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Remote Sensing Techniques for Identifying Flood Prone Areas Using the Vegetation Index, Water Index, and Simple Additive Weighting Methods for Mekarsari Areas, Cianjur Regency, West Java

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Abstract
Flood is a natural disaster with an intensity that often occurs in cities on a scale with excess water discharge in some areas. This research was conducted to determine the risk of flooding in Mekarsari Village and its surroundings, Cianjur Regency, West Java. (According to InaRisk, 2022) Risk and danger of flooding Moderate – High. This study uses data for the entire year 2022. With several parameters used in this study including land cover, rainfall, soil type, slope, NDVI, NDWI and SAVI. Simple Additive Weighting or weighting for each parameter with different results, according to the classification of each of these parameters. The results of this weighting will become a Flood Hazard Risk Map which was previously the result of overlay and intersection of land cover map, rainfall map, soil type map, slope map, Normalized Difference Vegetation Index map, Normalized Difference Water Index map and Soil Adjusted Vegetation Index map. On the Flood Disaster Risk Map there are five categories of vulnerability levels Not Hazardous, Less Hazardous, Moderate, Hazardous and Very Hazardous. The cause of the risk of flooding in the study area is that most of the land use is diverted to rice fields, plantations, dry agricultural land and settlements so that the lack of vacant land causes low absorption of rainwater and also steep slopes and high elevations which also cause rainwater to be stored in the lowlands. settlements) with moderate to high rainfall intensity every month. There is also a lack of education for the community to mitigate the risk of flood disasters so that waste management and waterways in settlements are inadequate and well managed.

1. Introduction

This method is used to determine the potential location prone to flooding, with the scoring method or weighting (Simple Additive Weighting) with seven parameters such as Land Cover, Rainfall, Soil Type, Slope Slope, Normalized Difference Vegetation Index, Normalized Difference Water Index and Soil Adjusted Vegetation Index with the output being a parameter in determining the level of flood risk vulnerability in Mekarsari Village and its surroundings.

In its vicinity, the physiographic zone of the research area is included in the Bogor Zone [1]. The structural pattern on Java Island according to [2] there are three main structural stress direction patterns, namely the Meratus Pattern with the northeast-southwest assertion direction, the Sunda Pattern with the north-south assertion direction and the Java Pattern with the east-west assertive direction. In the research area, the pattern of structural assertion is included in the Java Pattern.

Stratigraphy in the research area, according [3] with the formation of the research area as follows: Jatiluhur Formation Member Marl and Quartz Sandstone (Mdm) with lithology of Sandstone and Shalestone, Cantayan Formation Member of Breksi (Mttb) with lithology of Breccia and Sandstone, Cantayan Formation Member of Clay (Mttc) with lithology of Tuffaceous Shalestone, Batuserpih and Claystone. Then there is also a rock unit, namely the Old Yield Volcano Unit (Qot) consisting of Early Pleistocene Breccia lithology (Figure 1).

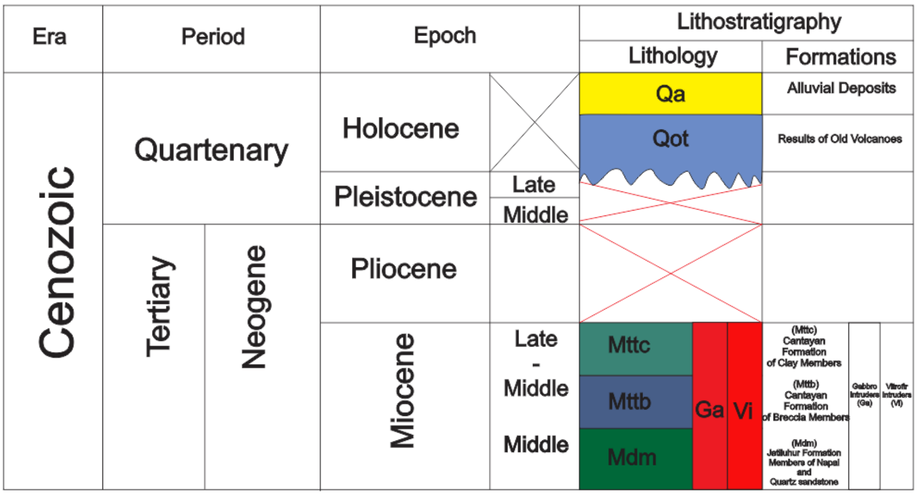

Figure 1. Stratigraphic column of the research area (modification of [3])

Flooding occurs due to 1) the process of overflowing river water caused by river water discharge that exceeds the carrying capacity of rivers with high rainfall intensity, 2) puddles with elevation or flat lowlands are usually not inundated by large amounts of water. Generally, floods occur due to high rainfall intensity, water drainage systems (rivers, river saplings, drainage canal systems and canals) are unable to cross the amount of accumulation in water so that it overflows. In the capacity of this water drainage system not every region is the same, this is also influenced by the geological conditions of the region, anthropogenic (influence by humans) causing narrowing of river bodies and other factors.

One of the main factors that also causes floods is lack of knowledge, preparedness and prevention of disasters. This mitigation is very useful to provide knowledge to the people of Mekarsari village and its surroundings as information for flood disaster management in order to reduce the impact of causes and damage to regional floods. Community empowerment is one of the activities that increase community understanding to prevent disasters either before or after the disaster occurs.

Remote sensing is the science of obtaining information on objects, regions and phenomena through data analysis using tools without direct contact. Remote sensing data is the result of recording the interaction of the transmission and reflection between electromagnetic energy and objects recorded by sensors or devices such as cameras, scanners, radar, thermal, ultraviolet and radiometry equipped with detectors in it.

