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Toward Resilience City: Potential Hazards and Scenario for Ternate Island, North Maluku

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ABSTRACT

Natural hazards and climate change significantly threaten almost every small island. This is due to the small island's isolation and lack of resources. Ternate Island is a small island that is now afflicted by this issue. Geographically, the island is surrounded by active plates and volcanic paths, making it at risk of serious catastrophes. Population growth and limited land resources also contribute to a high disaster susceptibility. We characterize the features of the small island of Ternate by classifying the types of disasters that threaten it based on a literature database. Earthquakes, volcanic eruptions, floods, extreme weather events, and tsunamis are natural disasters that occur often in Ternate. Additionally, these findings indicate the significant importance of a multi-hazard approach to disaster response. Our examination concludes with some recommendations for establishing the resilience of Ternate City.

Keywords: Disaster, Multi-hazard, Small island, Ternate island, Resilience city

ABSTRAK

Bencana alam dan perubahan iklim merupakan ancaman besar bagi hampir setiap pulau kecil di planet ini. Hal ini disebabkan terpencilnya pulau kecil dan kurangnya sumber daya. Pulau Ternate merupakan pulau kecil yang kini dilanda permasalahan ini. Secara geografis, pulau ini dikelilingi oleh lempeng aktif dan jalur vulkanik sehingga berisiko terjadinya bencana serius. Selain itu, pertumbuhan penduduk dan terbatasnya sumber daya lahan berkontribusi terhadap tingginya tingkat kerentanan terhadap bencana. Kami mengkarakterisasi ciri-ciri pulau kecil Ternate dengan mengklasifikasikan jenis bencana yang mengancamnya menggunakan database literatur. Gempa bumi, letusan gunung berapi, banjir, kejadian cuaca ekstrem, hingga tsunami hanyalah beberapa bencana alam yang sering terjadi di Ternate. Selain itu, temuan-temuan ini menunjukkan pentingnya pendekatan multi-bahaya dalam tanggap bencana. Kajian kami diakhiri dengan beberapa rekomendasi untuk membangun ketahanan Kota Ternate.

Kata kunci: Bencana, Multi-hazard, Pulau kecil, Pulau Ternate, Ketahanan kota

INTRODUCTION

Natural disasters may strike quickly or gradually such as earthquakes, are practically impossible to anticipate precisely when, where, and how potent they will be. On the other hand, tsunamis may still be forecast in advance. Yet, disaster always have a catastrophic effect and result in significant loss of life and property. The surprise was caused by a lack of attention and preparedness to deal with hazards. Moreover, Earthquakes are one of the generators of tsunamis, therefore, both often occur simultaneously.

Badan Nasional Penanggulangan Bencana (BNPB), (2012) noted that the potential disasters in Ternate Island may be classified into two categories: primary hazards and collateral hazards. The primary hazard potential is shown, among other places, on the map of probable seismic disasters in Indonesia, which indicates that North Maluku, including Ternate Island, is a region with earthquake-prone zones that may result in tsunamis. As a result of the indications above, it can be determined that Ternate has a high potential for major hazards. This is not profitable for Ternate, which is heavily populated.

Furthermore, Ternate Island also has a significant potential for collateral hazards. Numerous indices demonstrate this, including liquefaction, the proportion of wood-frame structures, building density, and commercial area density. Collateral hazard potential is quite high, particularly in the island's coastline portions, which are densely populated and serve as a centre of activity for the residents of Ternate. Based on data from the Indonesian Disaster Index, Ternate City experienced 27 disasters between 2010 and 2020 (Badan Nasional Penanggulangan Bencana (BNPB), 2022). These disasters include earthquakes, volcanic eruptions, landslides, tsunamis, floods, and coastal abrasion.

The degree of urban vulnerability in Ternate is important to characterize as one of the elements influencing the incidence of natural disasters since a catastrophe will occur if the vulnerability level is low. Disasters occur when potentially harmful natural processes meet with at-risk components and their corresponding physical, social, economic, and environmental vulnerability (Birkmann, 2006). As a result, a better knowledge of the following components and their interactions is crucial for disaster risk reduction: a) the risks that create a substantial danger; and b) the society's, economies, and built and natural environments' vulnerabilities (Birkmann, 2006; UNISDR, 2015).

One of the factors contributing to disasters in Ternate is a lack of community awareness and knowledge of the characteristics of disaster threats. It is often as if a crisis strikes unexpectedly, leaving people unable to cope with it, resulting in significant losses and even deaths. While many disasters may be foreseen with reasonable accuracy before their occurrence, they rely on the availability and readiness of technologies and human resources.

Ternate Island are suitable for the resilient city concept because they are complex systems constantly adapting to changing circumstances. Resilience is a diverse and expansive concept in and of itself. The word "resilience" originated in the study of ecology in the 1970s to define a system's potential to sustain or regain functioning in the case of interruption or disturbance(Rockefeller, 2015) . The term resilience was defined as "the ability of a system to remain in a practical state and to degrade gracefully in the face of internal and outside changes (Allenby & Fink, 2005)." While Bruneau et al., (2003)defined resilience as "the ability of social units to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways to minimize social disruption and mitigate the effectors of further earthquakes." While In engineering, resilience is the ability to "withstand stress, survive, adapt and bounce back from a crisis or disaster and rapidly move on"(Wagner & Breil, 2013).

