Published *online* on the journal's web page : http://innovatics.unsil.ac.id

Innovation in Research of Informatics (INNOVATICS)

| ISSN (Online) 2656-8993 |

Forecasting Flood Vulnerability in Pontianak Using Multiple Linear Regression and Geospatial Information Systems (GIS)

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ARTICLE INFORMATION

Article History:
Received: January 26, 2023
Last Revision: March 13, 2023
Published *Online*: March 30, 2023

KEYWORDS

Flood disaster,
Flood-prone locations,
Multiple Linear Regression,
Pontianak City,
Quantum GIS

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ABSTRACT

Flood disasters often occur in locations with certain geographical characteristics, such as being close to rivers and excessive rainfall, especially during the rainy season, so that most types of soil contain clay and are not suitable for water absorption. One of the cities in Indonesia that often experiences flooding is Pontianak City. The disaster caused various kinds of losses such as damage to infrastructure, traffic jams and accidents due to slippery roads. Based on the parameters that have been set in the previous situation, the multiple linear regression method is used to forecast and anticipate the level of flood risk in Pontianak City. The Quantum GIS application creates a digital map that displays the scores achieved in each sub-district. The results of calculations using this method show that the sub-districts most prone to flooding are Pontianak Kota and East Pontianak. This is done to identify flood-prone locations in Pontianak City and make mitigation activities more focused and effective.

1. INTRODUCTION

Indonesia is one of the emerging nations in Asia, particularly Southeast Asia, which has a higher risk of natural catastrophes because of its geographic location. Most of Indonesia's land is covered by water, and heavy rainfall can have several effects, including the potential for catastrophic flooding in some locations. Additionally, Indonesia experiences considerable rainfall, averaging between 2000 and 3000 mm per year, which makes floods a common occurrence, particularly during the rainy season [1].

Floods can occur when a river or drainage channel's capacity is exceeded by the discharge of water running through it, inundating areas of the dry ground like agricultural land and towns up to the city center. If stagnant water is present at a high enough elevation, for an extended period, and regularly, it will interfere with human activities and cause accessibility issues, infrastructure damage, and the spread of disease viruses [2]

One of Indonesia's major cities, Pontianak City, is frequently affected by flooding. From 2016 to 2020, Pontianak City experienced water stagnation and flooding, particularly during the rainy season. Flooding is more likely to happen when there is heavy rain and rivers traverse the area, as in Pontianak City [3]. West Kalimantan Province's capital city frequently experiences floods ranging in height from 10 to 30 cm, inundating various locations and major routes. This state results in various losses, including accidents on slick roads that result in fatalities, infrastructure damage, and traffic congestion, among other things.

Flood disasters are a hazard that frequently occurs each year, necessitating more efficient and focused actions. A scale of priorities is required to decide which places should be created first, in addition to preparing for infrastructure upgrades and building embankments. In addition, forecasting flood events for the upcoming year will help the government create policies and solutions that will be

more successful in lessening the impact of losses brought on by flood disasters.

Geospatial information systems (GIS) and forecasting methodologies are tools or instruments that can jointly predict or foresee a condition that will be experienced in the future based on previous or present conditions and identify places that will specifically experience these conditions. In order to make prevention and mitigation actions more successful and targeted, these two instruments can be used in disaster mitigation efforts such as floods.

In order to explicitly provide information on flood-prone locations, this study aims to forecast the amount of flood danger that will exist in Pontianak City in the future. The Multiple Linear Regression Approach, a mathematical model that can estimate outcomes under certain circumstances over a range of months to years, is utilized in the forecasting method [4]. The Quantum GIS tool will be used in the interim to process the mapping of flood-prone areas [5]. The findings of this study may contribute to aiding the government and associated organizations to create policies and plans for flood disaster mitigation in Pontianak City that are more successful in the future.

2. RELATED WORK

The Multiple Linear Regression method is often used to predict or forecast certain conditions using mathematical models based on current and past data or conditions. Marbun et al. 2021 research entitled Data Mining Analysis for Estimating Rainfall Potential Using the Multiple Linear Regression Method analyze the problem of predicting rainfall and compiling a desktop-based system for estimating rainfall using the Multiple Linear Regression method. The Multiple Linear Regression Method can overcome issues by anticipating future precipitation to foresee flood disasters brought on by high rainfall [6]. In a related work titled Prediction of Monthly Rainfall in Deli Serdang Using Regression Equations with Predictors of Air Temperature and Humidity Data, multiple linear regression techniques are used to make more accurate forecasts of the total monthly rainfall [7].

Weather forecasting using the Multiple Linear Regression method is also applied in a study entitled Analysis of Weather Forecasting with Parameters of Temperature, Humidity, Air Pressure, and Wind Speed Using Multiple Linear Regression. The results of this study show that the variables of air temperature, air pressure, air humidity, and wind speed affect rainfall [8].

