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Mapping of Flood-Prone Area under Impact of Tidal Influence in Singkawang City

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ABSTRACT

Flood is a seasonal threat that occurs when a body of water overflows from the existing channel and inundates the surrounding area. In the last three years, Singkawang City has experienced frequent floods. Although they did not cause casualties, the floods caused much harm to the surrounding community, such as educational and office activities that could not run normally. To reduce the impact of the flood disaster in Singkawang City, a complete and integrated flood control and management effort is needed, which maps flood-prone areas in its initial stage. This research aims to provide information about the characteristics of the tides and the level of vulnerability to flooding caused by the influence of the tides in Singkawang City in the form of a zoning map.

In this research, the parameters used are the distance from the beach, river buffer, land slope, land elevation, and land cover. Then, flood-prone areas can be mapped using Geographic Information Systems (GIS) and the weight overlay method.

This research shows that in Singkawang City, the area considered safe from flooding is 24048.449 Ha or 43.947%. Areas classified as not vulnerable have an area of 19938.498 Ha or 36.436%. Areas classified as vulnerable have an area of 9068.206 Ha or 16.571%. Meanwhile, areas classified as very vulnerable have an area of 1666.860 Ha or only 3.046%.

Keywords: *Flood vulnerability mapping, Singkawang City Geographic Information Systems (GIS), Tidal influence Flood risk assessment,*

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1. Introduction

Floods are among many natural disasters that often occur in Indonesia (Akafi et al., 2023; Alfaro et al., 2023; Soeryamassoeka et al., 2023). Flooding is a seasonal threat when water bodies overflow from existing channels and inundate the surrounding area (Soeryamassoeka et al., 2018).

Floods are the most frequent natural threat and cause the most harm from a humanitarian and economic perspective (IDEP, 2007). During the rainy season, many areas in Singkawang City are affected by flooding. The government has made many efforts, including improving drainage channels, constructing carrier channels, building dams, and forest reforestation, but this problem still needs to be solved. It is getting more comprehensive regarding frequency, depth, extent, and duration. In Singkawang City, floods are generally caused by natural factors, such as the influence of high rainfall and the impact of sea tides.

Singkawang City is one of the cities in West Kalimantan, located in a coastal area, which increases the potential threat of tidal floods. This research will focus on the causes of flooding due to the influence of tides in Singkawang City. To reduce the impact of flood disasters, a complete and integrated flood control and management effort is needed, the first step of which is mapping flood-prone areas.

2. Materials and Methods

2.1. Research Location

This research is located in Singkawang City, West Kalimantan Province, Indonesia. The administrative area of Singkawang City is divided into North Singkawang, West Singkawang, Central Singkawang, East Singkawang, and South Singkawang. The location of this research can be seen in **Figure 1**.

