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Spatial Analysis Model For Landslide Detection Using Relative Different NDVI (rdNDVI) Method Thought The Google Earth Engine Platform (Case Study: Sukajaya District, Bogor Regency)

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ABSTRACT

This research utilizes the Google Earth Engine platform to detect landslides with relatively different NDVI (rdNDVI) methods. The purpose of the research is to improve our understanding of landslide analysis and detection, particularly those that occurred in Sukajaya district, Bogor Regency, Indonesia, on January 1, 2020. This research identifies vegetation changes associated with landslide likelihood using Sentinel-2A satellite image data available on Google Earth Engine. The results show that the rdNDVI method is effective in detecting landslides and can be used to determine areas that may be affected by landslides. This research also evaluates the accuracy of landslide detection by determining the threshold value to determine which areas are affected by landslides, by applying different slope values, the slopes used are slope 10, 15, 20, and 25. Comparing each slope results in a slope of 10 percent and a slope of 15 percent with 90% accuracy making the best accuracy compared to other slopes. The results of this research are expected to help the Regional Disaster Management Agency (BPBD) of Bogor Regency in managing landslides by conducting a careful and accurate analysis of areas that may be affected by landslides.

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1. INTRODUCTION

Indonesia has a very high risk of natural disasters due to its location in the ring of fire with high seismic and volcanic activity, as several tectonic plates interact with each other, such as the Eurasian, Indo-Australian, and Pacific plates. These results make it prone to natural disasters such as floods, extreme waves, land fires, droughts, extreme weather, earthquakes, tsunamis, volcanic eruptions, and landslides (Badan Nasional Penanggulangan Bencana, 2016). Landslides are one of the most common disasters. Landslides are the sudden movement of masses of soil, rock, or other material down a slope or hill. Landslides can be caused by heavy rain, earthquakes, volcanic activity, or human activity can cause landslides. (Tanesab et al., 2023).

According to the study data from the IRBI (Indonesian Disaster Risk Index) in 2021, especially in Bogor Regency is categorized as highly vulnerable to landslides with a score of 15.48. This is due to the geographical location in the highlands with mountains and hills around it (Adi et al., 2022). Based on data from the BPBD (Regional Disaster Management Agency) of Bogor Regency in January 2020, 63 landslides have occurred in 25 sub-districts, one of which occurred in the

Sukajaya sub-district, so it is necessary to take steps to handle areas vulnerable to landslides to reduce disaster risk (BPBD Kabupaten Bogor, 2021).

Landslide risk management requires in-depth studies for prevention as well as identifying areas affected by landslides. Landslide detection can be done through several methods such as direct observation, rainfall monitoring, seismic monitoring to identify vibrations and small earthquakes, as well as remote sensing methods commonly used in the field of disaster management (Wibowo, 2019) (Tjahjadi et al., 2015).

Remote sensing technology, can be used to obtain information about objects on the earth's surface with its utilization in various fields, one of which is the use in analyzing and mapping areas with landslide potential and those affected by landslides(Mazzanti & Romeo, 2023). The data source that can be utilized is the Sentinel 2-A satellite image. The advantage of Sentinel-2A is that the multispectral sensor has a resolution of 10 meters and a temporal of 5 days which can be accessed on Google Earth Engine (GEE) (Lasaponara et al., 2022). GEE is used to analyze remote sensing data that offers tools to calculate vegetation indices and others, using GEE can facilitate the research process for data and information availability constraints (Mutanga & Kumar, 2019).

Based on previous research using remote sensing data to monitor natural disaster hazards such as landslides with the greenest pixel composite technique using the Relative Different NDVI (rdNDVI) method to calculate relative changes resulting in NDVI values (Wen & Teo, 2022). Another study mentioned that NDVI and geomorphological filters were very effective in detecting landslides in the two valley regions of Tanarello and Gavi. In the Tanarello and Arroscia valleys, it detected 80% of landslide cases, which represented 37% of the total cases, while in the Gavi region, it detected about 80% of landslide cases, which represented 43% to 49% of the total cases. Overall, the results show that the method is effective in detecting potential landslides (Notti et al., 2022). The advantage of the relative different NDVI (rdNDVI) method is that it allows rapid change detection by comparing NDVI values and thus has a strong correlation between before and after NDVI. A significant and rapid decrease in NDVI values may indicate an avalanche (Scheip & Wegmann, 2021).

