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Classification of Flood Disaster Risk Areas Using Vegetation Index Calculation and Landsat-8 Satellite Imagery in West Sumatra

M. Abhiel Laiths Qatadah
Department of Architecture
UPN "Veteran" Yogyakarta
Yogyakarta, Indonesia

Siti Zainab
Civil Engineering Department
UPN "Veteran" Jawa Timur
Surabaya, Indonesia

Abstract:- One of the Indonesian provinces most vulnerable to flooding catastrophes is West Sumatra. West Sumatra is a province that spans 98°36' to 101°53' East Longitude and 00°54' North Latitude to 03°30' South Latitude. Its total size is roughly 42,297.30 km², or 4,229,730 hectares, and it is surrounded by around 391 major and small islands. Flash floods and landslides have affected a number of regencies and cities in West Sumatra, including Agam Regency, Tanah Datar Regency, Padang Panjang City, Padang Pariaman Regency, and Padang City. The objective of this study is to use vegetation index estimates based on Landsat-8 satellite images to categorise flood catastrophe risk zones in West Sumatra. NDVI = -0.106 and NDWI = -0.03999, respectively, are examples of vegetation indices that define land as either non-vegetated or sparsely vegetated, and SAVI = 0.0002447 classify areas with water bodies such as rivers/floods.

***Keywords**:- Disaster Mitigation, Remote Sensing, NDVI, NDWI, SAVI.*

I. INTRODUCTION

One of the natural occurrences that commonly occurs around the world, especially in Indonesia, is flooding catastrophes. Floods pose a serious risk to human life and can result in large-scale material and intangible damages [1]. Thus, in regional planning and management, flood catastrophe management and risk mitigation are given top priority.

One of the Indonesian provinces that is susceptible to flooding catastrophes is West Sumatra. West Sumatra is a province that spans 98°36' to 101°53' East Longitude and 00°54' North Latitude to 03°30' South Latitude. Its total size is roughly 42,297.30 km², or 4,229,730 hectares, and it is surrounded by around 391 major and small islands. On Saturday, May 11, 2024, and Sunday, May 12, 2024, flash floods and landslides struck a number of regencies and cities in West Sumatra . In West Sumatra, Agam Regency, Tanah Datar Regency, Padang Panjang City, Padang Pariaman Regency, and Padang City are among the regions impacted by landslides and flash floods [1–3]. The primary determinants of flood frequency and intensity in this region are the diverse physical features, heavy precipitation, and land use changes. Under these circumstances, mapping locations at danger of flooding becomes essential to boost more efficient attempts at catastrophe mitigation and management [4].

Modern approaches to mapping and classifying flood risk areas utilize remote sensing technology and spatial analysis [5,6]. Landsat-8 satellite imagery, with its adequate temporal and spatial resolution, is an effective tool for observing land and vegetation changes. Vegetation plays an important role in reducing flood risk through its hydrological functions, such as absorbing rainwater and reducing surface runoff.

This study aims to classify flood disaster risk areas in West Sumatra using vegetation index calculations based on Landsat-8 satellite imagery. Vegetation indices, such as NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index), and SAVI (Soil Adjusted Vegetation Index), provide classifications for flood-affected areas . These indices offer information on vegetation health and density, which can further be used to identify areas vulnerable to flooding [7].

The steps in this research include the collection of Landsat-8 satellite imagery data, the calculation of vegetation indices, spatial analysis to identify flood risk areas, and verification of the results with historical flood event data [4]. It is hoped that the results of this study can make a tangible contribution to flood disaster risk planning and management in West Sumatra and can be applied to other regions with similar characteristics [8].