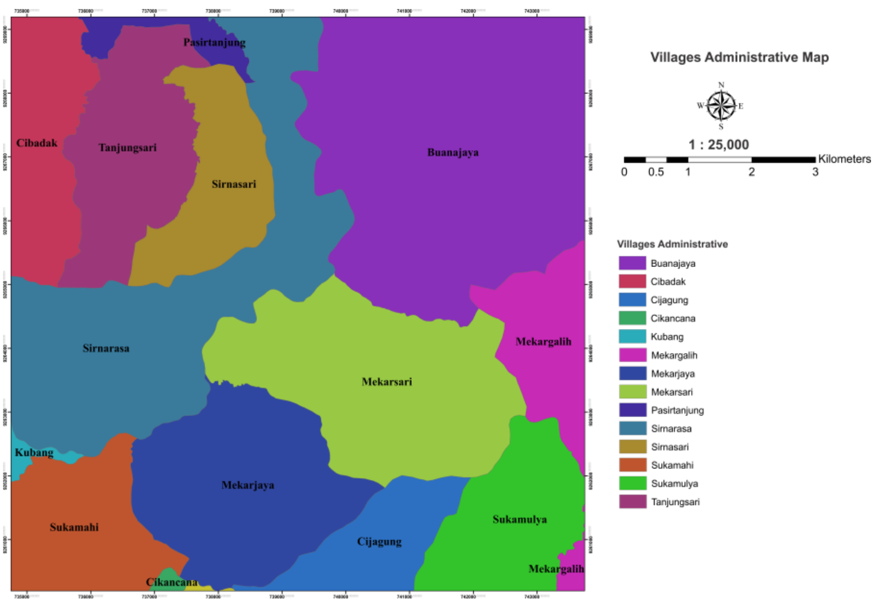

Figure 2. Map of Village Administration of the research area

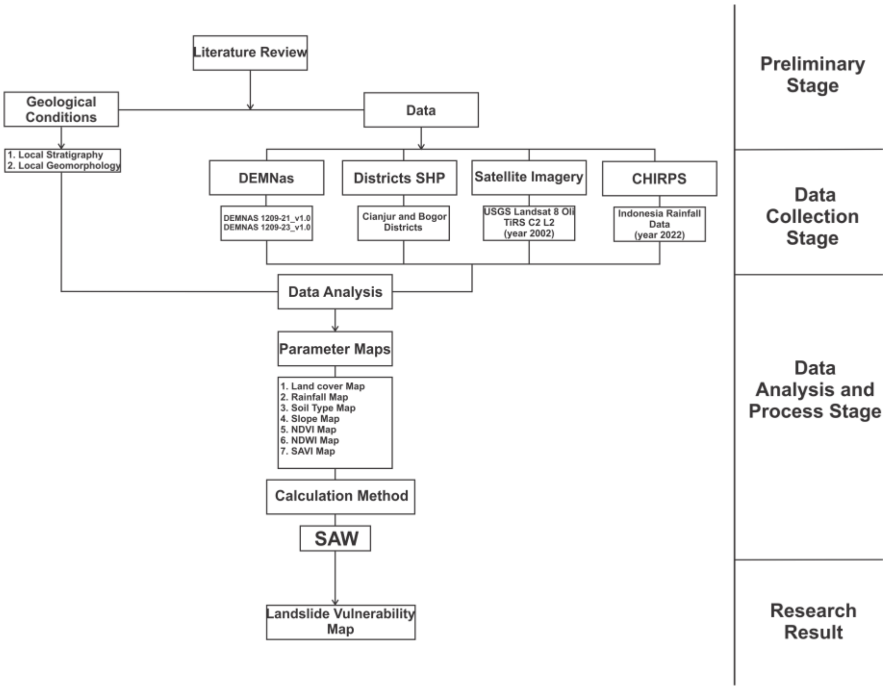

Figure 3. Research Method Flowchart

2. Methodology

2.1 Research Site

The location in the research area is in the Mekarsari area and its surroundings, Cianjur Regency, West Java. The research area is 9x9 km² or 81 km², with coordinates 6°49′16"S 107°08′24"E. The research area is divided into several parts of villages such as Mekarsari Village, Mekarjaya Village, Mekargalih Village, Buanajaya Village, Cibadak Village, Cicorn Village, Cikancana Village, Kubang Village, Pasirtanjung Village, Sirnarasa Village, Sukamahi Village and Tanjungsari Village. With village administration map of research area.

2.2 Research Materials and Tools

This research is in the form of spatial and digital data using DEMNas data from Cianjur Regency and Bogor Regency with series DEMNAS_1209-21_v1.0 and DEMNAS_1209-23_v1.0, SHP Cianjur Regency and Bogor Regency, Landsat 8 OLI/TIRS L2 C2 Imagery and Indonesian rainfall data CHIRPS. Next, process the data using GlobalMapper and ArcGIS 10.3 applications.

2.3 Research Method

Such as the preliminary stage, the data collection stage and the data analysis and processing stage. The method in this study also uses parameter data such as NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index), SAVI (Soil Adjusted Vegetation Index), rainfall maps and land cover maps. Stages of research flow diagram Figure 3.

Table 1. Land Cover Classifications, Source: [6]

Classification	Value
Plantation Forest	1
Secondary Dry Land Forest	2
Dryland Agriculture	3
Mixed Dryland Farming	4
Plantation	5
Paddy	6
Settlements	7

Table 2. Rainfall Classifications, Source: [7]

Classification	Value
Very Wet	1
Wet	2
Moderate – Damp	3
Damp	4
Very Damp	5

2.3.1 Preliminary Stages

Preliminary stages of collecting information about research site studies, literature studies on geological information in the research area, journal studies on local flood-prone risks. The research area is located in Mekarsari Village and its surroundings, Cianjur Regency, West Java with a study area of 9x9 km² or 81 km².