This research utilizes the rdNDVI method, this method shows the relative change in NDVI values over time which can be used to detect changes in vegetation, the relative difference can indicate whether the vegetation density in an area is increasing or decreasing (Sajadi et al., 2021). The research is expected to greatly contribute to the disaster management process, especially landslides, by assisting the Regional Disaster Management Agency (BPBD) of Bogor Regency in analyzing potential landslide-prone areas and mapping landslide vulnerability. With this research, the evacuation and mitigation process is earlier and faster, so it can help BPBD in natural disaster management, especially landslides.

2. METHOD

2.1. Time And Locations

This study aims to improve our understanding of landslide detection analysis through Remote Sensing and Geographic Information System (GIS) technology that is more efficient in detecting landslides so that the process is much faster than conventional so that emergency decision-making in disaster mitigation especially landslides is much faster.

The landslide event that occurred on January 1, 2020, is the background of this research to study the changes and development of geographical conditions that may be related to the event, with a comprehensive research time starting from March 2023 to July 2023. It is hoped that this study will help us understand the dynamics of landslides that are likely to occur in the future.

This study considers the Sukajaya District, one of the areas in Bogor Regency, West Java, Indonesia. This research location is not randomly selected, this area is considered to be very relevant to the chosen research topic, because there was a landslide disaster event in early 2020. This research aims to learn more about the impacts that have occurred in the aftermath of landslides, as well as to compare which areas are most impacted by landslides consisting of 11 villages at the Sukajaya District.

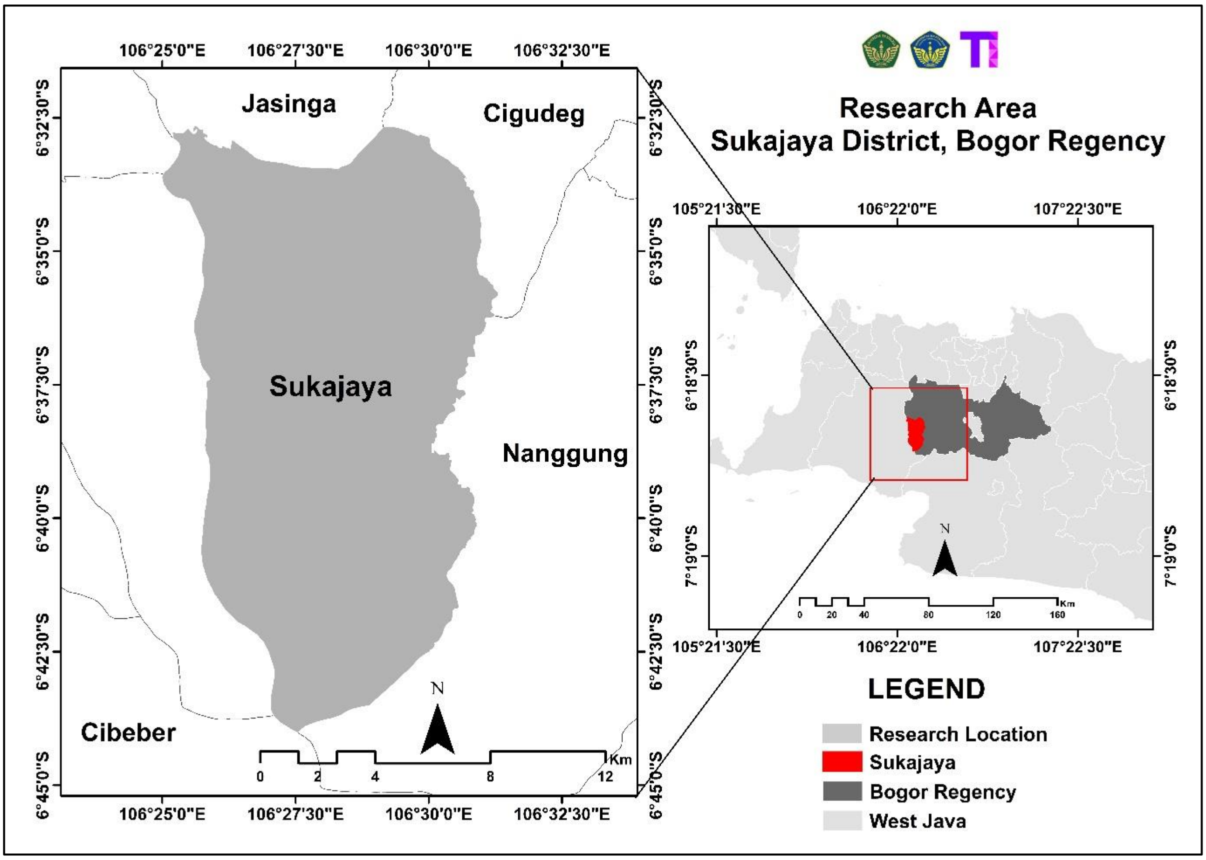

Figure 1. Research location

2.2. Research Flowchart

The flowchart that has been provided shows the sequence of steps that have been carefully planned to support this research. These methodical steps act as a strategic framework that helps conduct the research process in an orderly and systematic manner, thus providing a better level of structural organization and logical coherence.

