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Analysis of the Effectiveness of Flash Floods Disaster Mitigation in Java Island

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Abstract: Flash flood is one of the natural disasters that currently happens a lot in Indonesia. Java Island is one of the largest archipelagoes in Indonesia and has the highest incidence of flash floods. Several efforts were conducted to anticipate and mitigate flash floods in Java Island, including an early warning system, preparing safety equipment, building evacuation route signs, and monitoring watersheds. Through the dataset of Village Potential 2018, this study aims to explore the effectiveness of flash flood mitigation in Java Island using the R programming language. The stages of research carried out in this study are data preprocessing, including selecting, recoding the variables, exploratory univariate, bivariate, and multivariate data analysis. The results showed that the fatalities of flash floods often occurred in areas with plains surface, especially in West Java and East Java, followed by the topography of Central Java on the hills and the valleys in Banten. In addition, the most effective disaster mitigation established in Java Island is safety equipment and the construction of evacuation route signs compared to other disaster anticipation efforts.
Keywords: disaster mitigation, exploratory data analysis, flash floods

1. Introduction

Natural disaster is a set of related events that follow each other in a particular order caused by nature including earthquakes, tsunamis, volcanic eruptions, flooding, droughts, hurricanes, and landslides [1]. One of the natural disasters that often occurs in Indonesia is flash floods. According to Rahardjo [2], flooding occurrence with respect to time event can be divided into slow-onset flood that can take a week to develop and can last for months before floodwaters recede, rapid-onset floods occur more quickly, typically developing within hours or days and some rapid-onset floods known as flash floods occur very quickly within minutes or hours during periods of extremely heavy rain or other causes.

Flash floods are sudden, in the form of overflows that inundate, flow rapidly and wash away large materials, such as rocks, tree trunks, soil, and others. This big flood can occur in areas that have a low surface and are rained continuously [3]. The occurrence of flash floods is caused by the saturation of water in the soil that takes place quickly and cannot be reabsorbed. Stagnant water will gather in areas with a low surface and flow quickly to lower areas. Water flow is so heavy that it will wash away the surrounding objects and are destructive.

Java Island is one of the islands that has the highest incidence of flash floods about 602 events compared to other large and small islands in Indonesia. Based on the disaster risk assessment compiled by National Disaster Management Agency (BNPB), provinces in Java Islands are included in the provinces with the highest flash flood risk of about five million people [4]. Several efforts were made to anticipate and mitigate the natural disaster of flash floods in Java Island.

Disaster mitigation is an action to eliminate or reduce the impacts and risks of disaster, both through physical development program as well as awareness and capacity strengthening to face disaster threats [5]. A various of research and treatments for disaster mitigation in certain provinces in Java are designing an early warning system [6][7], preparing safety equipment, developing evacuation route signs [8], and maintaining or monitoring watersheds [9][10] such as rivers, canals, embankments, ditches, drainage, reservoirs, beaches, and others.

It is hoped that natural disaster mitigation as an activity to reduce disaster risk is able to minimize the loss of life and property by lessening the impact of disaster in the future. Using the dataset of Village Potential (Podes) 2018 from the Central Statistics Agency, this study aims to explore the occurrence of flash floods in Java Island in the last three years, 2015, 2016, and 2017. In addition, this study also analyzes the effectiveness of mitigation that has been carried out based on the number of fatalities caused by flash floods.

2. Material and Methods

The data used is multivariate data from the Podes 2018 [11]. The number of observations based on the data covers six provinces, namely Banten, DKI Jakarta, West Java, Central Java, DI Yogyakarta and East Java with a total of 25,269 villages or sub-districts in one island. The research procedure is conducted by data preprocessing to cleaning, selecting, and recoding selected variables into a structured format. Recoding process is constructed from the metadata of Podes code. R601CK4, R601CK6, R601CK8 are selected as the total of life loss in 2015, 2016 and 2017, respectively. R601CK3, R601CK5 and R601CK7 are selected as the total of occurrences of flash floods in 2015, 2016 and 2017, respectively. As the core of analysis, R602A, C, D and E are chosen as the variable of mitigation activity. The remained code R101, R104, R305B, R601CK2 are presented as the province, village, topography and the existence of flash floods. Table 1 shows the variables used from the dataset.