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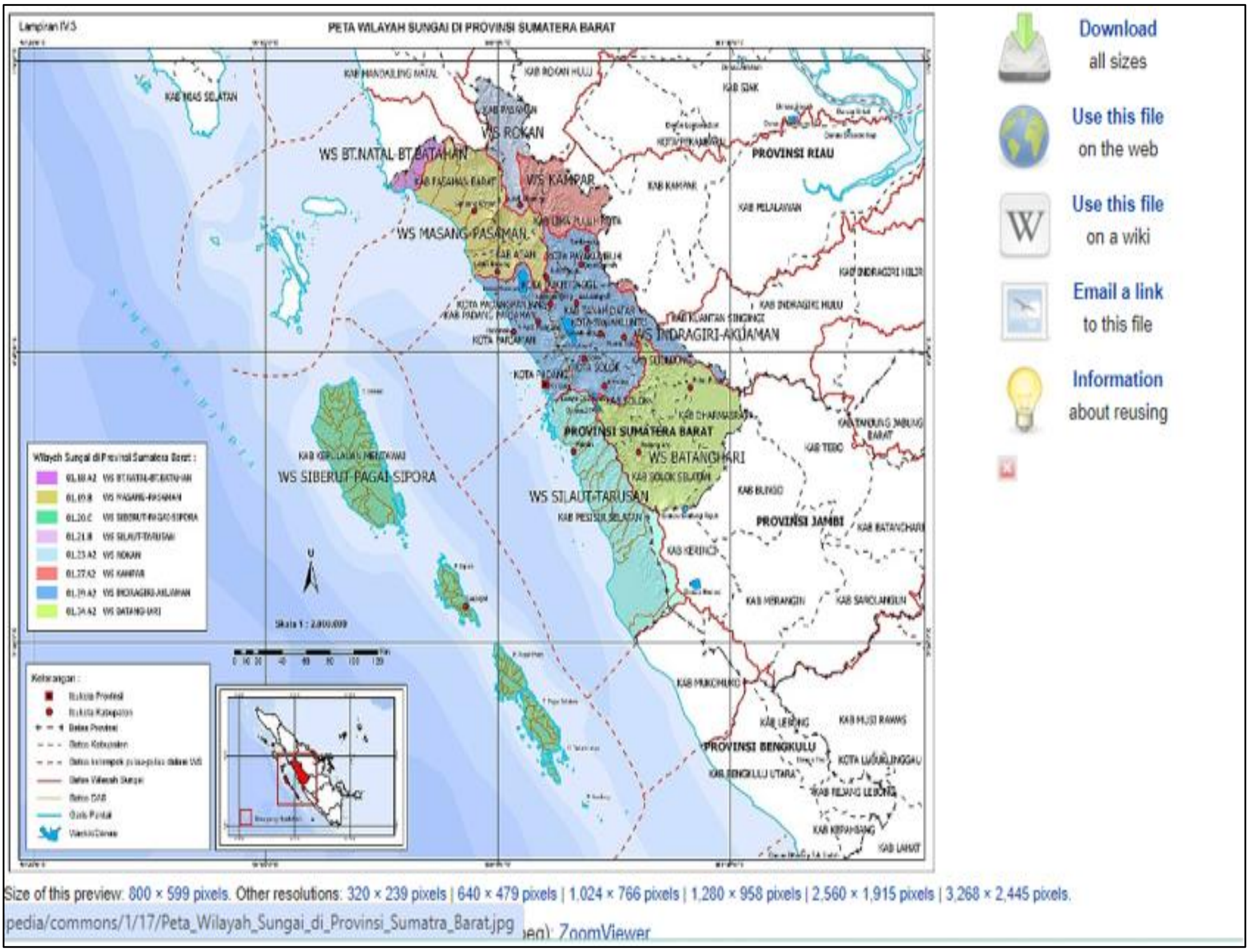

Fig 1: Position of West Sumatra affected by floods

II. LITERATURE REVIEW

A. Landsat-8 Satellite Imagery Data

Launched on February 11, 2013, Landsat 8 is an American Earth monitoring satellite. It is the seventh satellite in the Landsat programme to enter orbit and the eighth overall. Initially, NASA and the United States Geological Survey (USGS) collaborated on it under the name Landsat Data Continuity Mission (LDCM). Mission system engineering, development services, and launch vehicle procurement were handled by NASA's Goddard Space Flight Centre, while ground system development services and mission operations will be handled by the USGS [9].

The main contractor for the programme, Orbital Sciences Corporation, constructed the satellite. United Launch Alliance was tasked with launching the spacecraft, which included instruments constructed by Ball Aerospace and NASA's Goddard Space Flight Centre. LDCM was screened and verified by NASA during its first 108 days in orbit. On May 30, 2013, NASA handed over control of LDCM's activities to the USGS, and the spacecraft was formally dubbed Landsat 8.