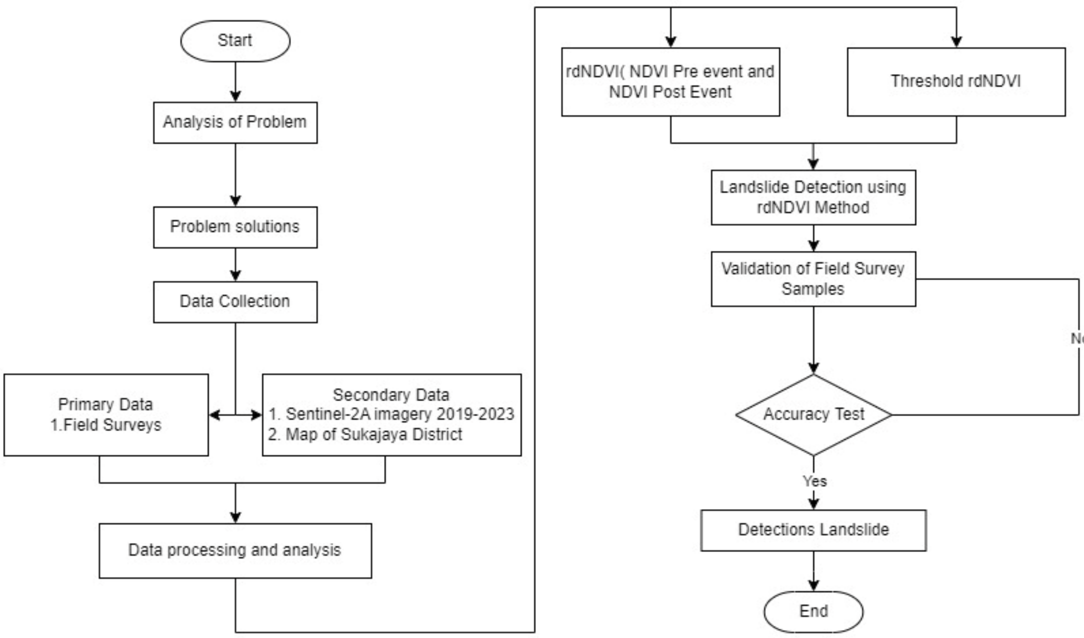

Figure 2. Research of framework

2.3. Reseach Method

This research utilizes the Relative Defferent NDVI (rdNDVI) approach is essential in detecting landslides. The following is an explanation of how to use the relatively Different NDVI (rdNDVI) approach to gather information on detecting landslides, which involves a complex workflow. Relative Different NDVI (rdNDVI) is a measure of the difference in NDVI values between two areas with different periods. rdNDVI can calculate and subtract NDVI values from one area from NDVI values from another area. This measure is useful for comparing the health and density of vegetation in the same or different areas over different periods.

The relatively different NDVI method has advantages in detecting landslides because it utilizes vegetation change analysis to identify landslide potential. By using the Normalized Difference Vegetation Index (NDVI). This method can show differences in vegetation density and health between areas, which can be an indicator of landslide potential (Ghorbanzadeh et al., 2022). The use of imagery data from satellites allows monitoring of changes in vegetation conditions widely and over a period, which supports the detection of potential landslide areas. Therefore, the relatively different NDVI method can help mroe efficiently in landslide detection by analyzing vegetation changes in a specific area (Prasetya et al., 2021).