In addition, the prediction of the productivity of a food ingredient can also be known using the multiple linear regression method in a study entitled Multiple Linear Regression Methods and SVR in Determining the Level of Influence of Weather on Rice Productivity in Indonesia. This study aims to predict rice productivity to see how much influence the weather has on rice productivity based on weather changes in Indonesia [9]. In other fields of science, the Multiple Linear Regression Method can also be used to predict diseases such as SARS-CoV-2 in the future. One is in a study entitled Forecasting the Future of SARS-CoV-2 Using a Multi-Linear Regression Model. In this study, the Multiple Linear Regression method is a machine learning method that can predict future COVID-19 cases based on total case data and case recovery (new infections and recovery situations). The results of this research can be used to assist the government in predicting future cases of COVID-19 and dealing with these crises over time [10].

The difference in research related to this research is that the results of calculations and analysis of the Multiple Linear Regression method related to the prediction of the level of vulnerability to flooding disasters in Pontianak City are represented by digital maps processed through Quantum GIS software to present spatial information related to flood-prone zones in Pontianak City.

3. METHODOLOGY

The Multiple Linear Regression Method was employed in this research to forecast or predict flood susceptibility in Pontianak. Regression analysis using the multiple linear regression method establishes the relationship between the dependent variable, to predict, and multiple predictors or variables (independent variable The following is the Multiple Linear Regression formula.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k$$

Y = dependent variable
X_i = independent variable (i = 1,2,4,...,k)
β_0 = intersep
β_i = regression coefficient

The Quantum GIS tool will convert prediction outcomes about scores and flood-prone locations in Pontianak City into digital maps. This research was conducted in several stages, as shown in the following flowchart.

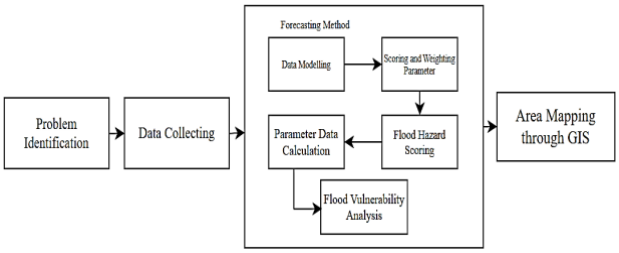

FIGURE 1. IMPLEMENTATION METHOD

4. RESULT AND DISCUSSION

4.1 Flood Vulnerability Prediction Mechanism in Pontianak City

Rainfall prediction analysis is used to predict how much rain will fall in the upcoming years. To model the results of the multiple linear regression analysis, SPSS software is used. Temperature and humidity variables with a 2018–2020 range predict rainfall.

The following is the outcome of multiple linear regression analysis performed with SPSS, utilizing temperature, humidity, and rainfall variables as parameters and outcome variables, respectively.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,252[a]	,064	-,144	2067,16651

a. Predictors: (Constant), V3, Rata-rata Kelembaban (Persen)

FIGURE 2. SUMMARY MODEL OF MULTIPLE LINEAR REGRESSION ANALYSIS OF RAINFALL

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2614876,547	2	1307438,274	,306	,744[b]
	Residual	38458596,370	9	4273177,374		
	Total	41073472,917	11			

a. Dependent Variable: VAR00004

b. Predictors: (Constant), V3, Rata-rata Kelembaban (Persen)

FIGURE 3. ANOVA FROM MULTIPLE LINEAR REGRESSION ANALYSIS OF RAINFALL

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	62439,649	78605,561		,794	,447
	Rata-rata Kelembaban (Persen)	-272,056	499,372	-,209	-,545	,599
	V3	-1341,498	1749,094	-,294	-,767	,463

a. Dependent Variable: VAR00004

FIGURE 4. COEFFICIENTS FROM MULTIPLE LINEAR REGRESSION ANALYSIS OF RAINFALL

The resulting model can project the rainfall parameters based on the analysis's findings. Three factors are used in the analysis of flooding vulnerability: the amount of yearly rainfall, soil height, and river buffer, with the scoring table shown below:

TABLE 1. RAINFALL PARAMETER

No.	Class	Score
1	>2500 (Very Heavy)	5
2	2001-2500(Heavy)	4
3	1501-2000(Moderate)	3
4	1000-1500 (Mild)	2
5	<1000 (Very Mild)	1

TABLE 2. SOIL HEIGHT PARAMETER

No.	Class	Score
1	0 m – 20 m	5
2	21 m – 50 m	4
3	51 m – 100 m	3
4	101 m – 300 m	2
5	>300 m	1

TABLE 3. RIVER BUFFER PARAMETER

No.	Class	Score
1	61,5% - 100% (Very Vulnerable)	5
2	50,1% - 51,4% (Vulnerable)	4
3	32,1% - 50% (Moderate)	3
4	17,7% - 32% (Low Vulnerable)	2
5	0% - 17,6% (Very Low Vulnerable)	1

Then, using the weight table, each parameter is weighted as follows:

TABLE 4. PARAMETER WEIGHT

No.	Class	Weight
1	Rainfall	0.4
2	Soil Height	0.35
3	River Buffer	0.25

Following the weighting process, the following scoring table is used to determine the level of flood vulnerability based on the weighted attributes:

TABLE 5. FLOOD VULNERABILITY SCORE

No.	Class	Score
1	Low Vulnerability	<3
2	Vulnerability	3 - <3,4
3	High Vulnerability	>3,4

Furthermore, an analysis of the rainfall prediction is carried out to determine the amount of rainfall in several years. This analysis uses SPSS software to obtain modeling from multiple linear regression analysis. The parameters used for rainfall prediction are temperature and humidity, ranging from 2018-2020.