Table 1: Orbital Parameters of the LDCM (Landsat-8) Satellite

Orbit	**Mendekati lingkaran sikron matahari**
Height	705 km
Inclination	98,2°
Period	99 mins
Recover Time (temporary resolution)	16 days
Time crossing phenomenon (localtime on descending node-LTDN) nominal	at 10.00 am s.d 10.15 am

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Table 2: Band Specifications on Landsat Image - 8 (OLI dan TIRS)

Kanal	Wavelength (micrometer)	Resolution (meter)
Channel 1 – Ultraviolet	0,43 - 0,45	30
Channel 2 – Blue	0,45 - 0,51	30
Channel 3 – Green	0,53 - 0,59	30
Channel 4 – Red	0,64 - 0,67	30
Channel 5 – Near Infrared (NIR)	0,85 - 0,88	30
Channel 6 – SWIR 1	1,57 - 1,65	30
Channel 7 – SWIR 2	2,11 – 2,29	30
Channel 8 – Panchromatic	0,50 - 0,68	15
Channel 9 – Sirrus (Thin Cloud)	1,36 - 1,38	30
Channel 10 – Hot Infrared (TIRS) 1	10,60 - 11,19	100
Channel 11 – Hot Infrared (TIRS) 2	11,50 – 12,51	100

Sumber: (USGS, 2014)

Table 3: Spectra Band Usage on Landsat-8 (OLI dan TIRS)

Channel	Wavelength	Data Usage
Channel 1 – Ultraviolet	0,43 - 0,45	Coastal research and aerosols.
Channel 2 – Blue	0,45 - 0,51	Batymetric mapping, distinguishing between soil with vegetation or seasonal trees and needle leaves..
Channel 3 – Green	0,53 - 0,59	Analisa pantulan puncak vegetasi yang bermanfaat untuk menilai kekuatan tumbuhan.
Channel 4 – Red	0,64 - 0,67	A reflection analysis of the peak of vegetation is useful to assess the strength of plants. Vegetation change analysis
Channel 5 – Near Infrared (NIR)	0,85 - 0,88	Biomass content and coastline analysis.
Channel 6 – SWIR 1	1,57 - 1,65	Better distinguish soil moisture and vegetation; able to penetrate thin clouds.
Channel 7 – SWIR 2	2,11 – 2,29	Better distinguish soil moisture and vegetation; able to penetrate thin clouds.
Channel 8 – Panchromatic	0,50 - 0,68	Spatial resolution with 15 m, sharpener record report.
Channel 9 – Sirrus (Thin Cloud)	1,36 - 1,38	Detection of sirrus cloud and contamination.
Channel 10 – Hot Infrared (TIRS) 1	10,60 - 11,19	100 m spatial resolution, temperature mapping and soil humidity estimates..
Channel 11 – Hot Infrared (TIRS) 2	11,50 – 12,51	100 m spatial resolution, temperature mapping and soil humidity estimates..

B. *Use of Spectral Bands on Landsat-8 (OLI and TIRS)*

This study uses Channels 3, 4 and 5.

➢ *Vegetation Index*

Based on digital signals of brightness values obtained from many satellite sensor data channels, the vegetation index depicts the degree of greenness of the vegetation [10]. The normalised difference vegetation index, or NDVI, is an algorithm that measures how green the vegetation is. It was utilised to examine vegetation for this investigation. For the purpose of classifying vegetation, NDVI can show the green leaf biomass parameter. Table 4 displays the NDVI categorization.

Table 4: NDVI Classification

Class	NDVI Value	Green Level	Density Level
1	-1<NDVI<-0,03	The land is not vegetated	-
2	-0,03<NDVI<0,15	Very low vegetation	-
3	0,16<NDVI<0,25	low vegetation	Seldom <1000
4	0,26<NDVI<0,35	Moderate vegetation	Currently <1000 -<1500 Tree
5	0,36<NDVI<1	High vegetation	Heavy > 1500 Tree

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Formula NDVI = $\frac{NIR - RED}{NIR + RED}$ (1)

Where,
NIR = Infrared channel reflectance value (band 5)
RED = Red channel reflectance value (band 4)

NDVI values range from -1 to 1. For areas where the vegetation index is below 0.3, they are classified as non-vegetated. Areas with values above 0.3 are considered to have dense vegetation.