2.3.2 Stages of Data Collection

Remote sensing, namely Landsat 8 image data with a time acquisition of August 18, 2022 sourced from the website https://www.usgs.gov/ The US Geological Survey (USGS), DEM and SHP data for Cianjur and Bogor regencies, the spatial data was obtained from websites based on https://tanahair.indonesia.go.id/demnas/ website, rainfall data obtained from the https://data.chc.ucsb.edu/products/CHIRPS-2.0/ website using Indonesian rainfall data with the acquisition time of 2022.

2.3.3 Stages of Data Analysis and Processing

At this stage, the analysis of the map parameter overlay results using the ArcGIS 10.3 application using the Simple Additive Weighting (SAW) method to become a flood-prone map output. Determination of weights for each thematic map based on considerations based on existing relevance data by referring to the possibility of each of the results of the flood weight affecting each geographical parameter using GIS analysis. Simple additive weighting (SAW) process of reference based on Ministry Regulations [4] from this weight the influence of map parameters on flood disasters. According to the parameters are given weighting based on the nature of the parameters themselves with dynamic factors. To get a score / total value, it is necessary to give a value and weight so that the multiplication between the two can produce a total value commonly called a score. The value of each parameter is the same, namely 1-5, while the weighting depends on the influence of each parameter that has the greatest factor in the level of flood vulnerability [5].

In the research area in Mekarsari Village and its surroundings, several parameters are needed such as slope, land cover or use, rainfall, soil type, NDVI, NDWI, and SAVI. From these parameters, it is used to determine the level of vulnerability from flood disasters using the simple additive weighting (SAW) method using the value factor of the parameter with the output of these parameters using classes according to their classification, if it has been determined, the factor of each value of the flood parameter will be known.

Table 3. Rainfall Classifications, Source: [9]

Classification	Value
Aluvial, Glei	1
Latosol	2
Mediterranean, *Brown Forest*	3
Andosol, Grumsol, Podsol	4
Regosol, Litosol, Organosols	5

Table 4 Rainfall Classifications, Source: [10]

Classification	Value
Flat	1
Gently Slope	2
Slopping	3
Moderately Steep	4
Steep	5
Very Steep	6

2.3.3.1 Land Cover

Land use can affect areas that are vulnerable to flood risks due to reduced catchment areas and the conservation of green open space as a cause of flooding. Land use allocated as settlements, mining, and others can cause the allocation of green open space to decrease. Then use the SAW method to perform value weights on slope classes, classification, and classified weighting (Table 1).

2.3.3.2 Rainfall

The effect of rainfall on the risk of flood disasters, if in areas with high risk of flooding, the intensity of river overflow and low water infiltration power is also influenced by high rainfall intensity. The classification of the amount of rainfall according to [7] with fixed weights referring to [8] can be seen in Table 3 as follows. Then using the SAW method to perform value weights on slope classes, classification and weighting are classified (Table. 2)

2.3.3.3 Soil Type

The susceptibility of soil to erosion is gauged using the parameters of soil erodibility. Research conducted by the Institute of Soil Research in Bogor has categorized levels of soil erodibility based on specific soil types. The erodibility of the soil is divided into three main classifications: High erodibility, which encompasses soil types such as regosol; Medium erodibility, which includes soil types like andosol, gley humus, mediterranean, and podzolic; and Low erodibility, featuring soil types such as alluvial, latosol, and grumosol. Further, the SAW (Simple Additive Weighting) method is employed to assign value weights to the slope classes, their subsequent classifications, and the derived weightings, as detailed in Table 3.

2.3.3.4 Slope

The slope is the appearance of the earth's surface that has a difference in height in each place. The slope of the slope indicates the magnitude of the angle of difference in height of a landform, which is usually expressed in units of percentage or degrees. One of the determining factors for flooding is seen from the slope level of the area affected by flooding. Then using the SAW method to perform value weights on slope classes, classification and weighting are classified (Table. 4)

2.3.3.5 Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) is an index used for the photosynthetic activity of vegetation with algorithms applied spatially to digital images, by looking at the level of greenness of vegetation. The image comes from near-infrared with infrared wave emittance with an index range of -1 to 1. If an index closed to 1 indicates an area of dense and dense vegetation, conversely an index closed to -1 indicates an area of lack of vegetation and a high concentration of water (likely covered by clouds). The NDVI method uses band 5 (NIR) and band 4 (Red). The NDVI formula is as follows. Then using the SAW method to perform value weights on slope classes, classification and weighting are classified (Table. 5)

$$NDVI = \frac{Float\ (Band\ 5 - Band\ 4)}{Float\ (Band\ 5 + Band\ 4)}$$

Table 5. NDVI Classifications, Source: [11]

Classification	Value
Low vegetation	1
Moderate vegetation	2
High Vegetation	3

Table 6. NDWI Classifications, Source: [11]

Classification	Value
Non-Badan Air	1
Moderate Wetness	2
High Wetness	3

2.3.3.6 Normalized Difference Water Index

The Normalized Difference Water Index (NDWI) is an index used to analyze wetness levels captured by satellite imagery. The NDWI method uses band 5 (NIR) and band 3 (Green) to assess the comparison of vegetation type and vegetation activity by limiting water bodies and moisture to the soil. With the NDWI formula as follows. Then using the SAW method to perform value weights on slope classes, classification and weighting are classified (Table. 6).

$$NDWI = \frac{Float\ (Band\ 5 - Band\ 3)}{Float\ (Band\ 5 + Band\ 3)}$$

2.3.3.7 Soil Adjusted Vegetation Index

Soil Adjusted Vegetation Index (SAVI) is a vegetation index that minimizes the influence of soil brightness by using soil brightness correction factors. This parameter is used in arid regions with fairly low crop coverage. This SAVI uses band 5 and band 4 following the SAVI formula. Then using the SAW method to perform value weights on slope classes, classification and weighting are classified (Table. 7).

$$SAVI = \frac{Float\ (Band\ 5 - Band\ 4)}{Float\ (Band\ 5 + Band\ 4\ + 0.5) * (1 + 0.5)}$$

3. Results and discussions

The results of the flood-prone map by looking at the level of flood vulnerability on several parameters such as Slope, Land Cover or Use, Rainfall, Soil Type, Normalized Difference Vegetation Index, Normalized Difference Water Index, and Soil Adjusted Vegetation Index.