Tuckey [12] explained that exploratory data analysis is numerical or counting, or graphical detective work, to find and understand fingerprints. Initially, to quantify the ratio between the incidence of flash flood and number of villages, analysis of single variable is carried out at this stage. Moreover, the distribution of data can be obtained as well. Next stage, a two-way analysis is executed to retrieve information about the total of deaths with or without mitigation efforts. Finally, with the addition of the topography aspect, multivariate analysis is performed to observe more detail.

Therefore, R programming language version 4.2.1 with ggplot2 package is used in the technical aspect of executing and visualizing all of the processes above.

Tabel 1. Variable used

Podes Code	Variable	Description	Category
R601CK4, R601CK6, R601CK8	death_toll	The total of fatalities	
R101	prov	Province	
R104	vill	Village or sub-district	
R305B	topo	Topography of village	1=hills; 2=valleys; 3=plains
R601CK2	flash_floods	The occurrence of flash flood	yes/no
R601CK3, R601CK5, R601CK7	total_event	The total of occurrences of flash floods	
R602A	early_warning_sys	Early warning system	yes/no
R602C	safety	Safety equipment	yes/no
R602D	evacuation	Evacuation route signs	yes/no
R602E	watershed	Monitoring watersheds	yes/no

3. Results and Discussion

3.1. Univariate Analysis

On the dataset, it can be obtained that the number of flash flood occurrences on Java Island is 602 events. West Java with the most incidents followed by East Java, Central Java, Banten and DI Yogyakarta with 220, 204, 122, 42 and 14 incidents, respectively, while flash floods did not occur in DKI Jakarta. The result is comparable with the Indonesian Disaster Information and Data collected by BNPB. In fact, it is true that there was no incidence of flash floods in DKI Jakarta but the information about flash floods is limited from the other provinces since the generalization between slow and rapid-onset floods [13]. Based on the number of incidents with the number of villages in each province, the highest ratio was obtained in West Java, at around 4% (Table 2).

Figure 1 shows the right-skewed distribution of the number of flash floods o n Java Island. The median value in a histogram was about 1 to 2 incidents, indicating that most villages encountered flash floods 1 to 2 times during 2015-2017. The diversity of data (range) is quite large. It can be seen that one village in West Java encountered more than 20 flash floods in three years.

Table 2. The ratio of the incidence of flash floods

Province	Number of villages	The occurrence	Ratio
Banten	1.552	42	0,027
DI Yogyakarta	438	14	0,032
West Java	5.957	220	0,037
Central Java	8.559	122	0,014
East Java	8.496	204	0,024
DKI Jakarta	267	0	0

Boxplot (Figure 2) explains that in the three years period, the most significant flash flood did not cause any casualties with a median value of zero. It can be concluded that the probability of a number of victims of flash floods in an interval is generated by a Poisson process. The Poisson distribution is used for counts of events that occur randomly over time when outcomes in disjoint periods are independent [14]. However, an outlier shows that certain flash floods took many victims, particularly in 2017, the incident resulted in 60 deaths in Bojonegoro Regency. Herawaty confirmed that Bojonegoro Regency has massive potential for flash floods that continue to occur from 2018 to 2019. From 2010 until 2018, there were about 13 out of 64 villages in 15 sub-districts were most frequently affected and most severely affected [15].