Table 5: NDVI Classification

No.	Classification	NDVI Value
1.	< = 20% (Very Rarely)	NDVI > 0,01 - 0,18
2.	21, 40% (Rare)	NDVI 0,18 to 0,32
3.	41, 60% (Moderate)	NDVI 0,32 to 0,424
4.	61, 80% (Thick)	NDVI 0,42 to 0,47

The Normalized Difference Water Index (NDWI) is an index used to detect the presence of water in satellite imagery. This index was first introduced by McFeeters in 1996 to enhance the detection of water on the Earth's surface. NDWI utilizes the ratio of bands from the electromagnetic spectrum, specifically the green and NIR (Near-Infrared) bands, which have different reflectance characteristics for water, vegetation, and dry soil [11].

NDWI = $\sqrt{\frac{Green - NIR}{Green + NIR}}$ ……………………(2)

Where as:

NIR = Value of Red Infrared Channel Reflector (Band 5)
GREEN = Value of Red Red Channel Reflector (Band 3)

NDWI classification is often used to distinguish between areas that contain water and those that do not. Here is an example of common classification based on NDWI values:

- Water: NDWI > 0.3
- Wet soil or vegetation with high water content: 0.1 < NDWI ≤ 0.3
- Vegetation: -0.1 < NDWI ≤ 0.1
- Dry soil or urban areas: NDWI ≤ -0.1

Soil Adjusted Vegetation Index (SAVI) is an algorithm derived from NDVI with the principle of accounting for background soil brightness at the canopy level. Table 5 explains the classification of SAVI values based on the type of Green Open Space (GOS). The formula for SAVI is as follows on the Table 5.

Table 5: Classification of SAVI Value, Density and Type of Green Free Space

Class	Density	Types Green Free Space
-0,3667 to 0,0187	Non Green Free Space	Water bodies such as rivers, etc.
0,0187 to 0,1041	Very Low	Residential open land covered with asphalt or paving, as well as asphalt roads
0,1041 to 0,3667	Low	Vegetated land cover,such as dirt road, vacant load,not cover with asphalt with Paving
0,3667 to 0,5214	Moderet	Vegetated land cover such as coconut plantations, mixed gardens, reclamation vegetation, golf courses, or weeds
0,5214 to 0,7895	High	Forest vegetation

The Landsat 8 image data used consisted of bands 4 and 5, covering the period from 2022 to 2024, each at its peak before and after the flood event. Subsequently, data processing was performed, including atmospheric correction of the image data and cropping it according to the research area. Next, exploration of vegetation index data such as NDVI, NDWI, and SAVI was conducted. After obtaining the vegetation index results, the research stages can be seen in the Figure 2.

III. METHODOLOGY

The Landsat-8 imagery data was collected from the website link: https://ocean color.gsfc.nasagov/cgi/browes.pl. with the choosen time collected data is April 2024

➢ *The Data of Landsat-8 Imagery Satellite Data Since 2022 to 2024 was Showed:*

LC09_L1TP_127061_20240412_20240412_02_T1_B3
LC09_L1TP_127061_20240412_20240412_02_T1_B4
LC09_L1TP_127061_20240412_20240412_02_T1_B5
LC08_L1TP_128061_20230612_20230614_02_T2_B3
LC09_L1TP_128061_20231205_20231209_02_T1_B4
LC08_L1TP_128061_20231205_20231209_02_T1_B5
LC08_L1TP_128060_20221202_20221212_02_T2_B3
LC08_L1TP_128060_20221202_20221212_02_T2_B4
LC08_L1TP_128060_20221202_20221212_02_T2_B5

Next, the image data above is pinned to obtain the digital number values, which are then converted to obtain the reflectance values for bands 3, 4, and 5 for each Landsat 8 image from 2022-2024 using the following formula:

Reflectan = (Digital Number x 0,00002) – 0,1

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➢ *The Next Step is to Calculate the NDVI Value Using the Formula Below:*

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}} \quad (3)$$

Where:
NIR = Reflectan of infrared channel value (band 5)
RED = Reflectan of red channel (band 4)

Analyzing the NDVI, NDWI, and SAVI values from 2022 to 2024, conducting statistical tests, and performing ANOVA tests on NDVI values from 2022 to 2024.