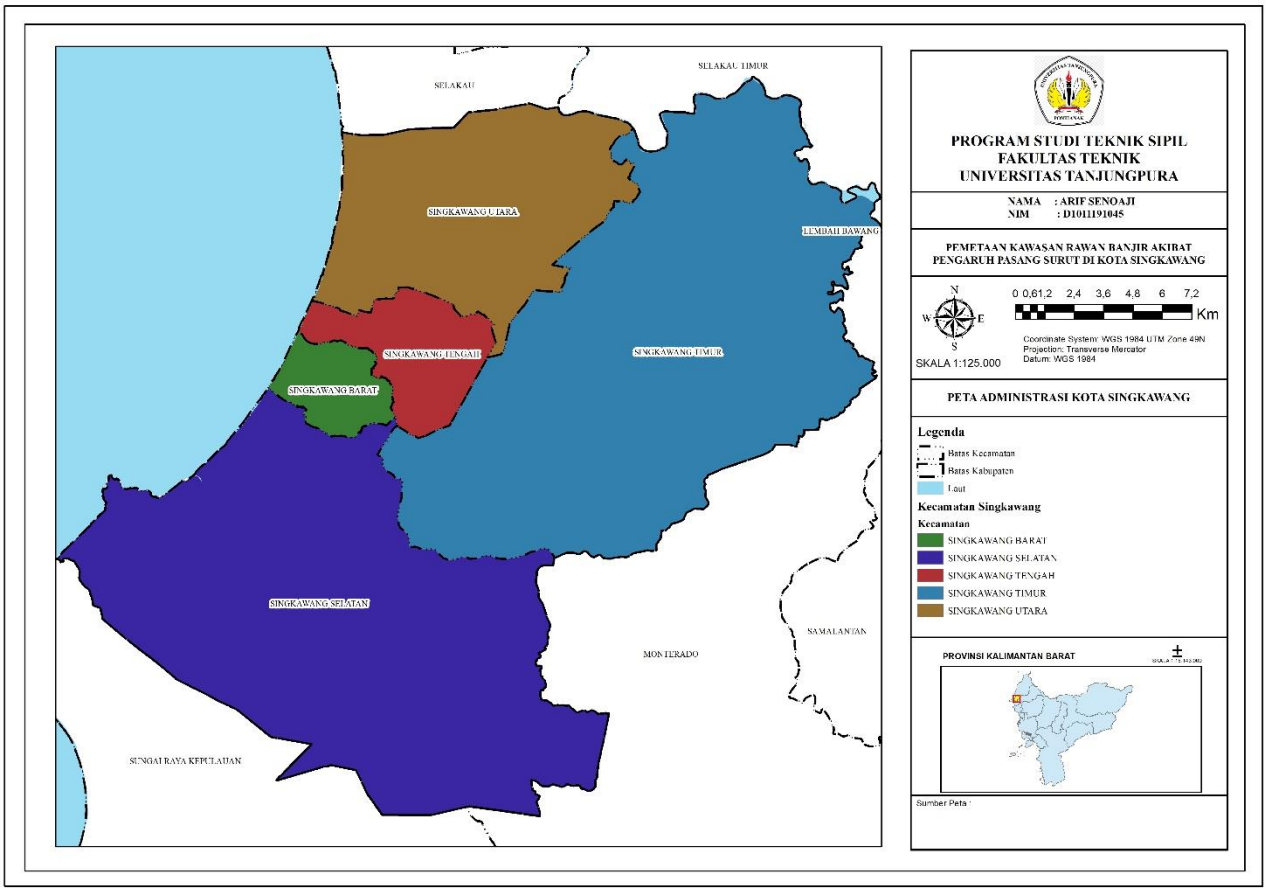

Figure 1. Singkawang City

2.2. Data

Inventory and secondary data collection is in the form of thematic maps and other supporting policies/regulations obtained from relevant agencies/institutions with the authority to make and publish them. The data needed in this research are:

a. West Kalimantan Administrative Map from West Kalimantan Provincial Government Geoportal.
b. Rupa Bumi Indonesia (RBI) Map of West Kalimantan Province from the Geospatial Information Agency.
c. Land Cover Map of West Kalimantan from the Directorate of Inventory and Monitoring of the Ministry of Environment and Forestry.
d. DEM (Digital Elevation Model) of West Kalimantan from the DEMNAS

2.3. Analysis Method

The purpose of data analysis in this research is to provide information regarding the level of flood vulnerability caused by the influence of sea tides in Singkawang City in the form of a zoning map. Data processing is done with:

2.3.1 Distance from the Beach Analysis

Distance from the beach analysis of Singkawang City can be done using the West Kalimantan Administrative Map and ArcGIS 10.3 software.

2.3.2 River Buffer Analysis

River buffer analysis of Singkawang City can be done using the West Kalimantan Administrative Map and ArcGIS 10.3 software.

2.3.3 Land Slope Analysis

Land slope analysis of Singkawang City can be done with the help of ArcGIS 10.3 software, using Digital Elevation Model (DEM) data.

2.3.4 Land Elevation Analysis

Land elevation analysis of Singkawang City can be done with the help of ArcGIS 10.3 software using Digital Elevation Model (DEM) data.

2.3.5 Land Cover Analysis

Land cover analysis of Singkawang City can be done with the help of ArcGIS 10.3 software, using shapefile data from the Directorate of Inventory and Monitoring of the Ministry of Environment and Forestry.

2.3.6 Scoring and Weighting

Scoring gives a score for each parameter (distance from the beach, river buffer, land slope, land elevation, and land cover). Weighting gives an assessment weight to each flood parameter and how much influence it has on flooding due to tides.

2.3.7 Overlay Analysis

Overlay analysis is the sum of the total values (score × weight) for all parameters that cause flooding due to tides. The higher the total value obtained, the more vulnerable that area is to flooding. Otherwise, the smaller the value obtained, the safer that area is from flooding.