The conceptual constraint of resilience is that it does not always account for the power dynamics that underpin how cities operate and respond to crises(Rockefeller, 2015). Resilience has aided in bridging the divide between catastrophe risk reduction and adaptation to climate change. It departs from more typical approaches to disaster risk management, which are based on risk assessments related to hazards. Rather than that, it acknowledges the potential of a broad variety of disruptive events - both stressors and shocks – occurring but not always anticipated. Resilience is concerned with boosting a system's performance in the face of various threats, rather than with avoiding or minimizing asset loss due to single incidents (Rockefeller, 2015).

Building more resilient cities enables them to endure and recover from shocks and pressures, allowing them to alter plans and processes before, during, and after new or unforeseen disruptions and operate normally throughout the disruption (Patel & Nosal, 2016). Building city resilience is a comprehensive process that requires the engagement and collaboration of all local stakeholders (Malalgoda et al., 2013). Consequently, resilient cities guarantee more sustainable development (Iturriza et al., 2019). Sustaining sustainability involves a system's capability to adapt to changes and continue operating over time (Maclaren, 1996; United Nations, 2007). As a result, a sustainable city must acquire characteristics that enable it to absorb stressors and adapt to and deal with change (Alberti, 1996; Carpenter et al., 2001). Numerous studies have examined the link between city resilience and sustainability (Derissen et al., 2011; Marchese et al., 2018). Still, no clear agreement exists about the relationship between the two concepts. Nonetheless, all studies demonstrate that increasing a city's resilience encourages sustainable development (Iturriza et al., 2019).

The identification of disaster characteristics is the initial stage in disaster management activities toward aresilient city. Government authorities and the public, particularly those who live in disaster-prone regions, must understand the features of the impending calamity on Ternate Island. Efforts to identify the characteristics of disasters that frequently occur on Ternate Island are a mitigation effort because, by identifying these characteristics, all stakeholders can gain a better understanding of the behaviour of threats and take the necessary steps to overcome them or at the very least mitigate their potential consequences. Finally, it will empower all stakeholders to comprehend the disaster management idea, which has shifted from traditional to holistic. In the holistic paradigm, each person and community in the region is exposed to the numerous risks that exist in their area, how to mitigate their hazards and vulnerabilities, and how to strengthen the community's ability to cope with each threat. Therefore, this study aims to briefly explain most of the disasters on Ternate Island and the opportunity to build a Ternate resilience city.

METHODOLOGY

This study is qualitative research that applied literature study, which is data collection by searching for sources and constructing from various sources such as books, journals, magazines, newspapers, and existing research. The research design was obtained through a holistic-contextual phenomenon by collecting data from other researchers and using it as a key instrument. Moreover, several pieces of information were collected by FGD with the Ternate City Disaster Risk Reduction Forum, academicians, and other stakeholders particularly related to building Ternate City resilience.

The present paper is organized as follows: In Section 2, we describe the resilience city concept. In Section 3, we present an overview of the Ternate small islands, and in Section 4, we show the types of disasters that have occurred on the Ternate small islands. Section 5 shows the discussion and recommendation on how strategies the government applies a multi-hazard approach to for Building Ternate City resilience. Finally, in Section 6, we conclude all explanations.

RESULTS AND DISCUSSION

An Overview of Ternate Municipal

Ternate Municipal is in North Maluku Province, Eastern Indonesia. Geographically, it is located at 02°28′54.51" S, 02°39′28.76" N, and is between 124°16′58.62" and 129°40′57.62" E. The total area of Ternate municipal is 5,709.72 km^2, which consists of 162.17 km2 of land and 5,547.55 km2 of sea (BPS, 2022). Ternate municipal areas consist of eight islands: Ternate Island, Hiri Island, Moti Island, Gurida Island, Mayau Island, Tifure Island, Maka Island, and Mano Island. Administratively, the Central Ternate sub-district is the government center of Ternate Municipal. Ternate municipal is divided into eight sub-districts: Ternate Island, South Ternate, Central Ternate, North Ternate, West Ternate, Hiri Island, Moti Island, and Batang Dua Island. The percentage of sub-district area in Ternate municipal shows that West Ternate sub-district is the largest (20,89%), while Hiri Island is the lowest (4.12%) (BPS, 2022).

Ternate Island, as a part of Ternate Municipal, is classified as a small island. Based on Law No. 27 of 2007 concerning the management of coastal areas and small islands, a small island is an island whose size is less than 2000 km2 (Mutaqin, Marfai, et al., 2021). Ternate, as a small island, is unique in terms of geomorphology. The component materials on Ternate Island are the result of volcanic processes or sub-aerial deposition. The eruption material produced is in the form of pyroclastic flows, lava flows, lahars, and various types of tephra, including ash, sand, gravel, and blocks. The eruption material was gradually deposited continuously to form the island of Ternate as it is today (Mutaqin, Handayani, et al., 2021). This process may have occurred thousands of years ago. Furthermore, the topography of the land on the island of Ternate is predominantly hilly and mountainous in morphology (Mutaqin, Marfai, et al., 2021). The island has a steep slope of over 25%, but the biggest physical slope of over 40% is conical to the top of Mount Gamalama(Mutaqin, Marfai, et al., 2021). Meanwhile, in coastal areas, the average slope is about 2% to 8% (Firmansyah, 2011; Nagu et al., 2018) . In addition, Ternate has three lakes (Laguna Lake, Big Tolire Lake, and Small Tolire Lake) that are in the east part of Ternate and the southwest part of Ternate. Those lakes were created because of a volcano eruption (Hidayat et al., 2020b).

