Analysis of the tsunami disaster evacuation lane in Palu based on satellite imagery

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Abstract. Palu is one of the areas which frequently occurs earthquakes and has high seismicity which causes frequent earthquakes. This area has caused earthquakes and tsunamis which through the largest fatalities. The total number of 1,636 people who don't have knowledge and information about safety areas or compilation of safe nodes evacuation lane for disasters. The purpose of this study was for analyze the location of safe nodes evacuation lane points from floods and tsunamis in Palu City. The analytical method in this study was used inaSAFE analysis with the open-source QGIS assistance program and complies with 7 indicators from safe nodes evacuation lane requirements. The location of this research was in Palu Central of Sulawesi, specifically a road around the coast and near the river that crosses the city of Palu. In this research, the results obtained 5 points that have planned based on EMBT indicators between 2 mosques, 1 field and 2 schools at level 5 of sea-level rise. The increased of sea-level at level 10 resulted in 36 points around 15 mosques, 6 fields, and 15 schools, then the rising sea level at level 15 there is 59 gathering points of 21 mosques, 10 fields, and 28 schools. For the evacuation lane it already mapping based on evacuation lane analysis, which average of two lane per node.

1. Introduction

The territory of Indonesia is located at the confluence of three tectonic plates which results in earthquake and tsunami-prone pathways [1]. Recorded several earthquakes followed by tsunamis to the coastal areas, including those in Aceh, Lombok and the area that recently experienced an earthquake following the tsunami was in Palu in 2018 with an earthquake with a magnitude of 7.4 SR then followed tsunami with a height of 11.3 meters. Those were the result of the observation of the Climatology and Geophysics Meteorological Survey. Besides being among the world's major plates, Indonesia's position is located in the Pacific Ring of Fire, which is an area of earthquakes and volcanic eruptions that surround the Pacific Ocean basin. About 90% of earthquakes occur and 81% of the largest earthquakes occur along the Ring of Fire [2]. Major earthquake events could cause primary impacts such as shocks, tectonic increases and decreases, surface fractures, and secondary impacts such as tsunamis causing the largest casualties of 1,636 people and very severe damage in terms of infrastructure [3].

All of the studies above show that indeed the Palu area is prone to earthquakes which allows tsunamis and floods. So as not to cause many casualties in the future if there are a flood and earthquake
accompanied by the tsunami, it is necessary to anticipate prevention in the form of determining the evacuation route so researchers intend to study the evacuation route and the gathering point when a similar disaster occurs again, to minimize the existence of the impact of major fatalities. For this reason, in this research through the Quantum GIS application and the Inasafe plugin (National Disaster Management Agency / BNPB) would analyze safety evacuation lanes in that area.

2. Methods

2.1. Location of research
This research was conducted in Palu as a characteristic of the spatial model of the area analyzed based on GIS and remote sensing. The main focus in this study is the City of Palu with 4 districts which namely North Palu, East Palu, South Palu, and West Palu (Figure 1).

![Figure 1. Palu City research location.](image)

2.2. Analysis of methods
Analysis with Inasafe will be carried out with the help of the open-source QGIS program in terms of Location affected by disasters, road verification, elevation, evacuation zones, evacuation routes. Furthermore, analyze the threat and exposure data to get a map of the area affected by the disaster [4].

The evacuation lane analysis uses spatial data (flood and tsunami hazard maps, road network maps, river network maps, and contour slope data) to be used as a basis for analyzing the determination of flood and tsunami disaster evacuation routes in Palu City. According to the guidelines for the construction of a tsunami disaster evacuation lane, the factors to consider in selecting an evacuation route are the lane chosen to be a short distance which is an arterial road, a collector road, and a local road. Evacuation lane is designed to move away from the river flow. Evacuation lanes are sought not to cross rivers or bridges. The slope angle is more than 4%. To avoid mass accumulation, several parallel evacuation routes were made. Prioritize open coastal areas without trees or rocks or dunes. The routes chosen must also be suitable for use during the evacuation that it does not slow down for the evacuation process [5].

3. Results and discussion

3.1. Map of disaster impacted areas
This research presents a summary of areas affected by the Flood and Tsunami disaster in Palu City on September 28, 2018. The impact of damage that occurred in several areas in Palu.

At the end of the process, InaSAFE statistics would appear in the results section and a new layer will be added to the Layers panel that explains the results of the analysis. The map will distinguish between
affected roads and unaffected roads (table 1). Similarly, what will be done on the building will display the results of buildings affected and not affected (Figure 2).