(1) $K = \sum_{i=1}^{n}(W_i \times X_i)$

Flood Vulnerability Level Analysis

The level of flood vulnerability in this research was divided into four classes: safe, not vulnerable, vulnerable, and very vulnerable. The minimum and maximum values were obtained after overlaying all parameters using ArcGIS 10.3 software. The interval width for each vulnerability class is determined using the following equation:

(2) $i = R/n$

3. Result and Discussion

The following are the results and discussion of mapping the flood-prone area under the impact of tidal influence in Singkawang City.

3.1. Distance from the Beach Analysis

The distance from the beach class in Singkawang City is divided into five classes, namely 0 – 500 m, 500 m – 1000 m, 1000 m – 1500 m, 1500 m – 3000 m, > 3000 m. Areas with a distance from the beach of 0 – 500 meters are very vulnerable to tidal floods, while areas with more than 3000 meters are very safe in Singkawang City.

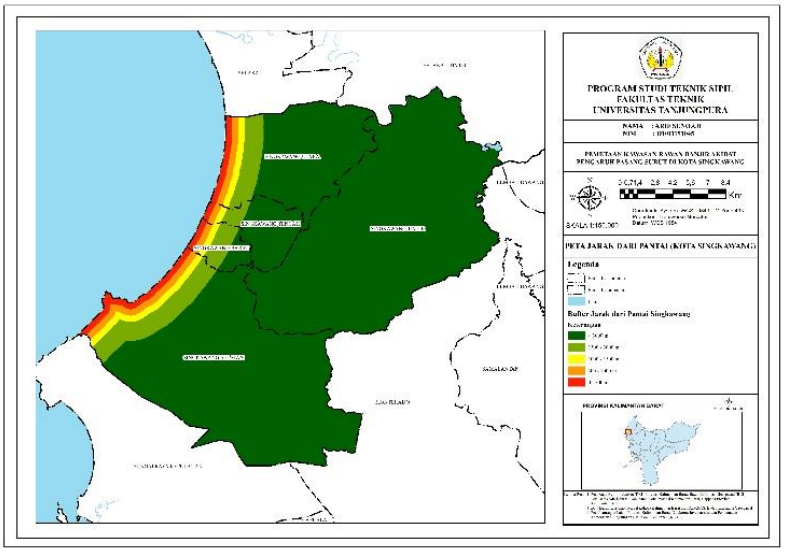

Figure 2. Distance from the Beach Map of Singkawang City

The largest area is a distance of more than 3000 meters with a value of 47748.488 Ha (86.852%), while the smallest area is 500 meters – 1000 meters with a value of 1161.345 Ha (2.112%).

Table 1. Distance from the Beach of Singkawang City

Score	Distance from the Beach	Area (Ha)	Area (%)
1	> 3000 m	47748.488	86.852
2	1500 m – 3000 m	3682.671	6.699
3	1000 m – 1500 m	1181.853	2.150
4	500 m – 1000 m	1161.345	2.112
5	0 – 500 m	1202.387	2.187
	Total	54976.745	100

3.2. River Buffer Analysis

The river buffer class in Singkawang City is divided into five classes: 0 – 100 m, 100 – 200 m, 200 – 300 m, 300 – 500 m, and> 500 m. Areas 0 – 100 meters from the river are very vulnerable to tidal floods, while areas more than 500 meters from the river are very safe from tidal floods in Singkawang City.