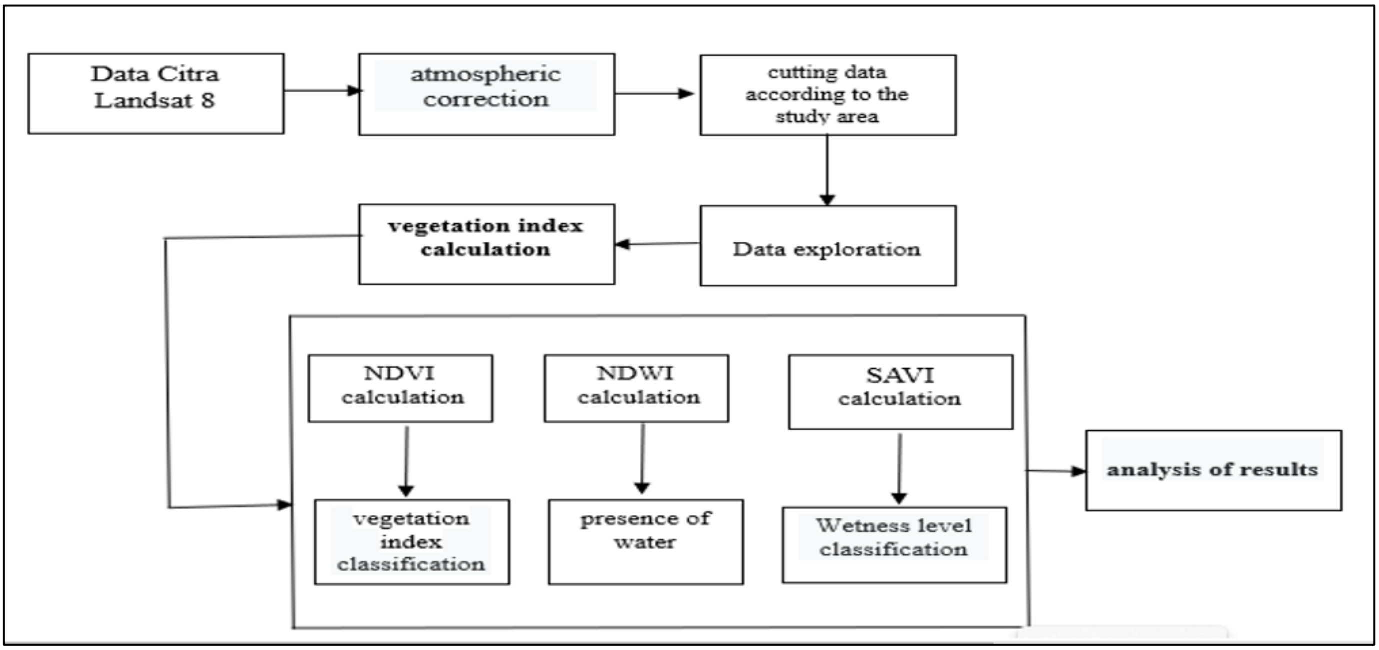

Fig 2: Flowchart of Research

The next step is to calculate the NDWI and SAVI values using the formula below:

$$\text{NDWI} = \frac{\text{Green - NIR}}{\text{Green + NIR}} \quad (4)$$

Where is :
NIR = Reflectan of infrared channel value (band 5)
GREEN = Reflectan of red channel (band 3)

$$\text{SAVI} = \frac{1{,}5*(NIR-RED)}{(NIR+RED)*0.5} \quad (5)$$

Where:
NIR = Reflectan of infrared channel value (band 5)
RED = Reflectan of red channel (band 3)

IV. ANALYSIS AND DISCUSSION

Throughout the years 2022, 2023, and 2024, circumstances before and after flood occurrences are detected using Landsat 8 data. This is used as reference information to assess the state of the Soil Adjusted Vegetation Index (SAVI), Normalised Difference Water Index (NDWI), and Normalised Difference Vegetation Index (NDVI) vegetation indices [3,4].