From a demography aspect, Ternate is the most densely populated city among others in North Maluku Province. The population of Ternate City at the end of 2021 was 205.870 compared to 2012, which was 191.053 (BPS, 2022). The population has increased by around 15,000 yearly, and it is estimated that by 2030 will reach around 210,000. Moreover, the population is concentrated in the districts of Central Ternate and South Ternate, with 26.13% and 36.33%, respectively(Umanailo et al., 2017). Furthermore, the total sex ratio of the Ternate City population in 2021 was 101. That is, for every 100 female residents, there are as many as 101 male residents (BPS, 2022). Most of the residents live in coastal areas (Marasabessy, 2016; Sarihi et al., 2020).

Regarding the economy's growth, Ternate has been a famous area since colonial times. Several European countries, such as the Dutch, Spanish, and Portuguese, built networks with the Ternate Kingdom related to spices such as cloves and nutmeg trading (R. M. Said, 2019). Until now, Ternate continues to be the center of economic development in the province of North Maluku (Umanailo et al., 2017). Almost all economic activities, including construction, trading, transportation, and other services, take place in Ternate. Those activities are supported by facilities being built in this city, ports, airports, shopping centers, educational centers, and government centers. As a result, the economy in the city of Ternate continues to increase (Kosuma et al., 2016). In 2021, the economic growth rate of Ternate City was 2.88%(BPS, 2022).

As a small island with formed geomorphology, Ternate is faced with the problem of limited land area for infrastructure and housing construction. This problem is closely related to population and development growth. As stated by M. Said, (2019); Sarihi et al., (2020); Umanailo et al., (2017) , due to the increasing demand for land for settlements and development, has led to very significant land changes in coastal areas. Vrita et al., (2021) also revealed that with the increase in the population of the city of Ternate, which continues to increase, it is predicted that in 2030 the number of houses needed is 96,089 units with a land requirement of 960.89 ha. Moreover, Surahman (2007) stated that from 2003 to 2007, the development of settlements in the coastal area of Ternate City increased by 549 ha. These changes generally occur in the sub-districts of South Ternate, Central Ternate, and North Ternate (Umanailo et al., 2017). Consequently, a land-use change problem arises on Ternate Island. For example, the reclamation of coastal areas for business centers (Marasabessy, 2016; M. Said, 2019) It is also exacerbated by changes in some forest areas in the hilly areas approaching the peak of Mount Gamalama. In 2010, the forest area in Ternate reached 6,937.3 ha, but over ten years it decreased to 5,592.8 ha (Sarihi et al., 2020). Indeed, small islands suffer from the most common environmental problems (i.e., land degradation and loss of biodiversity) because of their small size, remoteness from major markets and the world, and high exposure to natural disasters (Briguglio, 1995); this problem is being further facilitated by population growth and urbanization (Barnett, 2011).

Potential Hazards on Ternate Island

Earthquake

Indonesia is located at the confluence of three active plates of the earth, such as the Indo-Australian Plate to the south, the Euro-Asiatic Plate to the north, and the Pacific Plate to the east. The three plates move and collide with each other so that the Indo-Australian plate subducts under the Euro-Asia plate and causes earthquakes, volcanic pathways, and faults (Hall, 2009).

Tectonically, North Maluku is an area that has a high and complex seismicity level because it is influenced by three large plates, namely the Pacific Plate, the Eurasian Plate, and the Indo-Australian Plate, which meet in the Halmahera region (Hall et al., 1991). The meeting of several plates causes activities to push each other between one plate and another, making North Maluku Province have a high seismic potential (La Masinu et al., 2018). Moreover, in the northern part, based on the direction of North Maluku, several microplates affect seismicity in this area, namely the Halmahera, Sangihe, and microplate arcs in the Maluku Sea. The three microplates are fragments of the margins of the Eurasian and Pacific mega-plates that are pressing against each other, especially the Maluku Sea plate, which characterizes complex seismicity patterns as a source of such great pressure (Brilliantina et al., 2021; Hall et al., 1991).The Sangihe arc was built over the Eocene oceanic crust and originally formed on the edge of Sundaland in the Early Cenozoic. The modern Halmahera arc builds on older arcs, the oldest being the Mesozoic intra-oceanic arc that formed in the Pacific. The Australian arc–continental collision in the Early Miocene ended northward subduction, and the northern Australian plate boundary became the main left-lateral shear-slip zone in New Guinea. Volcanism ceased, and there was widespread deposition of shallow marine limestone. The arc field moves westward within the Sorong fault zone. At the western end of the fault system, there was subduction under the Sangihe arc and the collision of continental fragments in Sulawesi that were cut off from New Guinea (Bock et al., 2003; Hall, 2009).