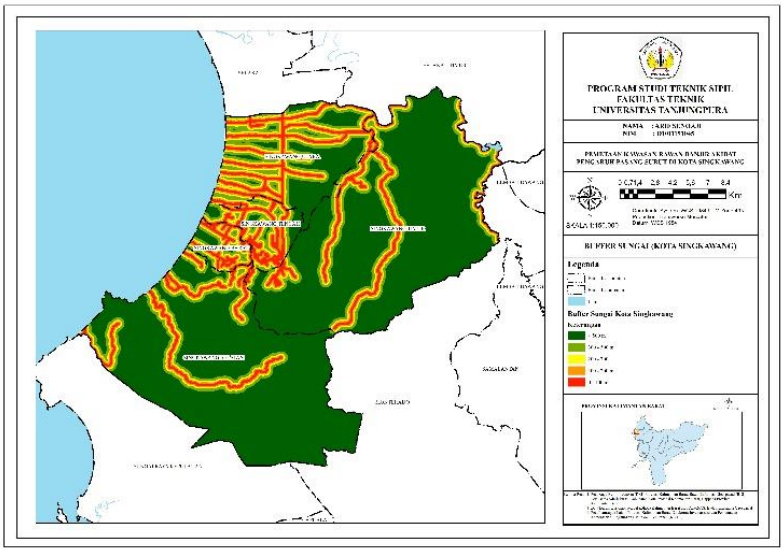

Figure 3. River Buffer Map of Singkawang City

The largest area is more than 500 meters, with a value of 36322.294 Ha (66.068%), while the smallest area is 200 meters—300 meters, with a value of 3686.634 Ha (6.706%).

Table 2. River Buffer of Singkawang City

Score	River Buffer	Area (Ha)	Area (%)
1	> 500 m	36322.294	66.068
2	300 – 500 m	6155.114	11.196
3	200 – 300 m	3686.634	6.706
4	100 – 200 m	4169.046	7.583
5	0 – 100 m	4643.658	8.447
	Total	54976.745	100

3.3. Land Slope Analysis

Land slope in Singkawang City is divided into five classes, namely flat (0% – 4%); flat–sloping (4% – 8%); choppy (8% – 15%); somewhat steep, wavy, hilly (15% – 25%); hilly (>25%). Areas that have a flat slope (0% – 4%) are areas that are very vulnerable to tidal floods, while areas that have a hilly slope (>25%) are areas that are very safe from tidal floods in Singkawang City.

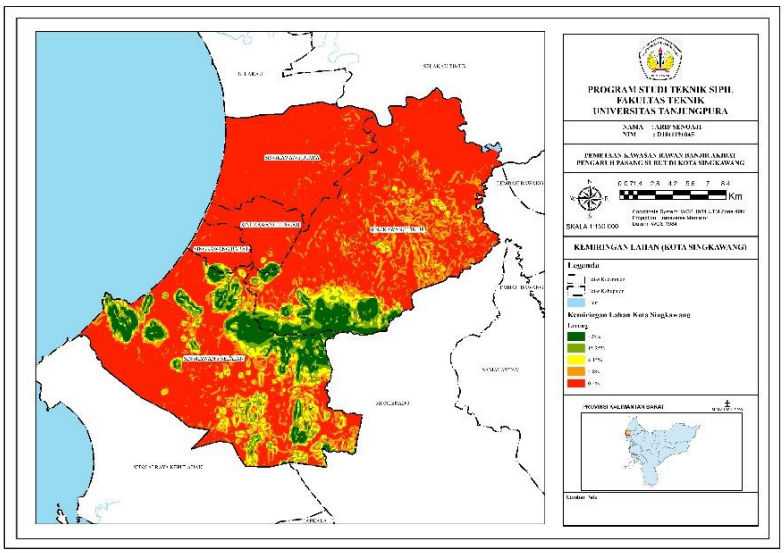

Figure 4. Land Slope Map of Singkawang City

The largest area is the flat slope (0% – 4%) with a value of 37368,883 Ha (68,207%), while the smallest area is the somewhat steep, wavy, and hilly slope (15% – 25%) with a value of 2828,839 Ha (5,163%).

Table 3. Land Slope of Singkawang City

Score	Land Slope	Area (Ha)	Area (%)
1	Hilly (>25%)	3958.146	7.225
2	Somewhat Steep, Wavy, Hilly (15% – 25%)	2828.839	5.163
3	Choppy (8% – 15%)	3501.469	6.391
4	Flat – Sloping (4% – 8%)	7130.197	13.014
5	Flat (0% – 4%)	37368.883	68.207
	Total	54787.535	100

3.4. Land Elevation Analysis

Land elevation in Singkawang City is divided into five classes: 0 – 2 m, 2 – 4 m, 4 – 8 m, 8 – 10 m, and> 10 m. Areas with 0 – 2 m elevation are very vulnerable to tidal floods, while areas with more than 10 meters are very safe.

