Journal Basic Science and Technology 12 (1) (2023) pp. 20-24

Published by: IOCSCIENCE

Journal Basic Science and Technology

Journal homepage: www.iocscience.org/ejournal/index.php/JBST

Identification of Flood-Prone Areas Using the Topographic Wetness Index Method in Fena Leisela District, Buru Regency

Philia Christi Latue[1], Heinrich Rakuasa[2]

[1]Biology Education Study Program, Universitas Pattimura, Ambon, Indonesia

[2]Department of Geography, Universitas Indonesia, Depok, Indonesia

ARTICLE INFO

Article history:

Received Jan 30, 2023
Revised Feb 18, 2023
Accepted Feb 28, 2023

Keywords:

Flood
Fena Leisela
Topographic Wetness Index

ABSTRACT

Fena Leisela District is often hit by floods in the rainy season. Floods that often occur in Siwalalat District are caused by the overflow of the Waegeren River. Research using DEMNAS data and analysis using the Topographic Wetness Index method. The results of the analysis of the inundation potential are divided into three classes, namely the low potential class with an area of 92,196.09 or 63.04%, the medium class covering 45,769.48 ha or 31.29% and the high potential class covering 936.12 ha or 5.67 %. The research results are expected to be a reference for the government and the community in handling future floods to minimize the impact that occurs.

Corresponding Author:

Philia Christi Latu,
Biology Education Study Program,
Universitas Pattimura,
Jln Ir. M. Putuhena Kampus Unpatti Poka Ambon Kode Pos 97233.
Email: philialatue04@gmail.com

1. INTRODUCTION

Flooding is a condition in which water flows over lands that are usually dry, such as roads, rivers, and lowlands, because the volume of water is greater than its drainage or storage capacity (Souissi et al., 2020; Rakuasa et al., 2022). Floods can occur due to a variety of factors, including heavy rains, high tides, levee leaks, or damage to drainage systems (Rakuasa et al., 2023). Floods can cause damage to property and infrastructure and put human and animal life at risk (Latue et al., 2023). Therefore, floods are often considered a serious natural disaster (Zeleňáková et al., 2019).

On September 16, 2021, high-intensity rains triggered an overflow of the Waegeren River's water discharge and the swift river currents caused flooding with a water level of up to 70 cm that hit five villages spread across two sub-districts, namely in Fena Leisela and Lolong Guba Districts. The five villages include Waelana Lana Village, Preparation Silewa, and Wamana Baru in Fena Leisela District, and Waegeren and Wabolen Villages in Lolongguba District. BPBD reported that as many as 237 families fled to safe places, such as the Wamana village office hall and the local prayer room. BPBD officers helped residents evacuate with rubber boats to a safe point. Apart from having an impact on residents, the flood also submerged 364 housing units, damaged water pipes, and submerged 6 residents' vehicles (BNPB, 2021).

Topographic Wetness Index (TWI) is a method for measuring the level of wetness or soil surface moisture in an area based on topographical characteristics (Nucifera & Putro, 2017). TWI is based on the calculation of the topographical index which includes the elevation and slope of an area (Berhanu & Bisrat, 2018 ; Muin et al., 2023). A higher TWI value indicates a higher humidity level in the area, while a lower TWI value indicates a drier area. TWI can be used in a variety of applications, including mapping flood-prone areas and watersheds, monitoring soil conditions for agricultural purposes, monitoring ecosystem conditions, and flood modeling (Rakuasa et al., 2023; Muin et al., 2023). Using TWI can help to identify flood-prone areas in Fena Leisela District, Buru Regency. Identifying and mapping flood-prone areas in Fena Leisela Subdistrict, it can help the government and the community in mitigating future disasters. This study aims to identify flood-prone areas using the topographic wetness index method in Fena Leisela District, Buru Regency.

2. RESEARCH METHOD

This research was conducted in Fena Leisela District, Buru Regency, Maluku Province. Visually, the research location can be seen in Figure 1. The data used includes the Indonesian Rupa Bumi Map (RBI) of Buru Regency Scale 1: 50,000, Indonesian Village Administrative Boundaries, National Digital Elevation Model (DEM) data obtained from the official website of the Indonesian Geospatial Information Agency, Ina-Geoportal: https://tanahair.indonesia.go.id/portal-web . The software used in this study is Arc GIS and Microsoft Office. The method used to analyze this study is the Topographic Wetness Index (TWI).