According to Demets et al., (1994), the Indo-Australian plate is moving northward at an average speed of 7.23 cm/year and the Pacific is moving eastward at an average speed of 11-12.5 cm/year. While the Halmahera Microplate is moving at an average speed of 6.7 cm/year and the Plate Eurasia is moving east at an average speed of 1.7 cm/year in the Sangihe zona (Pasau & Tanauma, 2011; Saifuddin & Pertiwi, 2021). The difference in the speed and direction of the plates is the main factor in the occurrence of collisions between plates, which are often called earthquake tectonics and result in the formation of subduction zones on the earth's surface. The Subduction Zone, which is formed due to collisions between plates, makes one of the two plates sink and infiltrate into the asthenosphere so that the two lithospheric plates experience friction and an increase in temperature and pressure between the two plates (Saifuddin & Pertiwi, 2021).

The peak ground acceleration (PGA) is an important parameter for estimating the seismic hazard. The PGA maximum is 0.21 g to 0.44 g. The areas with the highest PGA values are West Halmahera (0.21 g-0.44 g) and South Halmahera (0.20 g-0.44 g). Ternate (0.31–0:37 g), Tidore (0.20–12:25 g), and Northern Halmahera (0:02–0.3 g). The lowest PGA was found in eastern Halmahera, Morotai (0.028 g–0.1 g), and central Halmahera (g = 12:02–12:16 g). It shows the regions along the western coast of Halmahera Island, along the east coast of Halmahera, Morotai, north Halmahera, and central Halmahera have the greatest seismic hazard. Meanwhile, southern Halmahera and the south of Morotai Island have low seismic hazard (Zulkifli et al., 2017).

Since 1858, this area has been hit by 16 destructive earthquakes with an intensity of VI to VIII MMI, which has resulted in 42 deaths and hundreds of houses collapsing (Sulaeman & Cipta, 2012; Supartoyo, 2015). Meanwhile, based on data from the United States Geological Survey (USGS), from 2000 to 2020, there were 580 earthquakes with a magnitude of 5 mb with an earthquake depth of 0–70 km in North Maluku Province (Brilliantina et al., 2021; Saifuddin & Pertiwi, 2021). Based on the results of the model built by Brilliantina et al., (2021) in North Maluku during the period 2000–2020, the basic seismic rate was 0.03873 earthquakes/day, aftershock productivity was 0.04075 aftershocks/day, earthquake efficiency with a certain magnitude produces aftershocks of 3.86734/m, the time scale of the aftershock decay rate is 0.01790 days, and the aftershock decay rate is 1.05281 days.

However, dominated by small earthquakes (less than 5 on the Richter Scale), large-scale events have sometimes occurred. The Ternate City Regional Disaster Management Agency has reported the impact of the large earthquake that occurred in North Maluku. The 7.1 SR earthquake that occurred in 2019, for example, damaged 36 buildings in Ternate City and injured 3 people. Tuhuteru (2020) revealed that most of the house structures in Ternate did not meet earthquake-safe building standards. In addition, Febriyanti et al., (2021) state that economic vulnerability will, of course, be impacted by the damage to buildings caused by the quake.

Unfortunately, the earthquake vulnerability in the city of Ternate was not accompanied by community preparedness. Andi (2011)mentioned that the community's preparedness and understanding in Mangga Dua village is still low. This can be seen from the ignorance of the community to save themselves from the earthquake as well as building houses that are not safe from earthquakes. In addition, Ahmad et al., (2018) with a cross-sectional study approach found that most (77%) of the families surveyed in the city of Ternate admitted that they did not have the knowledge to deal with disasters because they had never attended disaster training and thought that disasters were the responsibility of the government.

Tsunami

Tsunamis generally hit gently sloping shores. Hence, Tsunamis can be interpreted as ocean waves with a long period caused by impulsive disturbances from the seabed (Nugroho & Sadisun, 2015). Activities that generate tsunamis can be linked to plate movements (earthquakes), landslides and volcanic eruptions (Brune et al., 2009; Kurnio et al., 2019; Løvholt et al., 2012). Earthquakes that have a direct effect on causing a tsunami are generally earthquakes with a shallow epicentre. Tsunami-causing landslides are more likely to occur in coastal cliff landslides or on the seabed.

The eastern part of Indonesia, including northern Maluku, has a high tsunami risk. This is because tectonically, this area is influenced by plate subduction around this area. Anwar (2021); Horspool et al., (2014), about 67% of tsunamis in Indonesia occurred in eastern Indonesia which is evenly distributed from Sulawesi to Papua and from Timor to the Sangihe Talaud islands, where there were approximately 109 tsunamis in eastern Indonesia between 1600 and 2004. The latest tsunami that hit North Maluku was a tsunami caused by an earthquake with a magnitude of Mw 7.2 in 2017, with the epicentre located in the middle of the Maluku Sea. The earthquake, which was felt in almost all North Maluku, generated a tsunami recorded by tide gauges in Jailolo, Tobelo, and Manado with a height of 9, 1, and 3 cm, respectively (Gusman et al., 2017; Sriyanto et al., 2019). Therefore, the North Maluku region, which includes the city of Ternate, is very vulnerable to tsunamis (Evrita et al., 2014).

The tsunami simulation and interpolation conducted by Kurniawan et al., (2021) using a scenario of magnitude 8 on the Richter scale and a depth of 10 km resulted in a tsunami wave height in North Maluku Province with a range of more than 3 meters. Meanwhile, Sumtaki et al., (2017) with a simulated tsunami model, found that the maximum height of a tsunami wave caused by an earthquake with a magnitude of 7.7 Mw was 7.07 meters and occurred in the Kasturi area, West Halmahera, and the Sofifi-Tidore area of the archipelago, reaching 1.25 meters, where the wave travel time was 1.25 meters. It takes 38 minutes for the tsunami to reach Sofifi. So, based on this model, if an earthquake occurs on that scale, the height of the tsunami waves that spread to the City of Ternate is estimated to be 4-5 meters, with a travel time of less than 20 minutes.