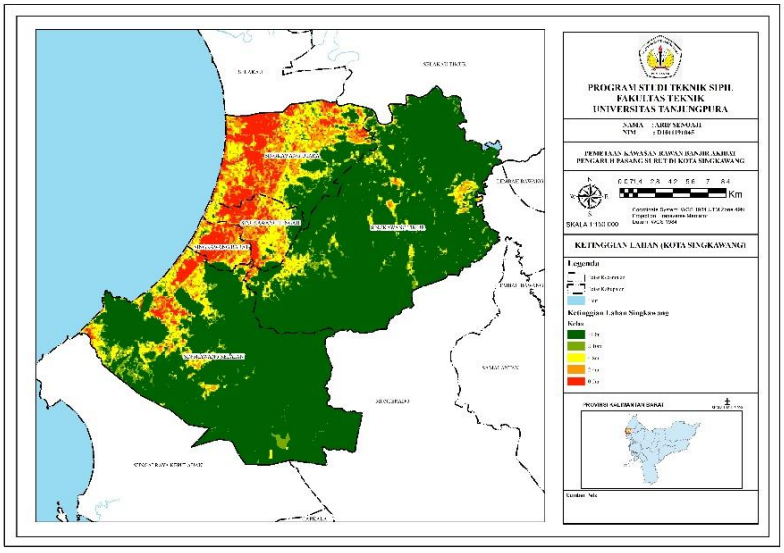

Figure 5. Land Elevation Map of Singkawang City

The largest area is elevation more than 10 meters with a value of 38576,577 Ha (70,414%), while the smallest area is elevation 8 – 10 m with a value of 2635,912 Ha (4,811%).

Table 4. Land Elevation of Singkawang City

Score	Land Elevation	Area (Ha)	Area (%)
1	> 10 m	38576.577	70.414
2	8 m – 10 m	2635.912	4.811
3	4 m – 8 m	6235.243	11.381
4	2 m – 4 m	3533.250	6.449
5	0 m – 2 m	3804.234	6.944
	Total	54785.215	100

3.5. Land Cover Analysis

Land cover in Singkawang City is divided into five classes: forest, mixed gardens, shrubs, plantations, moors, settlements, rice fields, open land, water bodies, and ponds. Areas that have a land cover open land, water bodies, and ponds are areas that are very vulnerable to tidal floods, while areas that have a land cover forest are areas that are very safe from tidal floods in Singkawang City.

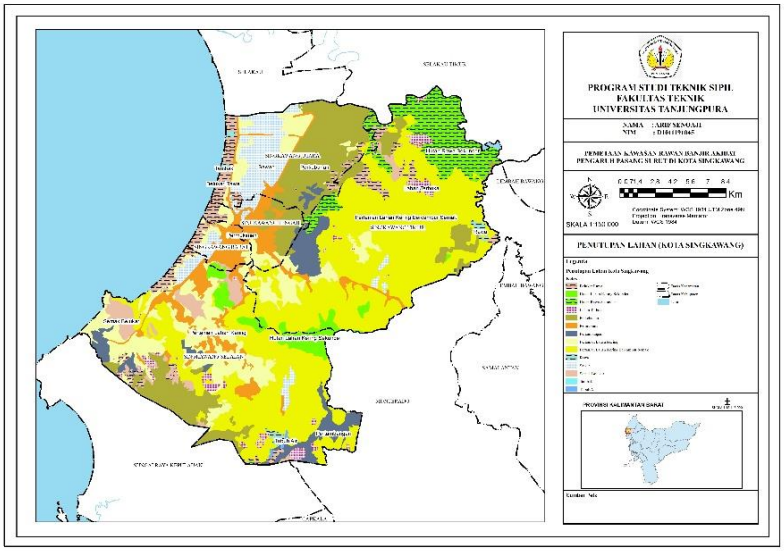

Figure 6. Land Cover Map of Singkawang City

The largest area is mixed gardens and shrubs, valued at 24783,402 Ha (45,080%), while the smallest area is open land, water bodies, and ponds, valued at 1210,090 Ha (2,201%).

Table 5. Land Cover of Singkawang City

Score	Land Cover	Area (Ha)	Area (%)
1	Forest	5173.805	9.411
2	Mixed Gardens, Shrubs	24783.402	45.080
3	Plantations, Moors	7423.264	13.503
4	Settlements, Rice Fields	16385.611	29.805
5	Open Land, Water Bodies, Ponds	1210.090	2.201
	Total	54976.172	100

3.6. Flood Vulnerability Level Analysis

This research divided the level of flood vulnerability into four classes: safe, not vulnerable, vulnerable, and very vulnerable. The interval value between flood vulnerability classes is 1.0, and the final result can be seen in Table **6**.