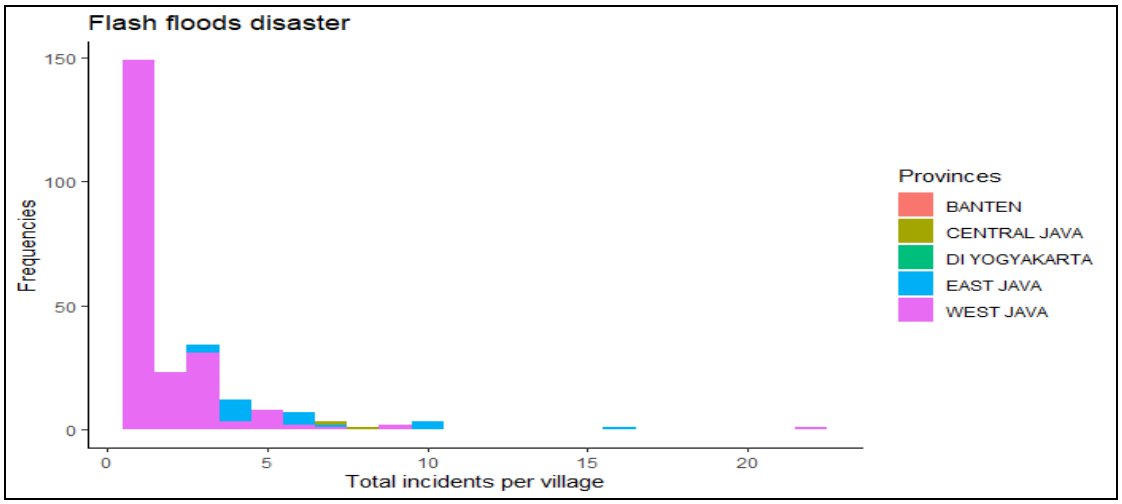

Figure 1. Number of flash floods by village

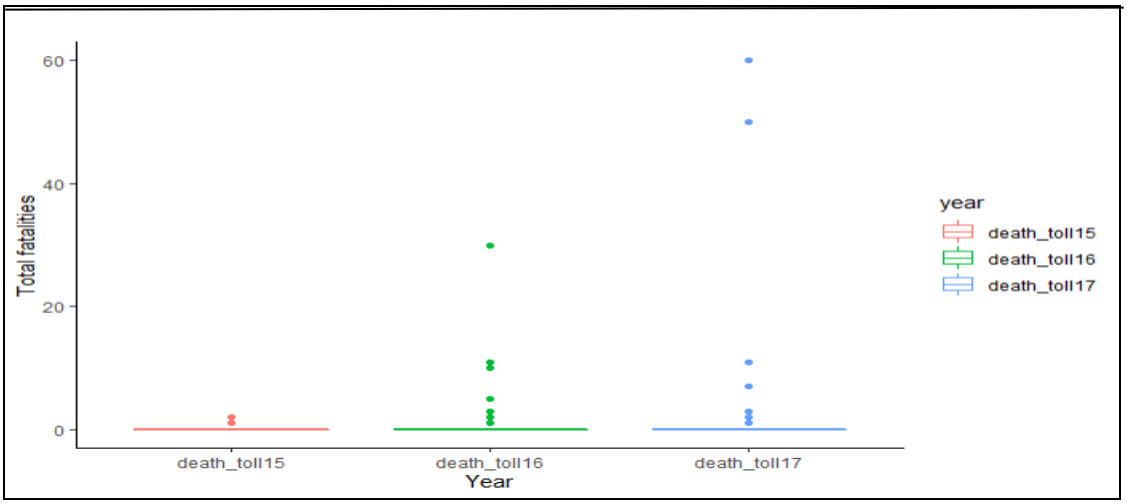

Figure 2. Number of fatalities in 2015-2017

3.2. Bivariate Analysis

In the analysis of two variables, the following boxplot (Figure 3) describes the villages that adopted four types of mitigation with a small distribution of variance with the incidence of flash floods at most 5 times. In contrast, the villages with zero mitigation efforts had a significant variance with the highest frequency of flash floods being about 22 times.

The explorations in figure 4 conclude that the death toll of flash floods in villages that do not have an early warning system, safety equipment, and evacuation routes signs is greater than in villages that do not provide mitigation actions. However, the death toll from flash floods is more in villages that maintain watersheds in their area. The result is contrary to the 2016 Indonesian Disaster Risk Index (IRBI) that one of the best preventions to reduce flash flood is sustainably monitoring the water flow, dam and watershed [16].