Based on the previous explanation, most of the people of Ternate City live in coastal areas, and the large number of vital infrastructures built by the government in coastal areas will increase the vulnerability of this area to the threat of a tsunami disaster. The research results of Evrita et al., (2014) found that some villages in coastal areas of the Southwest Coast and South Coast of Ternate Island have a high vulnerability to tsunami disasters. Sasa Village and Gambesi Village, as well as parts of the Fitu Village in the Southwest Coast area, are the most vulnerable areas to the tsunami disaster, where 15.32% of the total area is at the high vulnerability level and 11.4% is at the medium vulnerability level. While on the South Coast, Bastiong Karance Village, parts of Kalumata Village, Kayu Merah Village, Bastiong Talangame Village, Mangga Dua Village, Mangga Dua Utara Village, and Toboko Village have 26.9% of areas at a high vulnerability level and only 5.54% of areas at a medium vulnerability level.

This is further exacerbated by the lack of an early warning system provided by the government. Ibrahim et al., (2021), the number of seismic sensors installed throughout the province of North Maluku is 13 units, and this has not yet reached all areas in North Maluku. Only one unit of the tsunami early warning system has been installed in the Maluku Sea (Dian D, 2014). Of course, with conditions like this, the government, and the people of the city of Ternate must formulate a disaster mitigation strategy, including evacuation routes and an early warning system, to deal with the threat of a tsunami in a short time.

Volcanic Eruption

Mount Gamalama is one of the most active volcanoes in Indonesia, located on Ternate Island, North Maluku Province (Hidayat et al., 2020a, 2020b). The type of Gamalama Volcano is an almost perfect conical stratovolcano with a radius of 5.8 km and an area of approximately 105 km^2. The peak is at an altitude of 1,715 meters above sea level (Hidayat et al., 2019). In historical records, this mountain has erupted 77 times since it was first recorded in 1510 for the first time. Several recorded eruptions were very large and had a significant impact after a long rest (more than ten years). For example, the eruption occurred after a 50-year break from 1687 to 1737, resulting in a westward flow of lava reaching the sea. Another example is the eruption that followed an 18-year break from 1962 to 1980, resulting in a huge explosion that produced a new crater and ash that covered the entire Ternate Island (Hidayat et al., 2020a).

The eruption of Mount Gamalama not only produced eruptive material but also had an impact on the residents and environment of Ternate City. Material from pyroclastic flows, lava flows, lahars, ash, sand, gravel, and blocks are the samples of eruption materials produced by Gamalama. Meanwhile, the impact on the population and environment has been noted by several scholars (Mutaqin, Handayani, et al., 2021). In 1980, an eruption occurred which made the entire island of Ternate shrouded in volcanic ash with a thickness of 10–15 cm, so that 40,000 people fled to Tidore and other islands around Ternate (Hidayat et al., 2020b). In addition, the eruption that occurred in 2011 in the village of Tubo caused 3 deaths and 78 houses were damaged (Pradiptasari et al., 2015). Eruption material also causes lava floods during the rainy season, as happened in the city of Ternate in 2012, which resulted in 1,041 people being displaced (Masinu et al., 2018; Saputra et al., 2015).

As a mitigation action to warn the public of the dangers of the eruption of Gamalama, the government has compiled a map of the disaster-prone area of Gamalama (Syiko et al., 2013). Based on the map (fig.1), disaster-prone areas (hereinafter DPA) are divided into three categories; DPA I is located at a radius of 4.5 km from the top of the mountain along the basin and downstream from the summit. The area has a low disaster risk. This area is allowed for residence. At DPA II, an area that has a moderate risk of eruption hazard has a radius of 3.5 km. Its territory includes the Togorara, Kulaba, Sosoma, Ruba, Kelawa, Piatoe, Taduma, and Kastela rivers. This area is only for agriculture. While DPA III, with a radius of 2.5 km, is the area closest to the source of the danger of eruption columns and lava flows, in this zone, it is forbidden to live and cultivate any kind of crop.

Landslide

Geomorphological conditions, land-use change activities, and rainfall on the island of Ternate allow this area to be at risk of landslides. Ikqra et al., (2012) expressed the landslide hazard class on Ternate Island is the moderate landslide hazard class, with an area of 3,015 ha, or 29.7% of the total area. This class is on a slope of 15%–45%. Unfortunately, housing development has now almost reached this area.

Furthermore, land use change activities in landslide-prone locations are dominated by open land, sand, and stone mining activities. Ibrahim & Rosita, (2020) stated that there are 14 locations for sand and stone mining in Ternate that have the potential to experience landslides. Those areas include Kalumata Village, Kulaba Village, Tubo Village, Sango Village, and Sulamadaha Village. Meanwhile, landslides related to rainfall patterns have been occurring several times. According to BNPB data over the past five years, there have been three landslides in the city of Ternate related to high rainfall. This landslide disaster resulted in road access being blocked by landslide material and several houses being damaged.