Table 6: NDVI, NDWI dan SAVI Value

YEAR	NDVI	NDWI	SAVI
2022	0,041	-0,03999	0,0002447
2023	-0,158	-0,196221	0,1593645
2024	-0,106	-0,157991	0,1226655

The NDVI values from 2022 to 2024 range from very low to non-vegetated land. Moderate wetness, if the NDWI Vegetation value is $-0.1 < \text{NDWI} \leq 0.1$, then the area is classified as having a high wetness level of the water surface. If the NDWI value is less than or equal to zero, it is not considered a water surface [12]. The Soil Adjusted Vegetation Index (SAVI) is an algorithm developed from NDVI with the principle of accounting for background soil brightness at the canopy level. Table 4 explains the classification of SAVI values based on the type of Green Open Space (GOS). The formula for SAVI is as follows equation 5.

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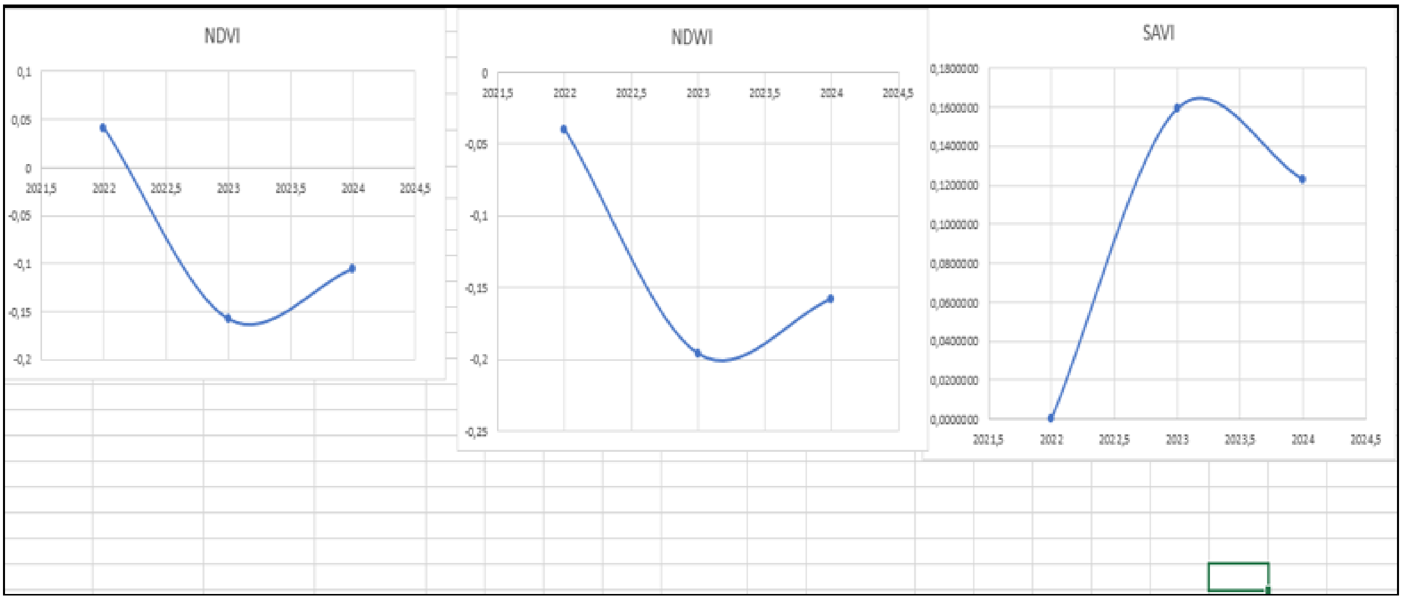

Fig 4: NDVI, NDWI, SAVI Graphics

The results of this study show that the NDVI value of 0.041 classifies the area as moderately vegetated land in 2022 before the flood, as seen in the thematic map difference in Figure 6, indicating a difference in vegetation density classification. In 2023, the NDVI value of -0.158 classifies the area as low vegetation land, and the NDVI value of -0.106 classifies it as low vegetation land after the flood in April 2024.

