Flood Points Distribution Mapping for the Determination of Evacuation Routes and Disaster Posts in Gorontalo City

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Abstract. This research used Geographic Information System (GIS) approach with Round Graph method. Data used in this research are high resolution satellite imagery, Peta Rupa Bumi Indonesia (RBI) scale 1: 25.000 and Statistics data. High resolution satellite imagery was used to obtain data about the distribution of flood points, road map and locations of disaster posts. After obtaining those data, then the quickest and nearest evacuation routes can be determined by using round graph method so that the casualty of flood hazard can be significantly reduced and effectively helped.

1. Introduction
Indonesia is a country that has a tropical climate with a high level of rainfall. This is a huge potential because it can store water reserves high enough. However, if not properly managed it can generate flood which can cause devastating damage.

Disaster is an event or series of events that threaten and disrupt people's lives and livelihoods caused by natural, non-natural and human factors. Hence, it causes human casualties, environmental damage, property loss, and psychological impact [1]. Some areas in Indonesia are areas that have high potential of disaster. One of these areas is Gorontalo Province. This young province was born in 2001 as a result of North Sulawesi Province regional division.

The city of Gorontalo as the Capital of Gorontalo Province is an autonomous region that is experiencing rapid development compared with some new autonomous regions in Indonesia. These developments provide many benefits to the community and also provide considerable challenges and problems. The geographical condition of Gorontalo city which is surrounded by hilly areas in Bone Bolango regency and Gorontalo regency makes Gorontalo city as an area that has considerable water potential as well as the potential of disaster. The low topographic condition certainly has a negative impact to the city of Gorontalo as a flood-prone area.

Gorontalo city and its vicinity experiences flooding from Bone and Tamalate rivers almost annually. Before 1996, the flooding event did not have significant impact to inhabitants. However, flooding tends to be severe, with a notable record being in 2002. The most recent serious inundation was in 2006. To avoid such disastrous accidents, mitigation planning is required. The first step is to establish a suitable risk mitigation plan requires evaluation of flood hazard and risk along the two rivers [2].

According to data obtained from Local Disaster Management Agency of Gorontalo City, Gorontalo City always experienced an increase both in terms of areas or casualties every year. This can be seen from some areas that previously did not experience floods but in recent years affected by floods. Some of the causes of the flood-affected area increase are the lack of good drainage, the low awareness of the community and a very high increase of land conversion in Gorontalo City. The first two problems can be immediately solved, but the problem of land conversion is inevitable because the city of Gorontalo as the provincial capital becomes the main objective of development in Gorontalo Province.
Disasters certainly cause negative impacts such as damage to houses, casualties, livestock, crops and many other impacts. To overcome this negative impact, especially casualties, it is necessary to conduct an early handling of floods. Two things that can be conducted to reduce the negative impact flood are to make evacuation routes and the disaster posts. So far, there are still considerable casualties caused by the flood because the evacuation routes has not been set optimally, especially for new areas that are just affected by floods. Available flood posts are mostly made at the time the flood strikes and only a few posts were provided before the flood.

An evacuation route is defined as a route that people must follow to escape from a dangerous area during an emergency. Focusing on indoor environments like workplaces, different types of emergency require the definition of different evacuation plans. For example, in case of a fire, people are required to go outside their workplace, but in a tornado it may be better to stay inside the building. There are three major aspects to consider when customizing emergency evacuation routes:

1) Type of emergency: whether fire, explosion or earthquake, etc.
2) Type of building: the building construction is very important to characterize the vulnerability due to the effects of disasters. Nearly every type of structure will be affected from major disasters; however, some buildings may collapse and others may be left with weakened floors and walls.
3) Type of people: depending on the abilities (permanent or contextual) of affected people, some could need additional assistance. Emergency evacuation routes are usually represented as maps generated from floor diagrams with signals that indicate the path to exits or safe places [3].

From flood points that existed in previous years, new evacuation paths and disaster posts could be built to reach all victim of flood. This sort of data will optimally work and can be easily used when presented as a map. The determination of evacuation points and assemble points is the design of the evacuation map by determining the shortest path to the assembly point. Determination of the shortest path conducted by observing alternative paths that can be passed to assembly points. The shortest distance is the fastest path to the assembly point.

When the disaster strikes, most of the people will try to escape a building to save themselves without direction or guidance. Both people in the living room and back room of a building will try to escape without considering the distance of a path that they take and safe assembly point. This sort of situation also causes casualties. The fact that there are still many buildings which have no evacuation routes becomes another obstacle in creating disaster-safe buildings. The existence of evacuation map, in the form of directional arrows from certain place to safe assembly points that has been determined. The simulation model will also be conducted to evaluate the direction of the path in the evacuation map that will be applied. The design of the evacuation map is conducted by determining the trajectory.

Looking at the importance of spatial data about the Evacuation Routes and disaster posts in Gorontalo City, then researcher concluded to research Flood Points Distribution Mapping for the Determination of Evacuation and Disaster Posts in Gorontalo City.

