The physical characteristics of the small volcanic island of Tidore and Hiri to support disaster management in Maluku

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Abstract. This article presents the characteristics of the small islands of Tidore and Hiri, which are vulnerable to the dangers of volcanic eruptions in Indonesia. The physical condition of the area is very important for carrying out a sustainable disaster risk reduction analysis; therefore, climate and topographic data are important to know. The limited availability of data in the study area causes climate data to be obtained from NASA’s Earth Science Data Systems (ESDS) and regional topographical presentation of Indonesia’s national DEM data. The results show that in the period 2004 to 2014, the temperature in the study area ranged from 292 K to 309 K. The islands of Tidore and Hiri have monthly precipitation between 50 mm to 500 mm.

1. Introduction

As an archipelagic country, Indonesia has the risk of being exposed to complex disasters, both from the sea and land. The various types of hazards that exist cause a high number of vulnerable groups in Indonesia. On the other hand, the level of community preparedness in facing disasters tends to be low [1,2]. Therefore, it requires a spatial arrangement that is in accordance with the characteristics of the local area, both physically, culturally and minimizing the boundaries of an area in order to increase community resilience. Institutionally this has been regulated in Law Number 26 of 2007 concerning Spatial Planning which makes disaster aspects in spatial planning considerations in Indonesia so that disaster-prone areas are the basis for disaster mitigation to improve the safety and comfort of life and community livelihoods. The objective to be achieved from implementing this rule is the creation of disaster management in Indonesia that supports sustainable development and improves the welfare of the Indonesian people.

Every action taken in a disaster analysis must be in accordance with the characteristics of the area, one of which is the characteristics of small islands. Based on the Law of the Republic of Indonesia Number 27 of 2007, a small island is an island with an area of less than or equal to 2,000 km² including its ecosystem unity. Volcanic eruption disaster management on a small island (e.g., Ternate, Tidore, and Hiri Island) requires more effort than volcanic eruption disaster management on a larger island (e.g., Java, Sumatra, and Sulawesi). This is due to all the limitations that need to be minimized so that small islands can support their communities to become more resilient to disasters. Some of the limitations they have are as limited of space, limited of natural resources, limited of accessibility, vulnerability to natural disasters, vulnerable to ecosystems damage, difficulties in terms of transportation and communication, limited of internet networks, limited of markets, limited of clean water supply, and high dependence on...
imports [3]. This is what causes people on small islands to be more vulnerable to disasters, especially people on small volcanic islands to volcanic hazards [4,5].

2. Method
This research begins with the collection of secondary data related to climate data (temperature data, rainfall data), Digital Elevation Model (DEM) data, and analysis of previous research related to the characteristics of the Tidore and Hiri Islands region. The climate data obtained from NASA's Earth Science Data Systems (ESDS), which was downloaded from https://earthdata.nasa.gov/esds, and regional topographical presentation of Indonesia's national DEM data, which was downloaded from http://tides.big.go.id/DEMNAS/.

3. Research Location
Mount Gamalama, Ternate, is one of the active volcanoes in Indonesia (Fig. 1). Based on the potential for volcanic hazards, data from the Indonesian Ministry of Energy and Mineral Resources (ESDM) explained that the Gamalama has a history of eruptions from 1538 to 2018 [6,7]. The first recorded eruption of Gamalama was in 1538, while the most significant eruption occurred in 1775. Gamalama eruptions in 1608, 1771, and 1840 have also triggered tsunamis that affected the surrounding area [8,9,6]. Since then, the activity of Gamalama has resulted in more than 200 death tolls [10]. As a small island with an area of 111 km² and 202,262 populations, Ternate is very prone to volcanic hazards from Gamalama, which is currently in a dormant situation [11]. Therefore, when Gamalama erupted in 1980, 40,000 people from Ternate were evacuated to Tidore since thick tephra and ashfall covered almost the entire island [12].