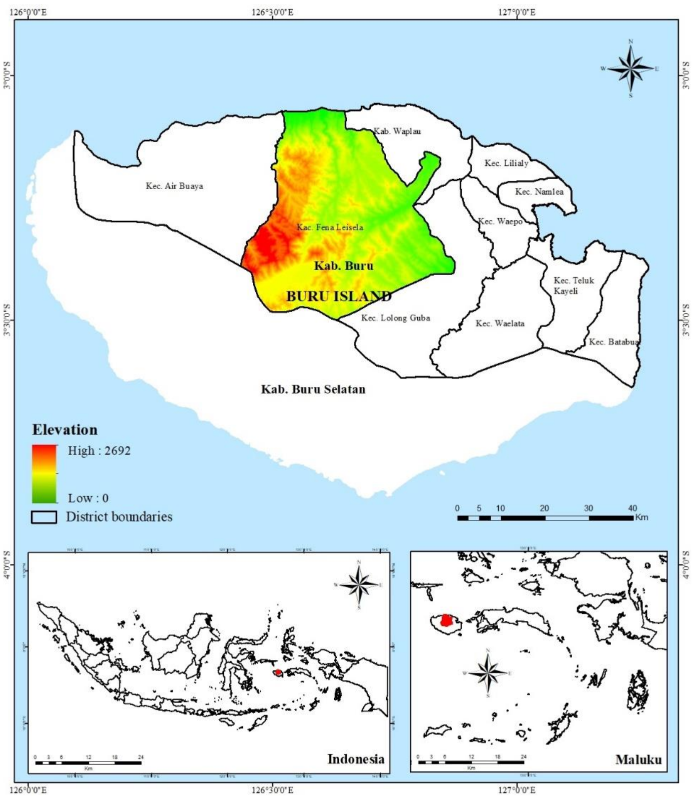

Figure 1. Research Locations

Topographic Wetness Index (TWI) was first developed by Beven and Kirby (1979) as part of runoff modeling. TWI assessed the effect of local topography on the resulting runoff (Pourali et al., 2016). TWI assessment can be widely used in modeling hydrological processes, biological processes, vegetation patterns, and forestry (Berhanu & Bisrat, 2018). Based on Beven and Kirby (1979), the main formula used in calculating TWI is as follows:

$$W = 1\text{n}\frac{a}{tan\text{ß}} \quad (1)$$

The W value is the wetness index where α is the accumulation of the upper slope that drains water at a point in each contour unit, while β is the slope angle at that point. This index describes the tendency of water to accumulate at one point based on gravity where water always flows to a lower place (Berhanu & Bisrat, 2018). In this case the water flows down the slope. Thus the index value will be greater on very flat slopes and vice versa the index value will be smaller on steep slopes (Buta et al., 2017). If an area accumulates water flow, the soil will become saturated with water. Water will stagnate because the soil pores are no longer able to hold water. Areas with high TWI values tend to be more prone to experiencing inundation flooding. Determination of flood-prone areas is based on the results of TWI calculations after normalization. TWI data normalization is done to facilitate data analysis. Normalization of the TWI value is carried out using the formula previously used by Nucifera & Putro, (2017), which is as follows:

$$Normalized\ TWI = \frac{a+(x-A)(b-a)}{(B-A)} \quad (2)$$

Value a = lowest normalized value, that is 0 b = highest normalized value, namely 1 x = TWI value A = lowest actual TWI value B = highest actual TWI value.

The greater the TWI value, the greater the potential for inundation to occur in an area (Pourali et al., 2016). Determination of inundated flood-prone areas is also associated with the presence of rivers. The results of the analysis of the TWI (Topographic Wetness Index) values are then classified into three classes of potential flood areas in the Fena Leisela District.

3. RESULTS AND DISCUSSIONS

The Spatial Distribution of TWI (Topographic Wetness Index) is a visual representation of the topographical humidity index in an area or region. The topographical moisture index describes the soil's ability to store and retain moisture, which can affect hydrological processes such as runoff, infiltration of water into the soil, and erosion (Pourali et al., 2016). The TWI value is determined based on the topography. The calculation of the TWI value is based on the elevation value in the DTM data. The maximum TWI value is 21.5756 and the minimum value is 2.71986. Normalization of TWI values is done to simplify analysis. TWI values are normalized to a 0-1 interval.