**Table 1.** Road and building threat data.

| NO | Threat | Road Length Affected (KM) | Total Building (Unit) |
|----|--------|---------------------------|-----------------------|
| 1  | 5 Meters | 4,609                     | 381                   |
| 2  | 10 Meters | 74,785                   | 10225                 |
| 3  | 15 Meters | 176,166                  | 24777                 |
| 4  | No Affected | 1161,774                | 91210                 |

**Figure 2.** Disaster impact zones.

3.2. *Determination of evacuation lane points*

Refugee Evacuation Points is an open area near the centers of residential neighborhoods that if a disaster occurs it becomes a meeting point for residents who want to evacuate in a safe place. The Evacuation Lane point is mostly a sports field, a small part of it is an open area that allows for evacuation activities such as school grounds or places of worship such as mosques (Figure 3).

**Figure 3.** Distribution of evacuation points in Palu City.

In the context of disaster mitigation, emergency response plans to become an important part of preparedness, especially concerning the rescue, because of that disaster victims could be minimized. This effort is crucial, especially during disasters and the first days after a disaster before assistance from the government and outside parties come. Some good indicators of evacuation lane points include adequate and young open space that is accessed by disaster victims and rescuers. There are several evacuation lane points from seawater threats on level 5, level 10 and level 15 (table 2).
Table 2. The evacuation lane points.

| Sea-level (Meters) | Evacuation Points | Total of Evacuation Points |
|--------------------|-------------------|----------------------------|
|                    | Schools | Fields | Mosques |                      |
| 5                  | 2       | 1      | 2       | 5                     |
| 10                 | 15      | 6      | 15      | 36                    |
| 15                 | 28      | 10     | 21      | 59                    |

3.3. The evacuation lane

After determining the collection point following the indicators and using InaSAFE data, which is a map of the affected area, to be used as a basis for analyzing the determination of flood and tsunami disaster evacuation routes in Palu City. In determining the evacuation route, several general conditions could be used to considering the selection of disaster evacuation lanes in Palu, it called the safety of the route, the mileage of the route, and the feasibility of the route (Figure 4).

The most adequate gathering point with the fastest route and the most effective route on water level 5 is SMAN 4 Palu. Alternative 1 is the southeast on Jl. Diponegoro, turn right Jl. Mokolembake, turn left into the entrance to SMA Negeri 4 Palu with a normal travel time of 2 minutes with a total distance of 1.03 km. Alternative 2 Head south on Jl. Rono, turn right on Jl. Diponegoro, turn left on Jl. Mokolembake, turn left into the entrance of SMA Negeri 4 Palu with a travel time of 2 minutes with a total distance of 960 meters of normal traffic.

The most adequate evacuation point with the fastest route and the most effective route on water level 10 is one of the Palu Great Mosque. Alternative 1 is eastward on Jl. Asam I, continue straight 47 meters with normal traffic time of 2 minutes with a total distance of 500 meters. Alternative 2 Take the southwest direction on Jl. WR. Supratman to Jl. Bantilan, turn left to the 57-meter grand mosque with normal traffic takes 1 minute with a total distance of 350 meters.

The most available evacuation point with the fastest route and the most effective route on water level 10 is one of the Palu State Junior High School. Alternative 1 To the east on Jl. Scouts to Jl. KH Ahmad Dahlan, turn left onto Jl. KH Ahmad Dahlan, turn right onto Jl. Cik Ditiro, turn right onto Jl. Gatot Subroto / Jl. Letjend Suprapto / Jl. Suprapto as far as 350 meters with normal traffic takes 3 minutes with a total distance of 1 km. Alternative 2 to the northeast on Jl. Gatot Subroto toward Jl. Masjid Raya, continue straight onto Jl. Letjend Suprapto as far as 100 meters with a normal travel time of 2 minutes with a total distance of 400 meters.

4. Conclusions

In this research, we have 5 planned evacuation points based on EMBT indicators between 2 mosques, 1 field and 2 schools for a sea-level rise at level 5. For sea-level rise at level 10 there were 36 gathering points including 15 mosques, 6 fields, and 15 schools, then to increase sea level at level 15 there are 59 evacuation points, 21 mosques, 10 fields, and 28 schools. The evacuation lane has been mapped based on the analysis of the evacuation lanes, which average of two routes per evacuation point.
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