![Figure 1. The research location.](image-url)
4. Result and Discussion
Research related to volcanic eruptions has been experiencing a fairly good development in recent years in Indonesia, including small volcanic islands such as Ternate Island [13]. Ternate Island is one of small island in Indonesia with an extensive land area of 162.17 km² where it is surrounded by 5,547.55 km² sea areas. This condition causes sea transportation to and from Ternate Island is the main access. The population growth rate continues to increase causing the population density on Ternate Island in 2021 to reach 1,264.11 per km². One of the famous tourist attractions in Ternate is Batu Angus (local name, or charred rock) as a lava flow transferred from the summit down the northern flank to the coastal on March 10-13, 1737 (Fig. 2 and Fig. 3).

Moreover, Gamalama Volcano (1,715 masl) has recorded eruptions that have been fairly routine, occurring almost every year since the first recording was made, namely in the 1538. Between 1990 and 2018, 14 eruptions were recorded, which occurred randomly in uncertain months (Table 1). The Global Volcanism Program notes that these eruption events last from 1 to 15 days. The shortest eruption occurred in 1991 on 5 June, and the eruption occurred for only one day. Then the longest eruption occurred in 2011 from 5 to 23 December. Reporting of the last eruption in October 2018 resulted in gas emissions (mostly water vapor) which caused visitors and residents to stay away from the crater for a radius of 1.5 km and have an alert level of 2 (scale 1-4). Gamalama volcano is monitored by the Center for Volcanology and Geological Hazard Mitigation (PVMBG, also known as the Indonesian Center for Volcanology and Geological Hazard Mitigation, CVGHM).

Table 1. Historical Gamalama eruption's data from 1990 to 2018.

| NO. | ERUPTION DATE (START) | ERUPTION DATE (END) | VEI | EVIDENCE                  |
|-----|------------------------|---------------------|-----|---------------------------|
| 1   | 2018 Oct 4             | 2018 Oct 6          | 1   | Historical Observations  |
| 2   | 2016 Aug 3             | 2016 Aug 4          | 1   | Historical Observations  |
| 3   | 2015 Jul 16            | 2015 Sep 8          | 2   | Historical Observations  |
| 4   | 2014 Dec 18            | 2014 Dec 25         | 2   | Historical Observations  |
| 5   | 2012 Sep 15            | 2012 Sep 17         | 1   | -                         |
| 6   | 2011 Dec 5             | 2011 Dec 23         | -   | -                         |
| 7   | 2008 May 10            | [ Unknown ]         | 1   | -                         |
| 8   | 2007 Aug 23            | [ Unknown ]         | 1   | -                         |
| 9   | 2003 Jul 31            | 2003 Oct 2 ± 3 days | 2   | Historical Observations  |
| 10  | 1996 Jul 2             | Unknown             | 2   | Historical Observations  |
| 11  | 1994 Jan 16            | 1994 Oct 15 (in or after) | 2 | Historical Observations  |
| 12  | 1993 May 6             | 1993 May 21         | 2   | Historical Observations  |
| 13  | 1991 Jun 15            | [ 1991 Jun 15 ]     | 1   | -                         |
| 14  | 1990 Apr 25            | 1990 Apr 26         | 3   | Historical Observations  |

Sc: volcano.si.edu/global volcanism program
Figure 2. Batu Angus (local name, or charred rock) as a lava flow transferred from the summit down the northern flank to the coastal on March 10-13, 1737 Sc: volcano.si.edu

To support disaster risk reduction in coastal areas and small islands due to potential of Mt. Gamalama eruption, especially Hiri Island and Tidore Island, local climate analysis is needed through several parameters, such as temperature and rainfall data [14,15]. The research locations, Tidore and Hiri Islands are part of the climate station on Ternate Island, and there is only one rain station that is actively taking measurements, namely the Sultan Babullah Station, Ternate City, North Maluku. Due to the limited historical data at the research location, rainfall data used in this study comes from data downloaded online via earthdata.nasa.gov with a time span from September 2004 to December 2014. NASA's Earth Science Data Systems (ESDS) facilitates users to access data as a general output product. The average surface temperature at the study site ranged from 292 K to a high of 309 K in the period from September 2004 to December 2014, which is shown in Fig. 4. The lowest temperature that occurs tends to be stable between 292 K to 294 K, while the upper average temperature tends to be more dynamic, from 302 to 309 K.