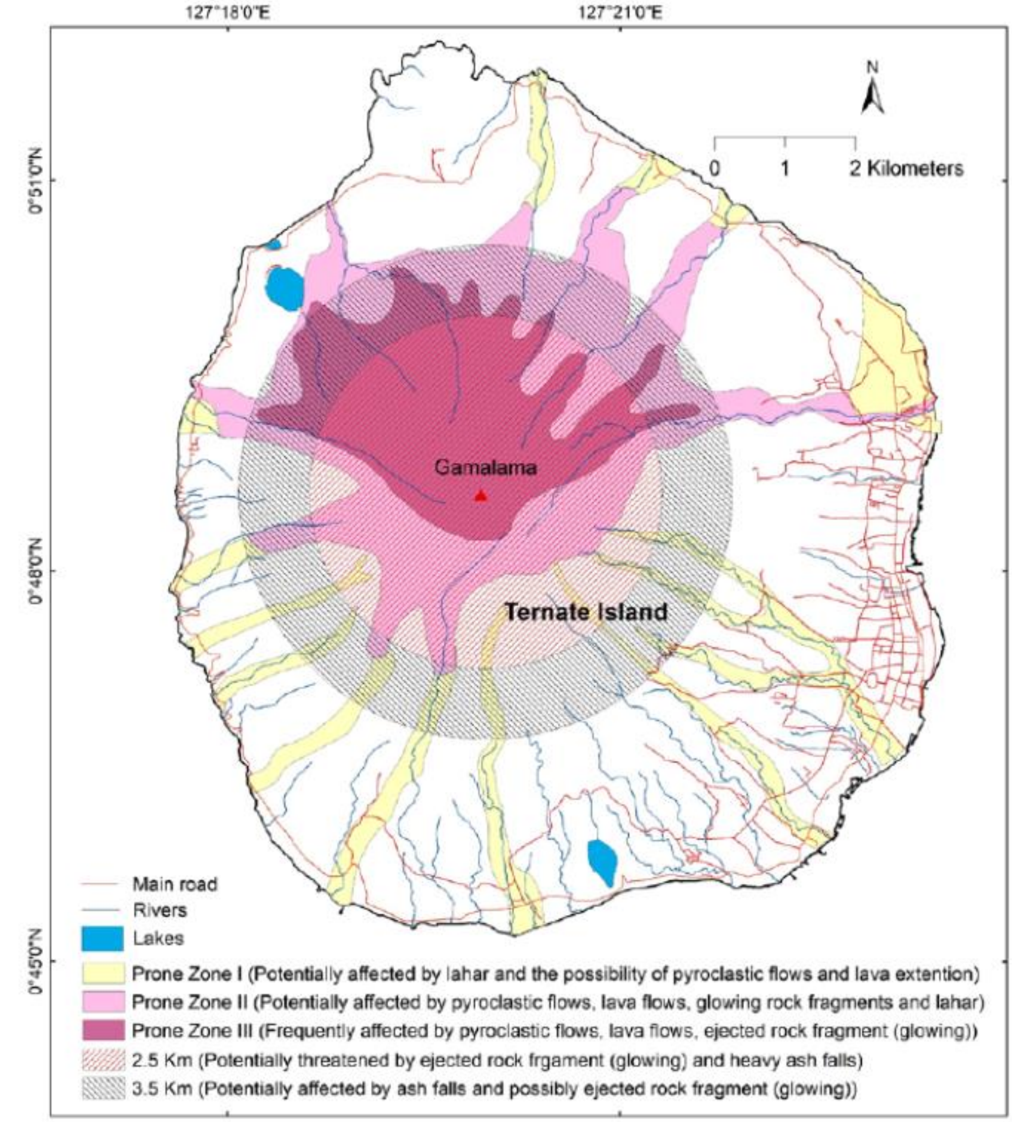

Figure 1. Map of Disaster-Prone Area Mt. Gamalama
(Badan Nasional Penanggulangan Bencana (BNPB), 2012)

Extreme Weather

Extreme weather is part of a hydrometeorological disaster. Hydrometeorological disasters are disasters caused by instability in climatic conditions, the hydrological cycle, and environmental changes that occur. on the earth's surface, which can cause the occurrence of flash floods, droughts, land landslides, hurricanes, and other events that cause ecosystem damage (Hermon, 2012).

However, extreme weather rarely happens in Ternate. It is closely related to climate change, which is increasing recently and in the future. Based on a report from the Regional Disaster Management Agency, a hydrometeorological disaster struck several areas in North Maluku Province on January 15–16, 2021. This is influenced by warm sea surface temperatures and the El Nio–Southern Oscillation (ENSO) phenomenon around the Pacific Ocean. The higher the SST value, the more water vapor is distributed to the atmosphere, increasing the likelihood of rain in the three types of rainfall, namely monsoons, equatorials, and local (Aldrian & Susanto, 2003).

Meanwhile, according to (Elake et al., 2018), the variability of rainfall in the Maluku region is strongly influenced by the ENSO phenomenon.

The incident occurred because of heavy rain and strong winds that had been happening for a long time. Based on observations of rainfall from Gamar Malamo Meteorological Station, Halmahera North, rainfall for 24 hours measured 232.0 mm on January 15, 2021 and 170.6 mm on January 16, 2021, as well as from observations of Sultan Babullah Meteorological Station weather ternate rainfall on January 15, 2021 and on January 16, 2021, it measures 74.9 mm and 27.0 mm respectively, with maximum winds of 16 knots which occurred at 03.00 WIT (Sabrina et al., 2021).