3.1. Land Cover

Land cover analysis is essential for understanding the spatial distribution of various natural and anthropogenic features on Earth's surface. A significant resource for such studies is the SHP Land Cover dataset for Indonesia. While the dataset provides seven classifications, these have been refined and modified based on recommendations by [6]. These adapted categories include Plantation Forests represented in light green, highlighting areas designated for commercial forestry. The light brown shade denotes the Secondary Dryland Forest, indicating areas where forests have regenerated after the removal of primary forests. Dryland Agriculture, shown in dark green, marks areas used predominantly for rain-fed agricultural activities. In contrast, the bright green of Mixed Dryland Agriculture signifies regions with a variety of non-irrigated crops. Plantations are depicted in a more profound green shade, focusing on areas dedicated to single-crop cultivation such as palm oil. Rice Fields, represented in a standard green hue, characterize lands primarily utilized for rice cultivation through flooding. Lastly, areas of human habitation, ranging from urban centers to rural locales, are showcased in orange as Settlements. The visualization, known as Figure 4, offers a detailed perspective on the land cover types in the region, assisting multiple stakeholders in decoding Indonesia's land use patterns.

Table 7. SAVI Classifications, Source: [11]

Classification	Value
Non RTH	1
Very Low	2
Low	3
Moderate	4
High	5

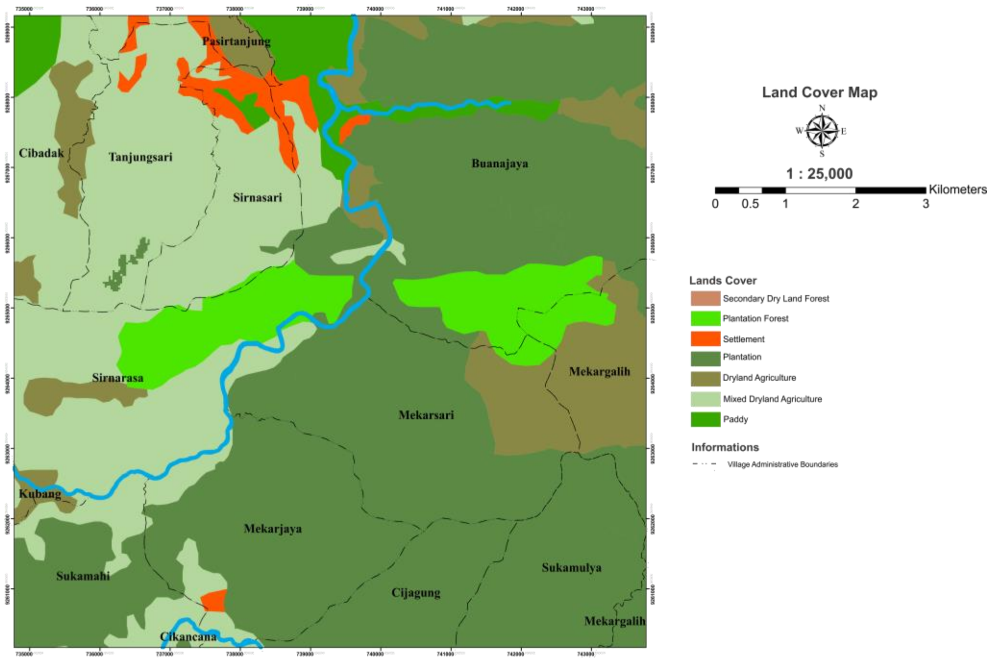

Figure 4. Land Cover Map

3.2. Rainfall

Rainfall is a pivotal parameter in environmental and hydrological studies. The accurate classification of rainfall data helps in making informed decisions for water resources management, agricultural practices, and even urban planning. As per the guidelines mentioned in [7], rainfall can be categorized into five distinct classifications. These classifications serve as a foundation to understand the precipitation patterns, offering insights into seasonal fluctuations, potential drought periods, and peak rainfall durations. The analysis of rainfall data for the year 2022 indicates that the region falls under the 'Moderate' or 'Moderately' category. This classification suggests that the region received a balanced amount of rainfall, which is neither too high nor too low. The said data, presented in Figure 5, provides a comprehensive visualization of the annual rainfall distribution, allowing researchers and policymakers to understand and assess the moisture and water availability scenario in the studied area.

