfall for 3 days before the landslide events (mm/day)
C = Average rainfall for 5 days before the landslide events (mm/day)
D = Average rainfall for 10 days before the landslide events (mm/day)
E = Cumulative average rainfall 3 days before landslide events (mm/day)
F = Cumulative average rainfall 5 days before landslide events (mm/day)
G = Cumulative average rainfall 10 days before landslide events (mm/day)
H = Average rainfall intensity (mm/hour) on the day of the landslide events (mm/hour)
I = Average rainfall intensity (mm/hour) for 3 days before landslide events (mm/hour)
J = Average rainfall intensity (mm/hour) for 5 days before landslide events (mm/hour)
K = Average rainfall intensity (mm/hour) for 10 days before the landslide events (mm/hour)

4. Conclusion
Based on the physical factors that cause landslides in 2018-2019 in Majalengka Regency, the grouping of landslide events is formed into five clusters with physical characteristics in each cluster dominated by steep slopes (8-16°), latosol soil types, volcanic rock, settlements land use, and non-vegetation with NDVI value <0.2.

The rainfall characteristics that trigger landslides are based on the landslide events group in Majalengka Regency in 2018-2019 have the highest rainfall on the D-Day average in cluster 5, which is 49 mm/day. The highest average cumulative rainfall 3 days before the landslide events was in cluster 4, which is 80 mm/day. The highest average cumulative rainfall 5 days before the landslide events was in cluster 3 is 112 mm/day. The highest average cumulative rainfall 10 days before the landslide events was in cluster 1, which is 174 mm/day.

For research future, it is suggested to use the landslide event point data for a longer period so that the landslide event cluster is more varied and this research can help reduce the occurrence landslide events.
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