Figure 3. Batu Angus current conditions as a tourism object

Figure 4. Temperature data of research locations in 2004-2014.
The precipitation data are presented in Fig 5. The precipitation at the study location fluctuated in ten years, increasing and decreasing in value each month; tropical climatic conditions also influence this in Indonesia. The range of precipitation experienced is from 50 mm per month to 500 mm per month. The lowest precipitation occurred at the end of 2009, which is under 50 mm and the highest occurred in mid-2010, which is 500 mm.

In answering the first objective, a topographic map is one of the outputs. Topographic maps help in the analysis of potential evacuation sites for the eruption of Mt. Gamalama on Ternate Island. Topographic maps in the study area represent differences in relief aided by the display of contour lines of the area [16]. The use of the distance between contours or contour intervals of 200 meters is presented in Fig 6. Broadly, the dominant topographic expression in the two research locations is stepped topography. This is the intention of occurring on Tidore Island compared to Hiri Island, not only because Tidore Island has a higher altitude than Hiri Island, but also because Tidore Island is bigger than Hiri Island, which causes variations in topographic expressions to be more varied.

Based on geological conditions and the risk of the eruption of Mt. Gamalama, volcano prone to eruption area type differ into three categories with various range of materials, shown in Fig. 7 [13]. Disaster prone area (DPA) of Mt. Gamalama, which is divided into 3, namely DPA 1, 2 and 3 distributed in several locations. DPA 1 with low risk is located along the basin and the downstream area in the summit, namely in Dufa-Dufa Tabam, Tubo, Kulaba, Bula, Tobololo, Takome, Loto, and Togafo Village. Then DPA 2 with a medium risk level in the form of rock outburst and thick volcano ash in the radius of 3.5 km from the crater. And the last DPA 3 closest to the center of the eruption consists of the eruption column, incandescent rock outburst and lava stream.
Figure 6. Topographic maps Tidore and Hiri Islands.

Figure 7. Map of Disaster-prone area Mt. Gamalama [13].
The above eruption disaster risk causes Hiri Island and Tidore Island to be safer locations to be used as evacuation sites for victims of the Mt. Gamalama. These two islands are located in two opposite directions. Hiri Island with an area of 6.69 km$^2$ is located to the north of the island of Ternate, while Tidore Island with an area of 1,550 km$^2$ is to the south. The selection of these two islands as alternative sister islands when the Mt. Gamalama volcanic eruption disaster is considered a relatively safer land for refugees, using sea transportation routes in the form of ferries or speedboats that can be provided by the local government of North Maluku Province. Hiri Island is one of the mainland that is equipped with public facilities, for example a source of lighting from PT PLN in North Maluku, this is one of the important factors in determining the location of an eruption evacuation.

5. Conclusion
To sum up, climatic conditions and geological situations greatly influence decision making in the evacuation of Mount Gamalama eruption disaster. Tidore and Hiri Islands were experiencing dynamic climate conditions within ten years (from 2004 to 2014). The results show that in this period, the study area's temperature ranges from 292 K to 309 K. The islands of Tidore and Hiri have monthly precipitation between 50 mm to 500 mm, and the dominant topographic expression in the two research locations is stepped topography. In the context of disaster risk, there is an increase in the elements at risk that can be affected by the activity of Gamalama in the future. Analysis of the physical characteristics of the small volcanic island of Tidore and Hiri is one of the strategies for disaster risk reduction (DRR) in this area. These efforts to reduce the risk related to the Gamalama eruption are helpful for the success of regional and national development and the realization of sustainable mitigation of natural disasters.

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