The city of Ternate was an area that experienced a significant impact at the time of the incident. Heavy rains accompanied by strong winds hit Ternate City, which damaged several public facilities, caused trees to fall and caused several coastal areas to experience abrasion. A total of 375 people from four sub-districts have been evacuated because their houses were damaged (Indotimur.com, 2021).

Coastal Abrasion

Several studies confirm that most of the coastal areas of the island of Ternate have experienced abrasion. found that the abrasion that occurred in the waters of the western part of the island of Ternate was very intensive during the last 20 years, causing the coastline to move as far as 68.27 meters inland. Furthermore, the abrasion process that occurred in the waters of the southern part of the island of Ternate caused the coastline to retreat as far as 9.71–27.14 meters (Angkotasan et al., 2012). Meanwhile, the abrasion rate on the southwest coast of Ternate Island, measured from 2011 to 2018, was 0.9–19.73 per year (Evrita et al., 2014).

Natural factors cause abrasion in the coastal area of Ternate Island, as well as human activities, Naturally, the abrasion process occurs due to oceanographic processes that occur in the coastal area, such as waves, currents, beach types, and beach materials (Lessy et al., 2019). The results of the measurement of wave height in the waters of the western and southern parts of the island of Ternate ranged from 0.99 m to 1.87 m, with the wave height reaching the coast ranging from 0.6 m to 0.9 m (Lessy & Abdullah, 2021). Meanwhile, the water mass movement measured in the northern waters of the island of Ternate is 0.18–0.38 m/s and in the waters of the southern part of the island of Ternate is 0.21–0.47 m/s. Sofyan et al., (2010)said generally, the beaches that experience abrasion on the coast of the island of Ternate are beaches with constituent material in the form of sand, and the shape of the beach is straight facing the sea. Furthermore, the process of abrasion in the coastal waters of the island of Ternate is due to human activities, including the cutting of mangrove trees in the coastal area (Sofyan et al., 2010) and due to reclamation activities in the coastal area (Djainal, 2017) .

Strategies for Building Ternate City Resilience

In the World Risk Report (2016) (Badan Nasional Penanggulangan Bencana, 2020), Indonesia is categorized as a country with a high level of disaster risk. This is due to the high level of exposure and vulnerability to disasters in this country. In fact, almost 75% of metropolitan cities, industrial infrastructure, and basic connectivity, including their supporting facilities, are built in coastal areas or small islands that are noted as disaster-prone areas (Badan Nasional Penanggulangan Bencana, 2020).

In the context of disaster management, disaster risk reduction activities in small islands in Indonesia will require more intensive efforts when compared to disaster management on large islands. This is because many small islands face special disadvantages associated with their size, remoteness, and vulnerability to natural disasters. In line with that, it is necessary to understand that the potential threats and disasters that exist on small islands can vary. This is partly because each island has different characteristics and island typologies from one another (Marfai et al., 2021). Therefore, an important aspect of disaster risk reduction is a better understanding of the hazards that cause significant threats and vulnerabilities, which include community, economic, and built environment, and natural vulnerabilities (UNISDR, 2015).

Earthquakes, volcanic eruptions, landslides, flooding, extreme weather, and coastal abrasion are all potential hazards on Ternate Island. Therefore, disaster risk reduction in Ternate City is a tremendous challenge for the government. On one hand, the island was classified as a small island, had an active volcano in the middle, and was surrounded by moving plates. On the other hand, it is the most densely populated province in North Maluku Province, and it is a difficult task to relocate the population community further landward due to land unavailability. To adjust to the situation, the Ternate government needs to develop a strategy because all the foreseen impacts of disasters will affect the land-use sector, threatening economic growth as well as community life.

As a recommendation, the government must formulate legal instruments that encourage the implementation of effective and independent disaster management at the regional level. This can be done by making government regulations on disaster management along with other related regulations, including building permit regulations, waste management regulations, land use regulations, etc. All these regulations must be translated into the form of regional spatial planning and disaster management documents, such as disaster risk assessment documents, disaster management plan documents, disaster contingency documents, and standard operating procedures (SOPs).

The Regional Spatial Plan (RTRW) document is an essential first step. As mandated by Law Number 26 of 2007 concerning Spatial Planning, all cities are required to prepare a Regional Spatial Plan (RTRW) document. This document is a reference in the preparation of the Regional Long-Term Development Plan (RPJPD) and the Regional Medium-Term Development Plan (RPJMD) as well as the basis for controlling the use of space in the development of urban areas, which includes the stipulation of zoning regulations, permits, and the provision of incentives and disincentives. Based on Law 24/2007 concerning disaster management, spatial planning must also ensure disaster-prone areas for adaptation and mitigation. According to Priatmodjo (2011), several steps must be taken to create a city that is ready to face disasters, namely: carrying out an analysis of the potential for disasters and then preparing a spatial plan based on adaptation and mitigation of disasters, as well as developing disaster prevention and management tools. Therefore, the Ternate City Regional Spatial Plan (RTRW) must contain in detail the land use plan for development activities and anticipation of possible disasters, both single-hazard and multi-hazard that occur simultaneously. Preparing for disasters and controlling physical development in areas that are likely to be hit by them are two ways to be prepared for them.