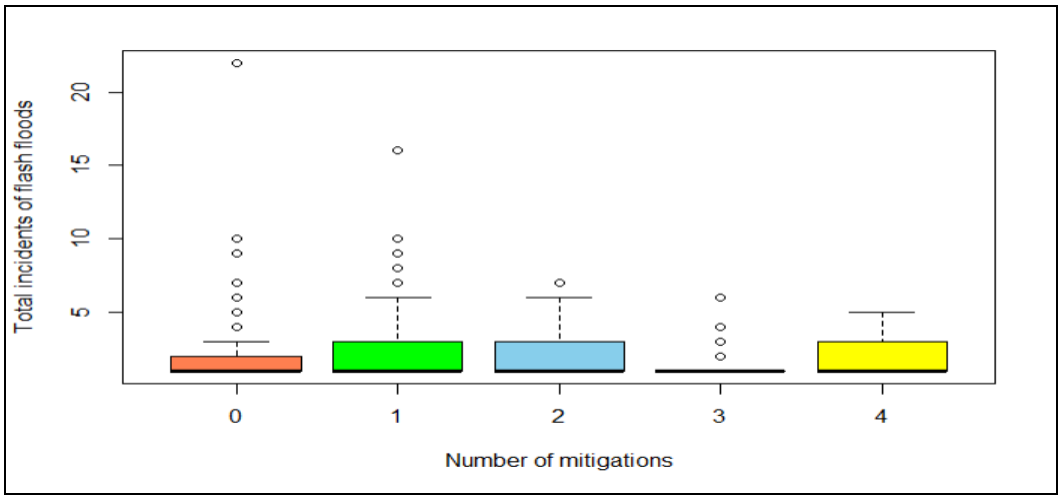

Figure 3. Number of mitigations

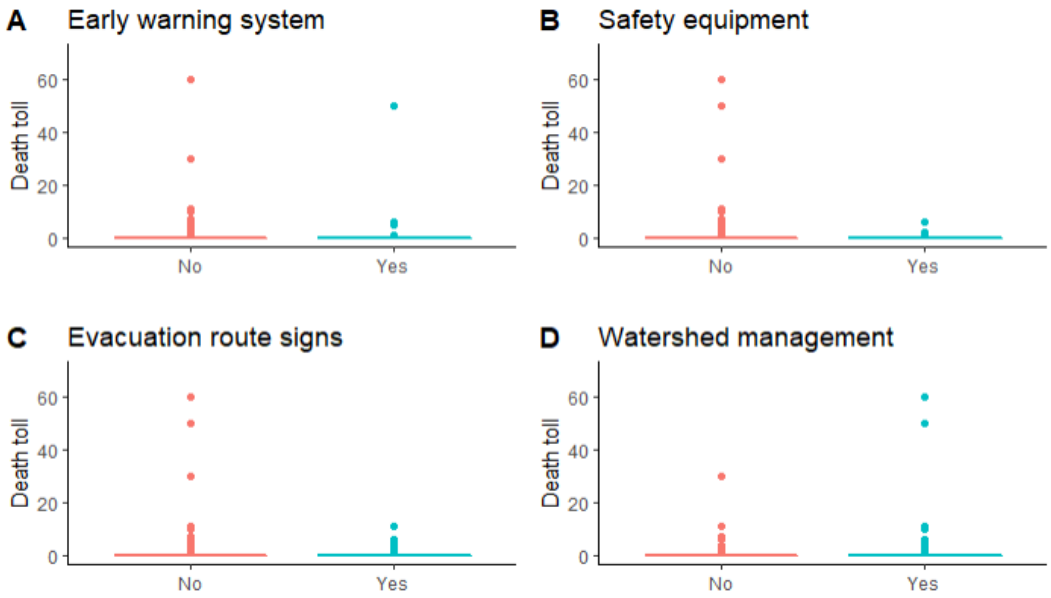

Figure 4. Flash floods occurrences with mitigation actions

3.3. Multivariate Analysis

According to IRBI 2016 [16], the driving parameter of the hazard of flash floods consist of landslides in the upstream area, the mainstem which has the potential to be unstoppable by landslide materials and topographic conditions around the river flow. Thus, the topography variables used in the multivariate analysis (Figure 5) show more informative results where flash floods occur more in plains areas, directly in the downstream area, especially in Bojonegoro Regency, East Java and Garut Regency, West Java.

Cimanuk watershed is not enough to hold water because of the extreme rainfall in Garut Regency. Another factor, land use change from forest to plantations cause run-off becomes increasingly large thus in just two to three hours the water can reach to Tarogong Kidul sub-district [17].

On the other side, flash flood in Central Java have the highest number of flash floods victims in the hills area. The result is also reported by BNPB [18] and the government of Magelang Regency [19] that the location of flash floods is a hilly area which is near the mountain of Andong and Telomoyo.