Meanwhile, the NDWI value of -0.03999 in 2022 before the flood classifies the area as moderately vegetated land. In 2023, the NDWI value of -0.196221 classifies it as dry or urban land, and the NDWI value of -0.157991 classifies it as dry or urban land (urban area) after the flood in April 2024 [7].

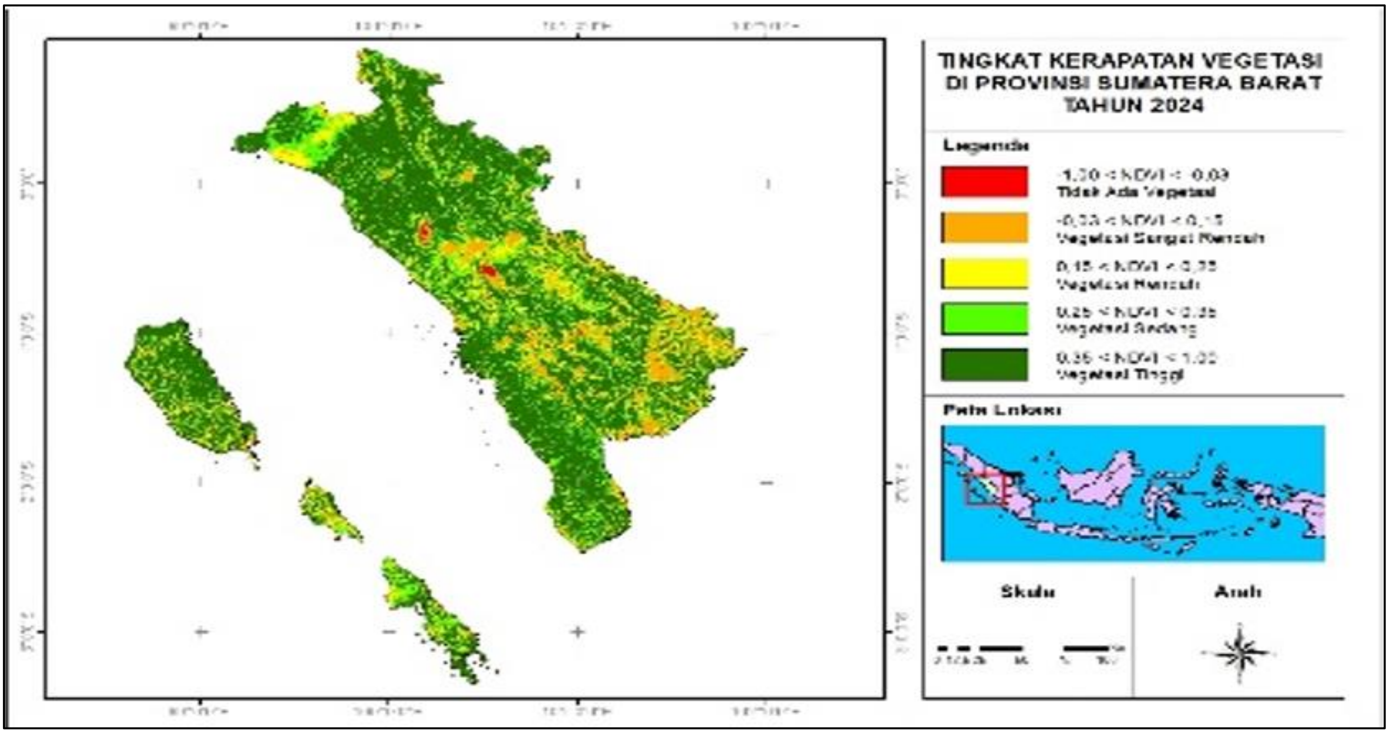

Fig 6: Thematic Map of NDVI from 2022 to 2024

The Soil Adjusted Vegetation Index (SAVI) is an algorithm derived from NDVI with the principle of accounting for background soil brightness at the canopy level. The SAVI value in 2022 was 0.00022447, classifying the area as vegetated land. In 2023, the SAVI value was 0.1593645, and in 2024, the SAVI value was 0.1226655, classifying the area as ground cover such as dirt roads, vacant lots, without asphalt or paving, and indicating the presence of water bodies like rivers or floods.