Disaster risk assessment documents, disaster management plan documents, and contingency plan documents, as well as standard operating procedures (SOPs), are the second set of instruments that should be prepared by the government. Based on Minister of Home Affairs Regulation Number 101/2018 concerning Service Technical Standards, disaster risk assessment and contingency planning documents are an obligation in the minimum service for district/city disaster sub-affairs. Disaster risk assessment is used as the basis for disaster management efforts. This study is a tool to assess the possibility and magnitude of losses due to existing threats. By knowing the possibility and magnitude of losses, the focus of planning and integrated disaster management will become more effective. On the other hand, disaster risk assessment is the basis for ensuring the alignment of the direction and effectiveness of disaster management in an area. Furthermore, disaster management plan documents are a plan that contains policies, strategies, and actions to achieve the implementation objectives of regional disaster management. This document was prepared by involving all regional governments and non-government organizations as well as regional apparatuses under the coordination of the Regional Disaster Management Agency (BPBD).

Contingency plan documents are carried out to coordinate all stakeholders to provide a fast and effective response and ensure the availability of resources during an emergency response. Therefore, the document must clearly explain each step that must be taken by each stakeholder in the event of a disaster. The follow-up to the document is a continuous preparedness exercise. While SOPs are fixed procedures and standards that must be complied with and are prepared as directions for every disaster management activity. SOPs cover activities in the pre-disaster, emergency response, and post-disaster stages. These documents can be arranged in a single-hazard or multi-hazard approach.

Considering that many types of disasters threaten the Ternate City, and they have a correlation with each other, it is advisable to look at disaster risk with a multi-hazard approach in both the disaster risk assessment and the contingency plan document. A multi-hazard approach is a combination of all types of disasters, both those caused by nature and those caused by human activities. The importance of a multi-hazard approach calls for conducting an integrated multi-hazard risk assessment, including vulnerability analysis, and comprehensive disaster management. However, multi-hazard risk analysis poses various challenges, not only regarding multi-hazard assessment but also investigation of vulnerability to multiple hazards (Kappes et al., 2012). Hazards exhibit very different characteristics such as time of onset, duration, extent, and the resulting impact on humans and risk elements that should be considered for multi-hazard vulnerability assessments. Therefore, one way to approach multi-risk is to consider the different types of hazards and vulnerabilities of a region and combine the results of various single-risk layers into a multi-risk concept (Komendantova et al., 2014) .

In a multi-hazard approach, all risks and vulnerabilities could be drawn on multi-hazard maps. The provision of multi-hazard information makes it easier for the government to make decisions. Indeed, it is not easy to achieve a disaster-resilient city like Ternate because the government must think about the limited resources and the preparation of infrastructure to deal with disasters. They also ensure that the implementation of spatial planning is carried out following the regulations.

Disaster mitigation infrastructure, both hard and soft should be provided by the Ternate government. Hard infrastructure includes construction of earthquake-safe buildings, construction of retaining walls and breakwaters, maintenance of drainage channels, preparation of temporary shelters, transportation systems, and logistics in emergency response. Furthermore, soft infrastructure includes the provision of evacuation route maps and the preparation of early warning systems according to the type of disaster. An evacuation route can be built manually or digitally. Manual evacuation route maps must be placed in disaster-prone locations that are easily seen and understood by all communities. With advances in information technology, evacuation route maps and early warning systems can be made digitally and displayed on a smartphone screen, making them easier for everyone to access. But in some conditions when electricity is shut off, the manual system can be used.

Regarding capacity building, the government needs to cooperate with other competent institutions to encourage institutions and community capacity building through training, preparation of disaster curricula in schools and higher education, dissemination of research, and emergency response simulations. For this reason, there needs to be a budget provided by the government and other parties to support these activities. All these activities are to strengthen preparedness and to change the community paradigm that preparedness planning is the responsibility of all stakeholders, including individuals and families as well. The establishment of an independent forum is important to engage all parties. This forum consists of academics, business entities, the media, NGOs, and the community. Through this forum, everyone needs to synergize in sharing roles in disaster risk reduction. Thus, disaster management in the city of Ternate will be more focused and sustainable, leading to a more resilient city.

Community capacity building can be applied with a community-based disaster risk reduction approach. In this approach, the community becomes the central point for planning, utilizing local resources, and applying the principles of disaster risk reduction. Meanwhile, government and non-government institutions only play a role in helping communities deal with disaster risks as well as possible. In addition, this approach gives the community the flexibility to use their local wisdom to build resilience independently.

CONCLUSION

Small islands have a high vulnerability to natural disasters and climate change, with the island of Ternate as an example. The island is located at the meeting point of the earth's plates, which are constantly moving and part of a volcanic pathway. Close to The Pacific Ocean causes weather and climate conditions on the island of Ternate to be easily influenced, so it often faces the threat of extreme weather. The narrow land area and the increasing population make the vulnerability value higher.

A significantly high vulnerability value will affect the socio-economic, environmental, and physical conditions of the people in the city of Ternate. The government immediately acted by drafting regulations not only to support development in the city of Ternate but also to support disaster risk reduction. Ternate city government must use a multi-disaster approach in implementing every development activity that begins with planning to program execution. In addition, the government also needs to work with all parties to carry out activities to strengthen the capacity of institutions and communities to deal with disasters..

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