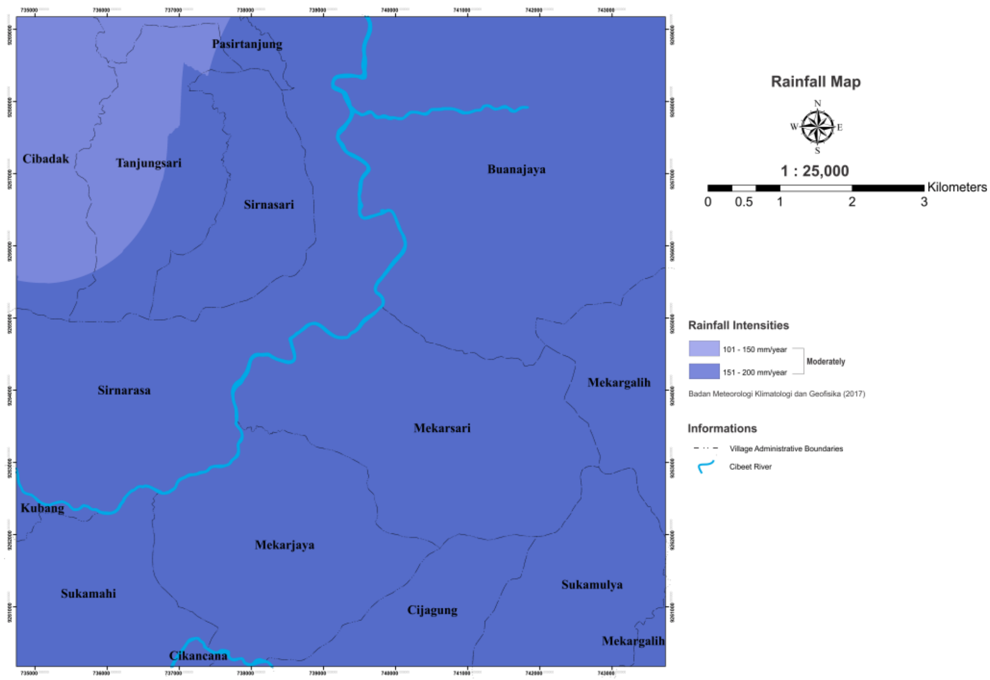

Figure 5. Rainfall Map

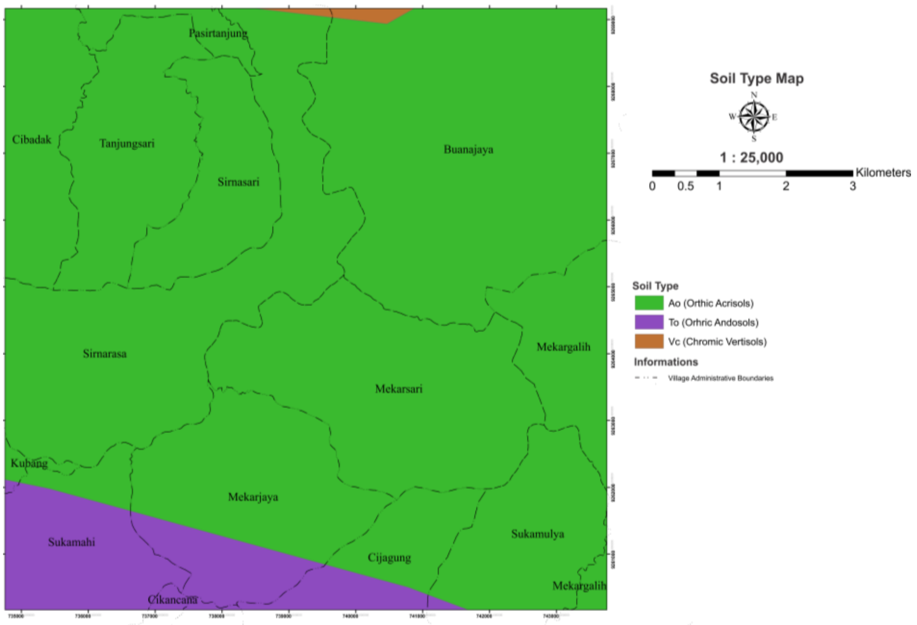

Figure 6. Soil Type Map

3.3. Soil Type

Soil classification is a critical component in understanding the characteristics and potentials of different land areas. Different soils offer varying attributes that determine their utility for agriculture, construction, and conservation. The study, as referenced in [9], categorizes soils into three primary classifications: Ao (Orthic Acriosols), To (Orhric Andosols), and Vc (Chromic Vertisols). Each of these classifications provides insights into the soil's properties, composition, and potential uses. For instance, Orthic Acriosols, represented by Ao, are characterized as being 'Very Sensitive.' This indicates that this type of soil may be more susceptible to environmental changes and might need more delicate handling or specific agricultural practices. On the other hand, Orhric Andosols (To) and Chromic Vertisols (Vc) fall under the 'Sensitive' sensitivity type. This suggests that while they are still susceptible to changes, they might offer a bit more resilience than the 'Very Sensitive' category. A comprehensive representation of these classifications and their sensitivity levels can be visualized in Figure 6. This visualization assists researchers, farmers, and land planners in making informed decisions based on the soil's inherent properties and sensitivities.