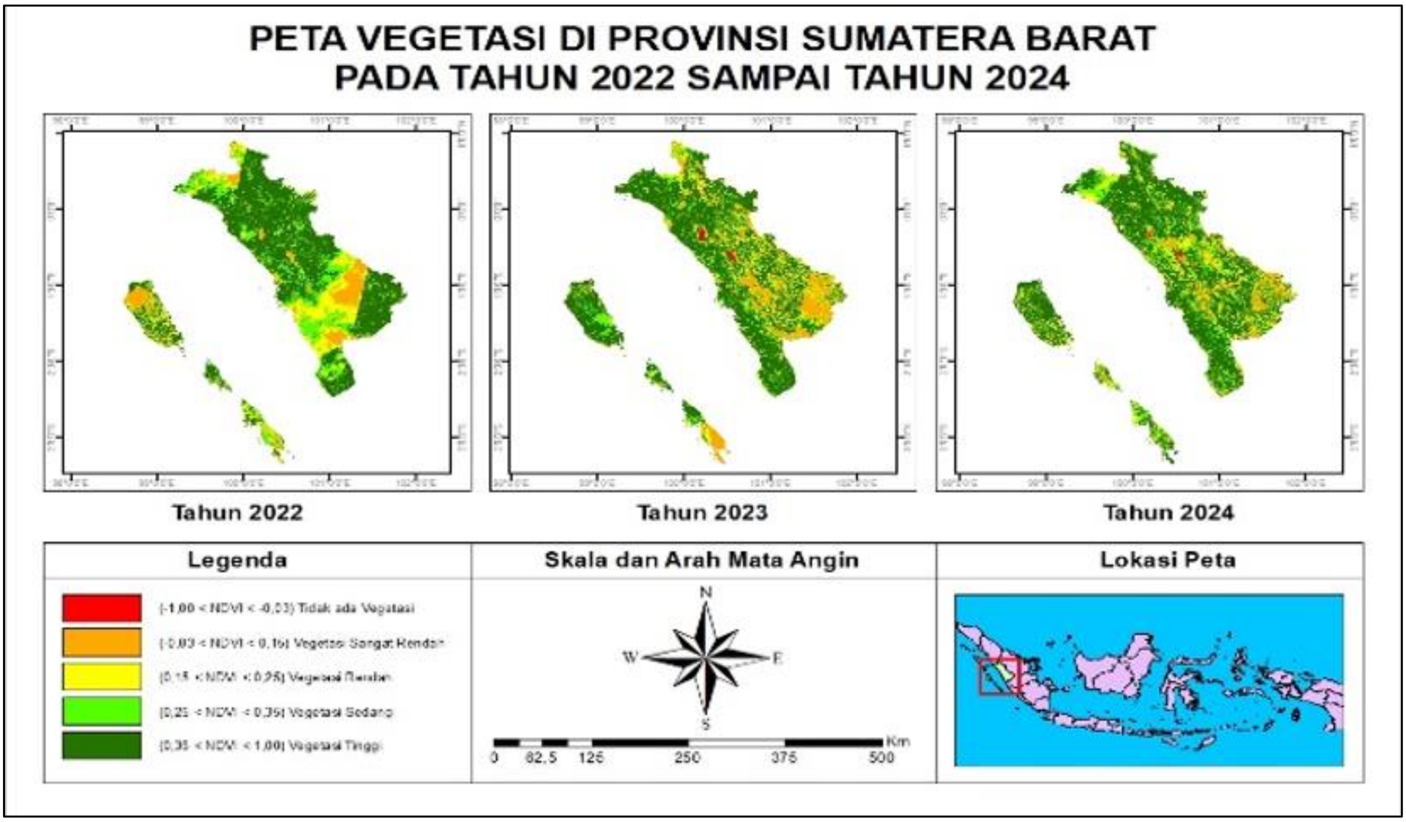

Fig 7: Thematic Map of NDVI for 2024

V. CONCLUSION

The NDVI calculations indicate that the vegetation in the affected area shows a significant change in greenness following the flood in West Sumatra. The greenness decreased significantly. The NDWI value of -0.157991 classifies the area as dry or urban land. The SAVI calculation results show that after the flood in 2024, the SAVI value was 0.0002447, indicating the presence of water bodies such as rivers or seas, corresponding to the flood-affected locations.

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