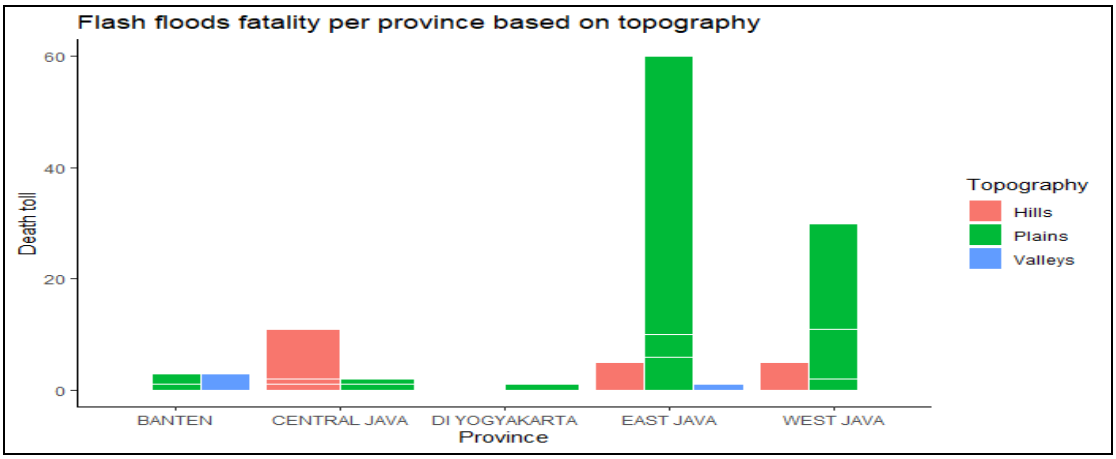

Figure 5. Death toll by topography

Figure 6 illustrates that in provinces with an early warning system support, the number of victims of flash floods caused is relatively lower than in areas that do not implement an early warning system. Based on the Law of the Republic of Indonesia Number 24 of 2007, the strategy of disaster management has been regulated and has to be implemented by the local government. One of the official real-time early warning systems is established by Meteorology, Climatology and Geophysical Agency (BMKG) [20] and it can be accessed online. Moreover, the Regional Disaster Management Agency (BPBD) of Bojonegoro, East Java produces three-day weather and rain forecasts [21].

However, in Sambungrejo village, Magelang Regency shows that an early warning system is limited to be accessed. The hill zone also is practically difficult to reach and the heavy rain triggers landslides causing flash floods [22]. Other findings in Jember Regency, East Java most of the people claimed to have no early warning system for flash floods since they were not known [23].

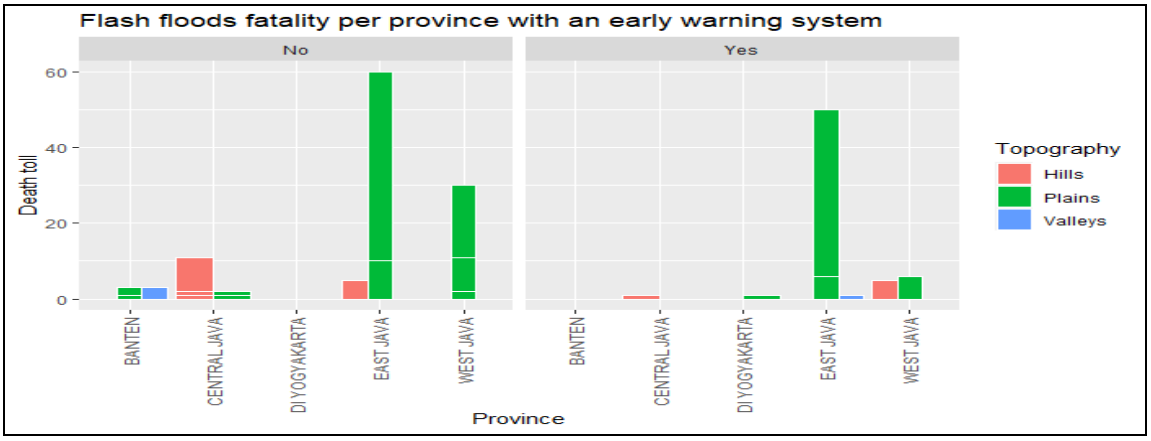

Figure 6. Flash floods fatality with an early warning system

Figure 7 illustrates in provinces that facilitate safety equipment, flash floods can be handled properly thus the fatalities are lower than in areas that do not. In fact, some remote villages located in disaster-prone areas in those provinces were lack of facilities and utilities. The Ministry of Public Works (PU) points out the problem clusters for lack of facilities and utilities. One of them is a minimum amount of equipment or inadequate instruments like rubber boats thus sudden disasters are not handled fast enough [24].