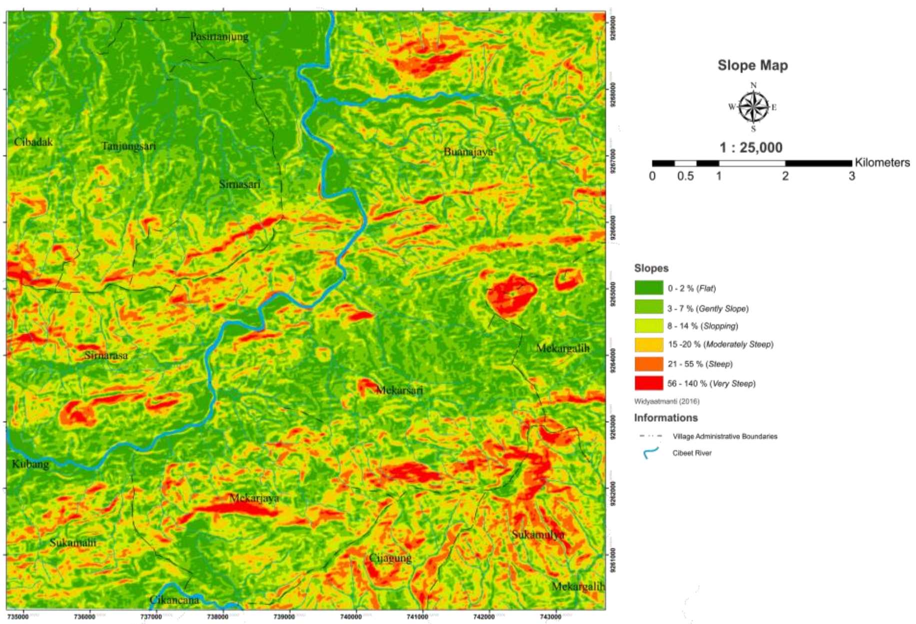

Figure 7. Slope Map

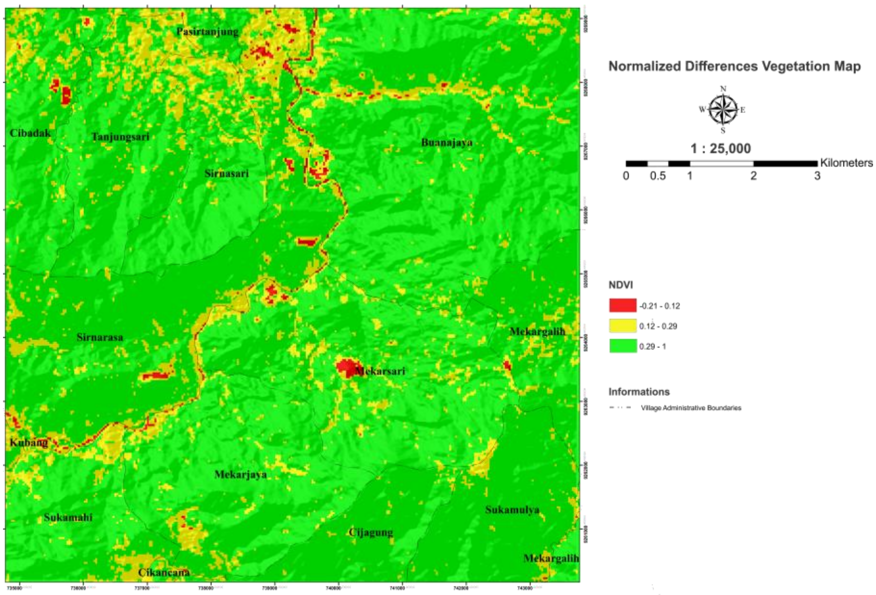

Figure 8. Normalized Difference Vegetation Index Map

3.4. Slope

Slope classification plays a pivotal role in various sectors, from civil engineering to agriculture, helping experts understand the topographical challenges and opportunities presented by a particular land area. According to the study cited in [10], there are six distinct classifications primarily defined based on the gradient percentage of slopes. Beginning with the flattest terrains, there are areas classified as 'Flat' which are represented by a green color and have a slope range of 0-2%. These areas are generally considered ideal for most construction and agricultural activities. Following this is the 'Gently Slope' category, highlighted in light green, which comprises slopes from 3-7%. As the gradient starts to increase, the next category is 'Sloping', which is illustrated in green-yellow and covers a slope range of 8-14%. Moving on to steeper terrains, 'Moderately Steep' terrains are indicated in yellow and have slopes ranging from 15-20%. Even steeper are areas categorized as 'Steep', shown in orange, with slopes from 21-55%. Lastly, the most challenging terrains to navigate are those that fall under the 'Very Steep' category, depicted in red, with slopes ranging from an impressive 56-140%. This detailed classification, visualized in Figure 7, provides vital insights for professionals across industries to make informed decisions based on the topographical nature of the land, ensuring optimal use and safety measures are adhered to.