The level of potential flooding can be predicted using the Topographic Wetness Index (TWI), which is an indicator to estimate the ability of the land to hold water. TWI can be calculated based on the difference in elevation in an area and the level of rainfall in that area. The higher the TWI value, the higher the potential for flooding in that area. Areas with low TWI values usually have better drainage capabilities and less risk of flooding. In this case, TWI is used to measure the land's ability to hold water and then drain the water into a river or small river. Areas with high TWI values will likely have a greater amount of water and thus, be at higher risk of flooding.

Based on the results of the flood potential analysis using the Topographic Wetness Index (TWI) method in Fena Leisela District, the flood potential class is divided into three classes, namely the low potential class with an area of 92,196.09 or 63.04%, the medium class covering 45,769.48 ha or 31. 29% and a high potential class of 936.12 ha or 5.67%. In Table 1 it can be seen that Waemite Village is the village that has the least flood potential compared to other villages in Fena Leisela District, while Waelana-Lana and Wamana Baru are villages that have the highest flood potential in Fena Leisela District. Detailed levels of potential flooding per village can be seen in Table 1, and a map of potential flood inundation can be seen in Figure 2.

Table 1. Flood Hazard Area

No	Village	Flood Hazard Potential Area (ha)		
		Low	Medium	High
1	Balbalu	387,15	159,72	216,76
2	Fena Leisela	5.765,94	1.412,75	80,90
3	Lemanpoli	4.951,44	1.230,21	-
4	Raheriat	8.360,43	8.243,39	-
5	Waekose	566,39	475,75	653,59
6	Waelana-lana	11.680,33	5.425,20	3.291,78
7	Waemite	12.305,48	7.541,40	-
8	Waenibe	2.641,78	1.493,34	928,77
9	Waereman	8.509,10	4.405,41	-
10	Wamana Baru	7.660,04	4.931,61	1.349,33
11	Wamlana	14.811,98	4.199,77	841,18
12	Wasi	9.395,68	4.487,23	-
13	Waspait	51.60,34	1.763,71	936,12
Total		92.196,09	45.769,48	936,12

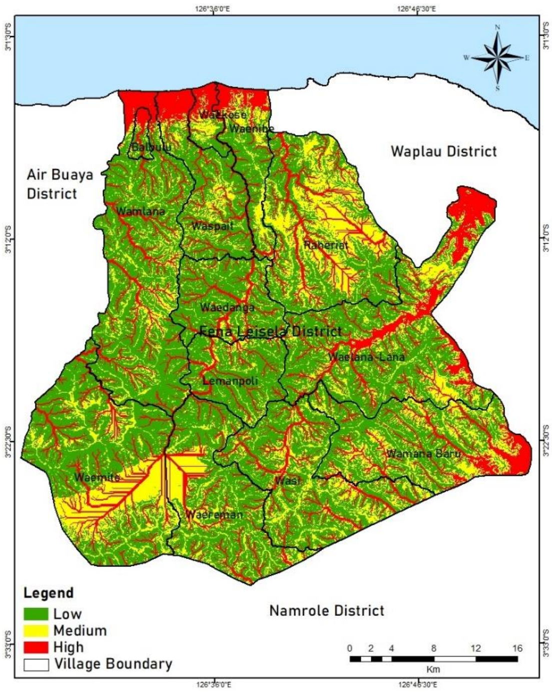

Figure 2. Flood Hazard Map in Fena Leisela District

Analysis of flood-prone areas using the Topographic Wetness Index (TWI) has several benefits including identification of flood-prone areas, regional development planning, management of water resources, disaster management and development of hydrological models. Berhanu & Bisrat, (2018), explained that using the Topographic Wetness Index (TWI) method can assist in flood disaster management, such as by predicting areas that will be affected by flooding and determining safe evacuation routes. TWI can be used in the development of hydrological models to predict water flow and river discharge in an area (Berhanu & Bisrat, 2018). By using TWI data, the hydrological model can provide more accurate information about the potential for flooding in Fena Leisela District.

4. CONCLUSION

The flood potential class in Fena Leisela District is divided into three classes, namely the low potential class with an area of 92,196.09 or 63.04%, the medium class covering 45,769.48 ha or 31.29% and the high potential class covering 936.12 ha or by 5.67%. The research results are expected to be a reference for the government and the community in handling future floods in Fena Leisela District, Buru Regency.

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