Calculations are made by performing mathematical calculations based on some of the data that has been obtained. The following is a calculation of the flood vulnerability level parameter data.

TABLE 6. SOIL HEIGHT

No.	District	Height
1	Pontianak City	7 meters
2	West Pontianak	6 meters
3	East Pontianak	7 meters
4	North Pontianak	6 meters
5	South Pontianak	7 meters

TABLE 7. RIVER BUFFER

No.	Districts	Wide (km^2)	Length of River per District	Persentage (%)
1	Pontianak City	15,51	12,72	82,011
2	West Pontianak	16,71	5,99	35,85
3	East Pontianak	8,78	10,23	116,51
4	North Pontianak	37,22	10,91	29,31
5	South Pontianak	15,54	2,1	14,44

TABLE 8. AVERAGE RAINFALL IN PONTIANAK (2018-2020)

No.	District	Average Rainfall (2018)	Average Rainfall (2019)	Average Rainfall (2019)	Average Annual Rainfall
1	Pontianak City	234,65	112,56	225	190,7366667
2	West Pontianak	345,67	234,56	785,23	455,1533333
3	East Pontianak	457,45	234,34	123,56	271,7833333
4	North Pontianak	345,34	345,56	144,55	278,4833333
5	South Pontianak	123,45	454,34	512,34	363,3766667

Analysis of the level of vulnerability to flooding uses a mathematical calculation with the following formula:

Flood Vulnerability Formula

$$x = \sum (Wi\ x\ Xi)$$

x = Vulnerability value
Wi = Weight for parameter i
Xi = Class score for parameter i

The results of flood vulnerability in Pontianak City in 2020 were as follows, based on the parameter data that was used in the scoring process:

TABLE 9. PREDICTION OF FLOOD VULNERABILITY IN PONTIANAK

No.	District	Rainfall	Soil Height	River Buffer	Total	Description
1	Pontianak City	0,4	1,75	1,25	3,4	Vulnerability
2	West Pontianak	0,4	1,75	0,75	2,9	Low Vulnerability
3	East Pontianak	0,4	1,75	1,25	3,4	Vulnerability
4	North Pontianak	0,4	1,75	0,5	2,5	Low Vulnerability
5	South Pontianak	0,4	1,75	0,25	2,4	Low Vulnerability

Quantum GIS then displays the vulnerability level results in geographic information system software. Here are the outcomes of the map representation of the degree of vulnerability:

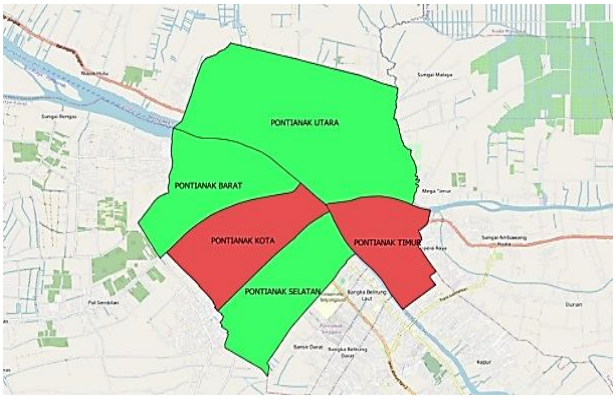

FIGURE 5. FLOOD VULNERABILITY LEVEL IN PONTIANAK

By using the model that has been obtained, the analysis for the following year can be carried out by predicting the annual rainfall level, which is then carried out by calculating the existing parameters. Land height and river buffer tend to be constant so that the forecasted parameters are rainfall parameters with dynamic data every year.

5. CONCLUSIONS

Pontianak City is one of Indonesia's major cities that is vulnerable to flooding. This is because rivers go through geographical conditions where settlements predominate the land cover, and the soil is primarily clay-textured, which is poor at absorbing water. Even though the average rainfall each year is not classified as very wet, during the rainy season, the rainfall intensity increases and lasts quite a long time. These factors cause Pontianak City to be frequently hit by floods. The disaster brought detrimental impacts such as infrastructure damage and accidents due to slippery roads. Therefore, efforts are required to lessen flood-related damages and lower the likelihood of flooding in Pontianak City. The developed policies must be efficient and precise and prioritize regions most vulnerable to flooding.

Forecasting can be done using multiple linear regression methods to predict the flood vulnerability level in the following year. By utilizing the multiple linear regression method, predictions can be made on flood vulnerability parameters, especially those that are dynamic yearly. With the integration of the Geographic Information System and the multiple linear regression method, areas that are prone to flooding can be explicitly identified, thereby facilitating the government and related institutions to develop mitigation strategies that are more effective and targeted as well as predicting parameter changes. Flood vulnerability can help the government and related institutions to prepare mitigation strategies for the following year.

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