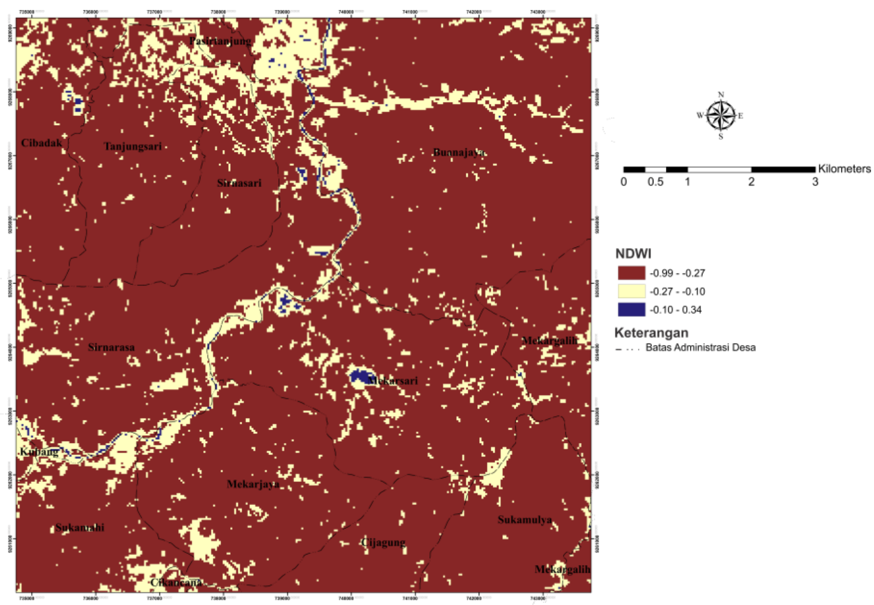

Figure 9. Normalized Difference Water Index Map

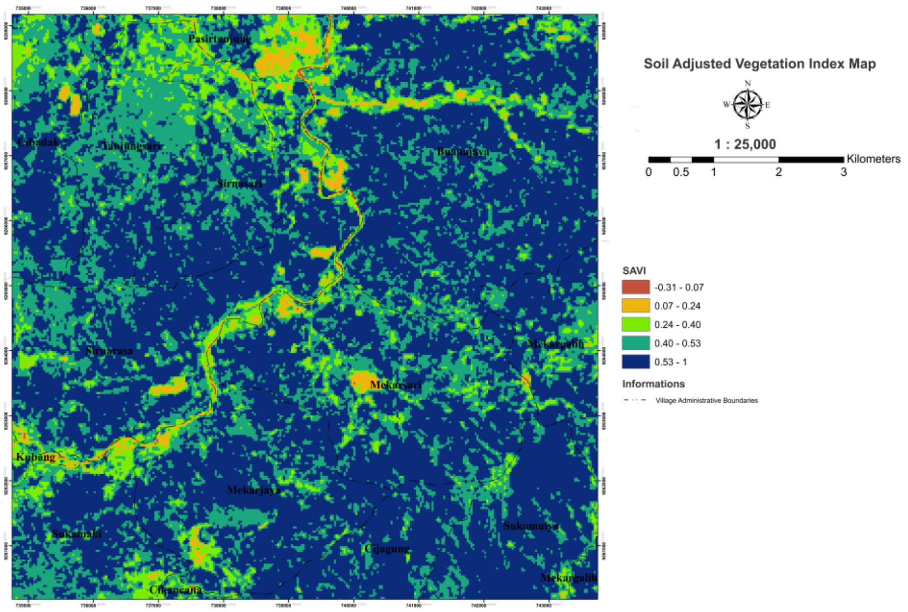

Figure 10. Soil Adjusted Vegetation Index Map

3.5. Normalized Difference Vegetation Index

The NDVI (Normalized Difference Vegetation Index) parameters offer a tiered classification system based on the study referenced in [11]. This system segments vegetation density into three distinct categories, providing insights into the health and density of the vegetation cover. The first category, termed 'Low Vegetation', is represented by a red color and encompasses NDVI values ranging from -0.21 to 0.12. This suggests regions with sparse or potentially stressed vegetation. Following this is the 'Medium Vegetation' category, signified by a yellow hue, which has NDVI values between 0.12 and 0.29, indicating areas with moderate vegetation density. Lastly, regions with the densest and potentially most robust vegetation fall under the 'High Vegetation' category. This category, depicted in green, boasts NDVI values from 0.29 up to 1. These classifications, visually detailed in Figure 8, are pivotal for professionals in environmental science, agriculture, and urban planning, helping them gauge the quality and density of vegetation in specific regions.

3.6. Normalized Difference Water Index

The NDWI (Normalized Difference Water Index) parameters employ a stratified classification system as per the findings documented in [11]. This classification provides a comprehensive assessment of the moisture content or water presence in a given area. Initially, regions that don't exhibit significant signs of water presence are classified under 'Non-Water Body'. This category is represented by a dark red color and encompasses NDWI values from -0.99 to -0.27, suggesting areas with minimal to no detectable moisture content. Progressing from there, areas exhibiting medium moisture levels are categorized as 'Medium Wetness'. Denoted by a cream hue, these regions register NDWI values between -0.27 and -0.10. Lastly, areas characterized by a high moisture content or pronounced water presence fall under the 'High Wetness' bracket. This category, visualized in dark blue, covers NDWI values ranging from -0.10 to 0.34. This classification, illustrated in Figure 9, serves as a crucial tool for hydrologists, environmentalists, and urban planners to accurately map and monitor the moisture content and water bodies within a specific landscape.

Table 8. SAVI Classifications, Source: [11]

Number	Classification	Area (Ha)	Area (%)
1	Not Prone	1042	12,86
2	Less Prone	1029	12,70
3	Moderately	2142	26,44
4	Prone	2963	36,58
5	Very Prone	924	11,42
	Amount	**8100**	**100%**