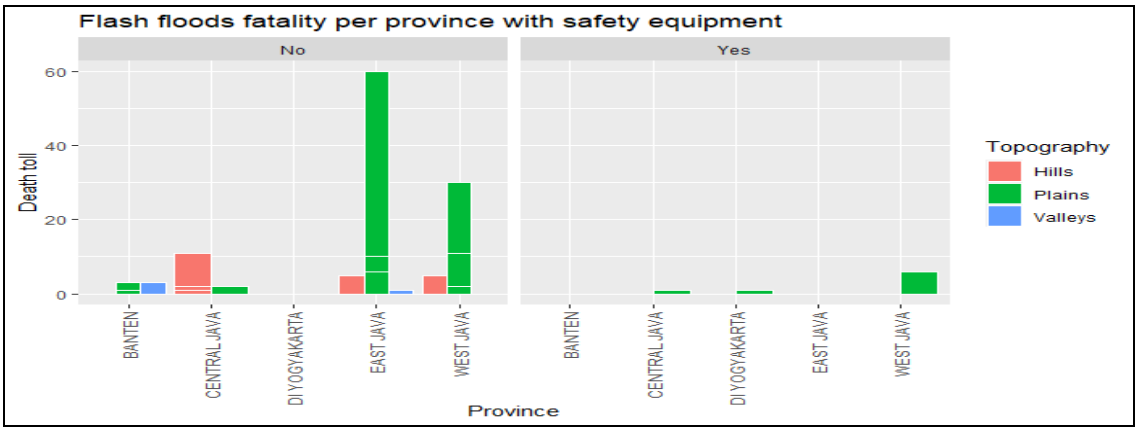

Figure 7. Flash floods fatality with safety equipment

Regarding the Head of BNPB Regulation Number 7, governments, stakeholders, or institutions have to complete the minimum standard of equipment to anticipate and respond to the disaster. Standard basic needs of safety equipment in provinces on Java Island have also been arranged and documented [25]. It can be concluded that those provinces have followed the regulation and prepared the mitigation requirements.

The manual from PU mentioned above also suggests the authorities prepare the area map, flash flood-prone area map, and evacuation route map, which are accompanied by a compass. A study by Sa'ida results that the level of community preparedness in Bojonegoro Regency was at a medium-high level [26]. One of the indicators understanding the evacuation route. Despite that, the high intensity of rain was inevitable. Thus, provinces with evacuation route signs (Figure 8) have also identified that the number of deaths from flash floods is relatively lower than in provinces that do not construct evacuation routes. In the area of Central Java in the topography of the slope surface, there is still quite a lot of life loss there.