Table 6. Flood Vulnerability, Class of Singkawang City

No.	Intervals	Classification
1	1.00 – 2.00	Safe
2	2.00 – 3.00	Not Vulnerable
3	3.00 – 4.00	Vulnerable
4	4.00 – 5.00	Very Vulnerable

3.7. Mapping of Flood-Prone Area

Data processing for various parameters in this research, such as distance from the beach, river buffer, land slope, land elevation, and land cover, which are then overlaid, will produce a map of the level of flood vulnerability in Singkawang City. The flood-prone area under the impact of tidal influence in Singkawang City can be seen in **Figure 7** and **Table 7**.

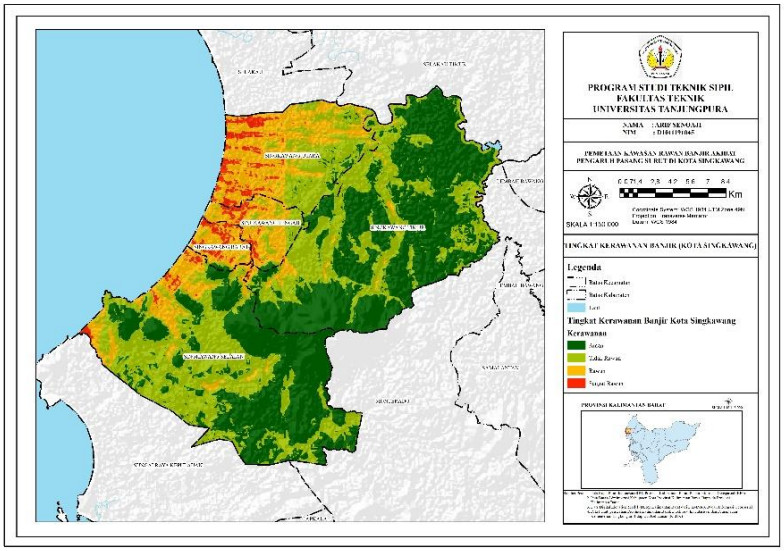

Figure 7. Flood-Prone Area Under Impact of Tidal Influence in Singkawang City

Table 7. Flood Vulnerability, Class of Singkawang City

Score	Flood Vulnerability Class	Area (Ha)	Area (%)
1	Safe	24048.449	43.947
2	Not Vulnerable	19938.498	36.436
3	Vulnerable	9068.206	16.571
4	Very Vulnerable	1666.860	3.046
	Total	54722.013	100

The overlay of flood vulnerability levels shows that most of the coastal areas of Singkawang City are classified as flood-prone, as indicated by yellow symbols, with an area of 9068,206 Ha (16,571%). Because this area has relatively low elevation and slope values, another factor that causes this area to become flood-prone is that residential areas and rice fields mainly dominate land use. Meanwhile, the areas classified as very vulnerable are primarily located around rivers in Singkawang City, with an area of 1666,860 Ha (3,046%).

Based on mapping the flood-prone areas in Singkawang City, which are classified as vulnerable and very vulnerable, most are in West Singkawang, Central Singkawang, and North Singkawang. This is because the area has low elevation and slope values and is dominated mainly by residential areas and rice fields. Meanwhile, the areas classified as safe and not vulnerable are primarily in East Singkawang and South Singkawang. This is because most of the area has high elevation values and is dominated by bush areas.

4. Conclusion

Based on the analysis of the level of flood vulnerability in Singkawang City, it can be concluded that the level of flood vulnerability in Singkawang City is divided into four classes: safe, not vulnerable, vulnerable, and very vulnerable. The area classified as safe is 2448.449 Ha or 43.947%. Areas classified as not vulnerable have an area of 19938.498 Ha or 36.436%. Areas classified as vulnerable have an area of 9068.206 Ha or 16.571%. While the area classified as very vulnerable has an area of 1666.860 Ha or only 3.046%. Singkawang City areas classified as vulnerable or very vulnerable are mainly in West Singkawang, Central Singkawang, and North Singkawang. At the same time, areas classified as safe and not vulnerable are primarily in East Singkawang and South Singkawang.

5. Acknowledgement

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6. Author's Note

The author now declares that this article is an original work and does not plagiarize any research, as it has successfully passed the examination to obtain a bachelor's degree in engineering at the Faculty of Engineering, Tanjungpura University, on October 16, 2023.

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