2. Data and Method

2.1. Time and Site of the Research
This research was conducted in Gorontalo City from February to May 2018 covering all areas of Gorontalo City as shown in Figure 1.
2.2. Tools and Materials of the Research

2.2.1. Tools. Tools used during the research are presented in Table 1.

| No | Materials | Use                                      |
|----|-----------|------------------------------------------|
| 1  | GPS       | Taking coordinates during field survey   |
| 2  | Camera    | Taking pictures of flood-affected locations |
| 3  | Computer  | Processing field data                    |
| 4  | QGIS      | Map creation                             |

2.2.2. Materials. Materials used during the research are presented in Table 2.

| No | Materials | Use                                           |
|----|-----------|-----------------------------------------------|
| 1  | RBI Map   | Basic map for road map and evacuation routes  |
| 2  | Satellite Imagery | Creation of evacuation routes and road map    |
| 3  | Disaster Data | Creation of flood points distribution       |

2.3. Research Variables

Research variables are presented in Table 3.

| Variables                  | Data source                      | Parameter                                          |
|----------------------------|----------------------------------|----------------------------------------------------|
| Land cover map             | Satellite Imagery                | Settlements, rice fields, open land, shrubs, mixed vegetation |
| Evacuation Routes map      | Road map, satellite imagery      | Arterial road and protocol road                     |
| Road map                   | Road map, satellite imagery      | Shortest and closest path                          |
2.4. Types and Sources of Data

2.4.1. Primary Data. Primary data used in this research were coordinate points, satellite imagery and locations of flood-affected points.

2.4.2. Secondary Data. Secondary data used in this research was the data of flood-affected areas in Gorontalo City during the last five years obtained (2012-2017) from BPBD of Gorontalo City.

2.5. Research Methods

The method used in this research was survey method. Survey method used to obtain data from certain natural place. The use of this method is more effective because the data obtained directly on the field [4]. Mapping also requires this survey method so that the results obtained from the image can be adjusted directly to the actual situation. Roundgraph method was used to determine the Evacuation Routes. Roundgraph method is one of Quantum GIS (QGIS) tools. This tool is used to find the nearest alternative paths.

2.6. Research Stages

2.6.1. Data Collection. The collected data were primary data and secondary data. Primary data obtained from field survey by checking flood-affected locations, land use and land cover. Secondary data obtained from 2017 high resolution satellite imagery and RBI map scale 1: 25,000 as a reference in making a village map obtained from related agencies. Secondary data collection from related institutions in this case was obtained from Local Disaster Management Agency.

2.6.2. Data Processing. This stage covers the making of land cover map, road class map, flood points distribution map, and disaster posts map from survey results and interpretation of high resolution imagery and RBI map. Here are the steps of data processing conducted by researchers:

1) Radiometric correction to remove atmospheric disturbances during recording.
2) Geometric correction to determine coordinate points using RBI Map Scale 1: 25,000 as a reference.
3) Using high resolution satellite imagery to create imagery map
4) Inserting flood distribution points on the imagery map, land cover and land use
5) Determination of evacuation route using Roundgraph method.
6) Determination of disaster posts based on the overlay of land cover map, land use map, road map, flood points distribution map
7) Imagery reinterpretation to reanalyze the data, correcting interpreter mistakes which is conducted by fixing the results of the interpretation with the results of field survey correction.

2.6.3. Result Arrangement. Result arrangement stage is a stage where the data from spatial analysis has been obtained and presented in a form of map which will be a basis for researchers to draw conclusion.

2.7. Data Analysis

In this research, researchers used visual spatial data analysis technique using GIS application so it can produce imagery map, land cover map and land use map flood points distribution map, and disaster posts map. Visual analysis is a very useful stage to find and clarify an interrelated pattern of an object with another object according to the phenomena that occur on the surface of the earth. Since visualization analysis is quite complicated to be detected. This analysis is then divided into Attribute Visualization (attribute data point objects) and Spatial Tesselation Visualization

3. Result and Discussion

3.1 Overview of Research Site

Gorontalo City is located at the longitude of 122° 59’ 44” - 123° 05’ 59”E and latitude of 00° 28’ 17” - 00° 35’ 56”N (as shown in Figure 1). It has an area of 64.79 km2, about 0.55% of total area of Gorontalo
Province. Sharing its border with Gorontalo Regency and Bone Bolango Regency. Gorontalo City consists of nine districts, i.e., Kota Selatan, Kota Utara, Kota Barat, Kota Timur, Kota Tengah, Dungingi, Dumbo Raya, Hulonthalangi, and Sipatana district [5]. It is widely understood that Gorontalo is a flood-prone area since it lies in the central basin of North Sulawesi. The city has been built on alluvial plains and the Bolango River alluvial fan [2].

3.2 Road Class Map
Road class map is created through remote sensing imagery interpretation to obtain road class data. There are two classes of roads on this map that are main / collector road class and arterial road class as shown in Figure 2.

![Figure 2. Gorontalo city road class map](image)

Collector road class is a public road class that used to serve collecting or splitting carrier with medium distance, medium speed average and limited number of entrances. Arterial roads are roads that serve main transport with long-distance travel and high speed average.

3.3 Flood Points Distribution Map
Flood points distribution map (Figure 3) is created through 2012-2017 flood points distribution data obtained from BPBD Gorontalo. Then, researchers took the coordinate of those points using GPS. After the coordinates of those points obtained, researchers inserted coordinates of those points to road class map.
3.4 Disaster Posts Map

To insert disaster posts data, researcher analyzed road class map and flood points distribution map. Locations of the posts is determined based on the largest number of flood points and accessible roads to closest disaster posts as shown in Figure 4.

3.5 Evacuation Routes Map

Evacuation routes map (Figure 5.) is created through an overlay of Road Class Map, Flood Points Distribution Map and disaster posts Map using roundgraph method. Roundgraph method will show required time and distance to reach disaster posts.
4. Conclusion

This research demonstrates that freely available mitigational data and high resolution imagery were advantageous in assisting mitigation and hazard-related planning in municipal areas. Availability to such data should help reduce damage and casualties in future flooding events.

References

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