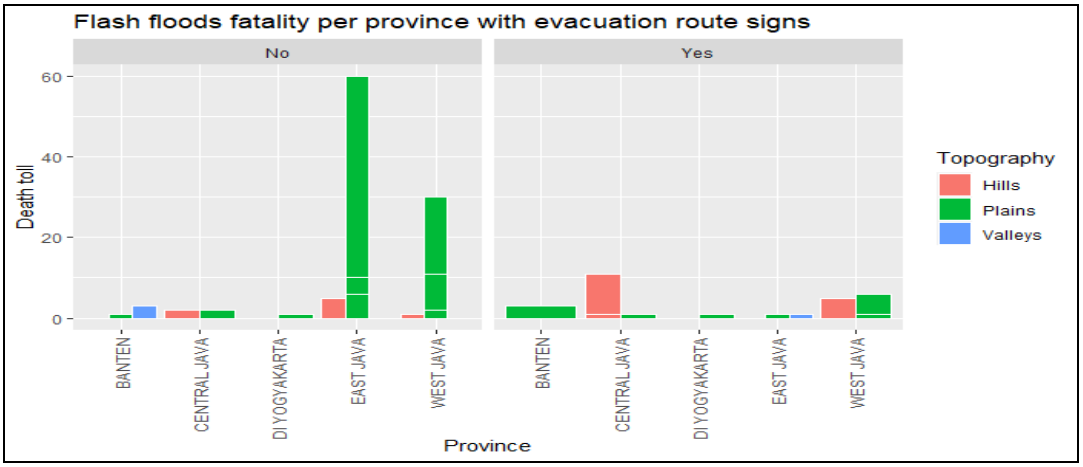

Figure 8. Flash floods fatality with evacuation route signs

The last result, provinces that provide facilities for the monitoring or normalization of watersheds in Figure 9 have a relatively lower number of flash flood victims than areas that do not have management of watersheds. Although the facilities are already available in Bojonegoro Regency, East Java, the flash flood disaster still causes many victims in the province. In Garut Regency, West Java based on the research by Tejakesuma, the Cimanuk watershed was lack of monitoring and control [17]. Deforestation and land degradation affected the flow of water and sedimentation. Briefly, because of the landslides in upstream, an overflowing river of water exceeding its capacity plus the close distance between slopes and valleys rising a large stream of water flowing.

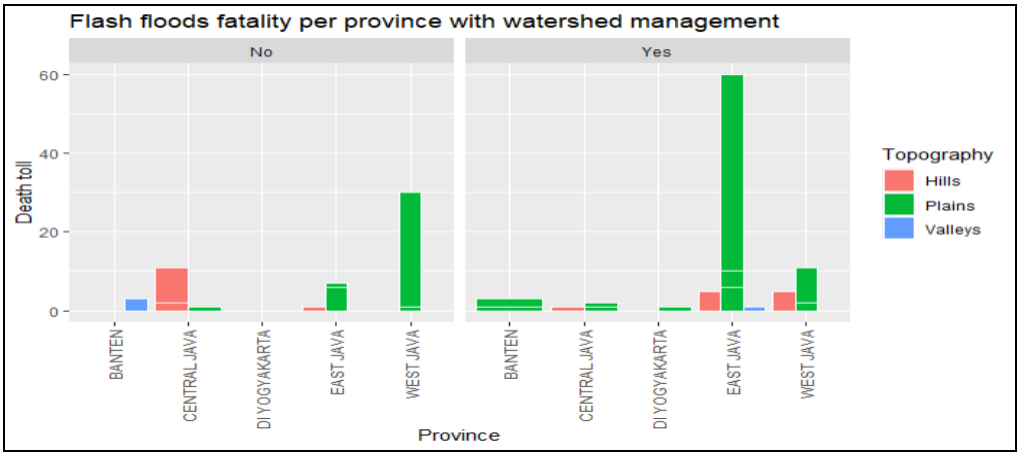

Figure 9. Flash floods fatality with watershed management

It is necessary to restore the ecosystem function of the watershed environment. A constructive conservation way has been established in Kulon Progo Regency among others rivers-flow improvement, normalization of the channel, making embankments, retaining walls flooding, and manufacture of wire ties [27].

Furthermore, the participation of the community is the important key to maintaining the watershed effectively. The disaster management project in the catchment area of Pakis and Jompo River in Jember Regency can be implemented in disaster-prone areas by Yayasan Pengabdi Masyarakat (YPM). Under the cooperation with Japan International Cooperation Agency (JICA), YPM has finished the creation of Standard Operating Procedures (SOP) [28]. The document contains the technical communication and coordination scheme of the community who live in the surrounding area of kalipakis watershed from the upstream, middle stream, and downstream area to monitor the watershed sustainably. Besides that, the monitoring watershed tools listed in the document are totally needed thus watershed management becomes more effective.

4. Conclusion

This study provides several analysis results based on the data exploration that has been done. The death toll of flash floods mostly occurs on the plains surface, especially in West Java and East Java, followed by the topography of Central Java on the hills area and also in the valleys in Banten. Most floods occur in the lowland region due to unusual amounts of rainfall and land use change activity in the forest or upstream area. Even though disaster mitigation measures have been conducted in East Java, the province still causes the highest death toll. This is because the incident occurred in a remote village area that lack of facilities and utilities.

From the analysis of multivariate exploration, the most effective natural disaster mitigation carried out in Java Island is safety equipment and construction of evacuation route signs compared to other natural disaster anticipation efforts. Most of the people in the village have no knowledge about the early warning system and the importance of maintaining the watershed. Despite the fact that the high intensity of rainfall is inevitable, it could be more effective if the provinces in Indonesia, especially on Java Island, integrate all of the disaster mitigation efforts so the impact of flash floods can be minimized.

Acknowledgement

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