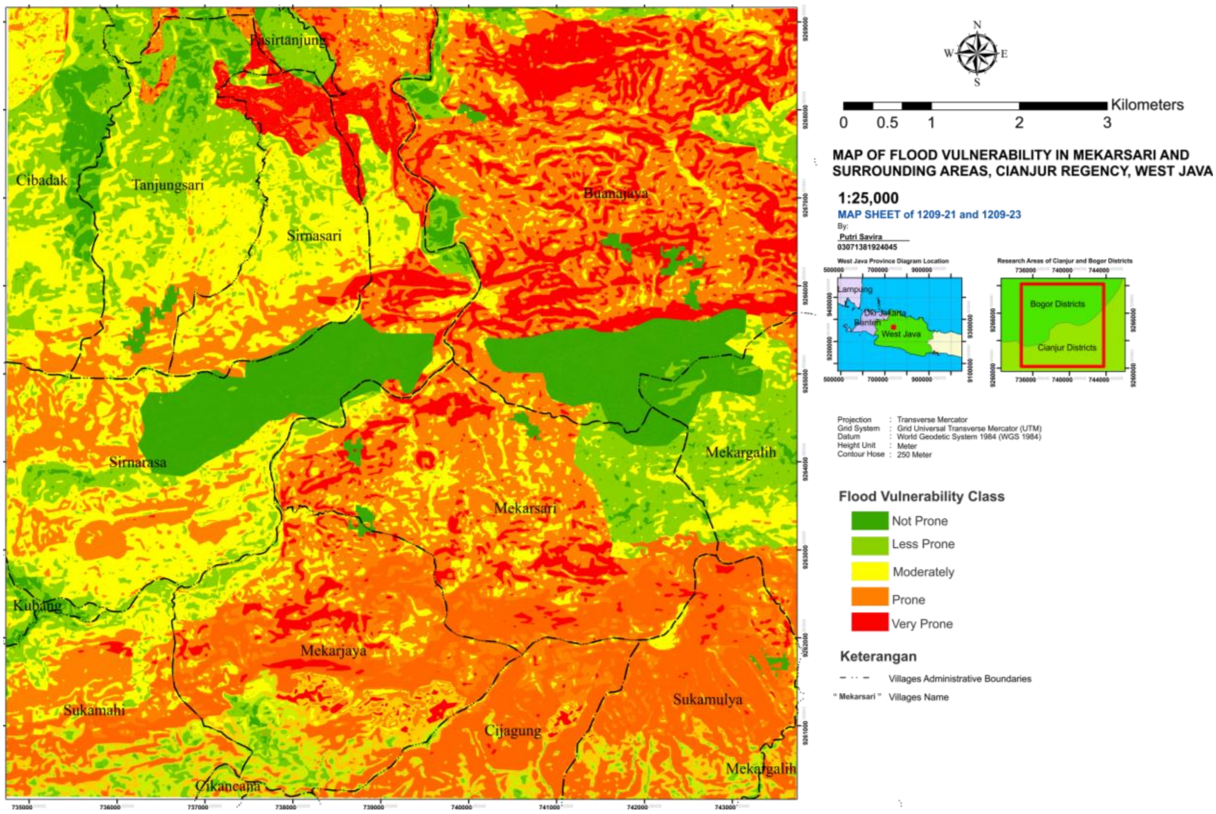

Figure 11. Map of Flood Vulnerability of Mekarsari Village and Areas

3.7. Soil Adjusted Vegetation Index

The SAVI (Soil-Adjusted Vegetation Index) parameters, as outlined in [11], have been methodically segmented into five distinct classifications to provide an in-depth understanding of the vegetation dynamics in the observed region. The 'Non-RTH' classification, denoted by the color red, captures areas that exhibit values ranging from -0.31 to 0.07. This classification primarily identifies regions with minimal or no vegetation presence. Advancing in vegetation density, we find the 'Very Low' category, represented in yellow, spanning values between 0.07 and 0.24. Following this, areas falling under the 'Low' classification, represented in green, encompass SAVI values between 0.24 and 0.40. These are regions with a moderate density of vegetation. Moving towards areas with denser vegetation, the 'Medium' category, depicted in light blue, covers values ranging from 0.40 to 0.53. Lastly, regions with the most abundant vegetation density fall under the 'High' bracket, characterized by a dark blue hue and covering SAVI values from 0.53 to 1. The systematic categorization, as depicted in Figure 10, offers a precise visualization of vegetation health and density, proving invaluable for environmental monitoring and conservation planning.

4. Flood Vulnerability Map

From the results of these parameters in the form of slope, land cover, rainfall, soil type, NDVI, NDWI, and SAVI. The level of flood vulnerability in the Mekarsari area and its surroundings can be scored on each parameter to determine the major influence on the risk of flood disasters, then from each data carried out the scoring process can determine the level of vulnerability of flood disaster risk.

Based on the total weight results of the seven parameters in the table above, a table will be obtained
The results of the level of flood risk vulnerability by overlaying data and also intersect on the seven maps using the level determinants of each parameter in determining the level of flood vulnerability that has been weighted. Then the final results are obtained in the form of a classification of the level of vulnerability of these parameters by looking at the extent of the level of flood vulnerability in Table 8 and the map results from the overlay can be seen in (Figure 11).

The results of the map of flood vulnerability in Mekarsari Village and its surroundings influenced by land use, namely plantations, dryland agriculture, rice fields, and settlements so that the drainage flow for water is less from the results of the water makes the river water tide and the flow of river water is heavy, there is also little open land or vacant land which causes also low absorption of rainwater with moderate to high monthly intensity of 100-200 mm/year. Because the slope of the Mekarsari and surrounding areas is predominantly tilted until steep with high contours the flow of water is less absorbed and can cause the flow of water to be accommodated in low or flat areas. The lack of public awareness of the consequences, impacts, and mitigation of flood disasters can cause people to be less disciplined and concerned about the dangers of flood disaster risks, therefore making this map one of the parameters of flood disaster mitigation so that people know that the area has the potential to be quite prone to flood disasters.

Conclusions

Based on the results of overlaying each parameter it becomes a flood disaster vulnerability map and also a representative analysis of these parameters which illustrates the state of the research area. Where there are solutions and conclusions from the results of the analysis of flood vulnerability problems in the study area can be concluded. Spatial analysis for flood data uses several parameters such as land cover, rainfall, soil type, slope, vegetation index (NDVI and SAVI), and water index (NDWI) using remote sensing techniques or GIS (Geospatial Information System). The results of the distribution of flood-prone areas are determined by scoring each parameter to be a reference for flood risk representatives, each parameter has a different weight value according to the representative of the state of the research area, then it will be processed on ArcGIS Intersect to be processed from the results of Overlay data to become a flood-prone map in the research area. Factors that cause flooding disasters in Mekarsari Village and its surroundings. Most land use is diverted to rice fields, plantations, dryland agriculture, and settlements so that the lack of vacant land causes low rainwater absorption also steep slopes and high elevations cause rainwater to be collected in lowlands (settlements) with moderate to high rainfall intensity every month. There is also a lack of education for the community to mitigate the risk of flooding disasters so waste processing and waterways in residential areas are inadequate and well- managed.

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