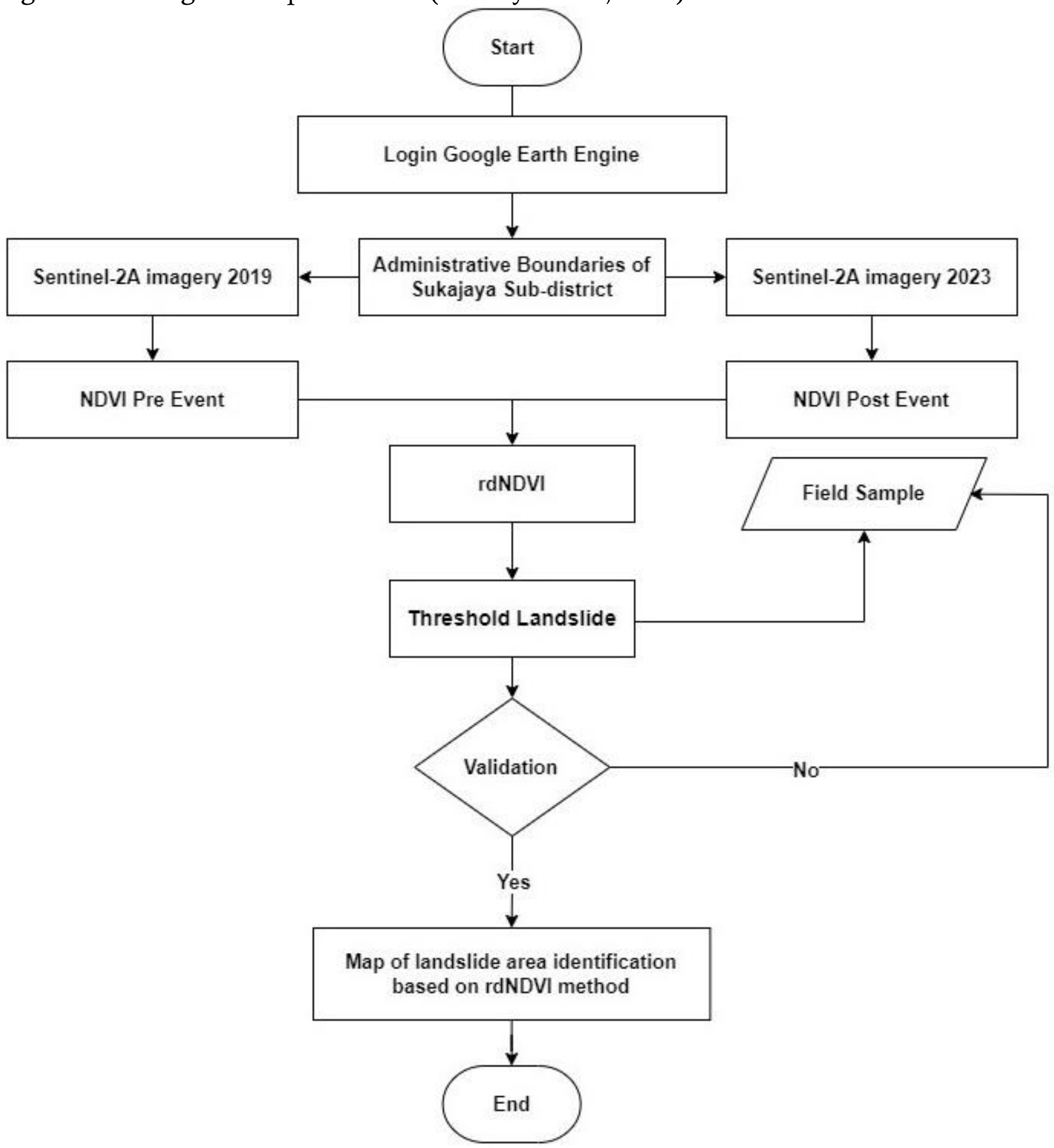

Figure 3. Research flowchart

2.4. Accuracy Assesment

The accuracy in detecting landslides is assessed by calculating rdNDVI which shows whether there is an increase or decrease in the value of NDVI pixels (Ghorbani et al., 2012), then using the standard deviation and the average value of the percentage change can determine the threshold of landslides so that the landslide detected areas can be obtained by comparing the data that has been generated in detecting landslides with data from field surveys (Scheip & Wegmann, 2021).

$$\text{Calculation of rdNDVI} = \left(\frac{NDVI_{post} - NDVI_{pre}}{\sqrt{NDVI_{pre} + NDVI_{post}}}\right) \text{x } 100 \quad (1)$$

$$\text{Threshold Landslide} = Th_{\mathrm{rdNDVI}} = m_{\mathrm{rdNDVI}} \pm \sigma_{\mathrm{rdNDVI}} \quad (2)$$

$$\text{Accuracy} = \frac{Corresponding\ Number\ of\ Point}{Number\ of\ Survey\ Points} \text{ x } 100 \quad (3)$$

3. RESULTS AND DISCUSSION

3.1. Data Processing

The processing of landslide data using Google Earth Engine (GEE) involves the application of the Relative Difference NDVI Algorithm to analyze the difference in vegetation index before and after the landslide event. This algorithm uses the NDVI before and after data to identify vegetation changes associated with landslide events. The results of this analysis can contribute to the identification of areas with potential landslide risk and guide decision-making in landslide disaster management efforts.

The following is a comparison of the vegetation index (NDVI) before and after the landslide in Sukajaya District. The comparison shows that before the landslide, the vegetation level was quite high, but after the landslide, there was a significant decrease in vegetation.

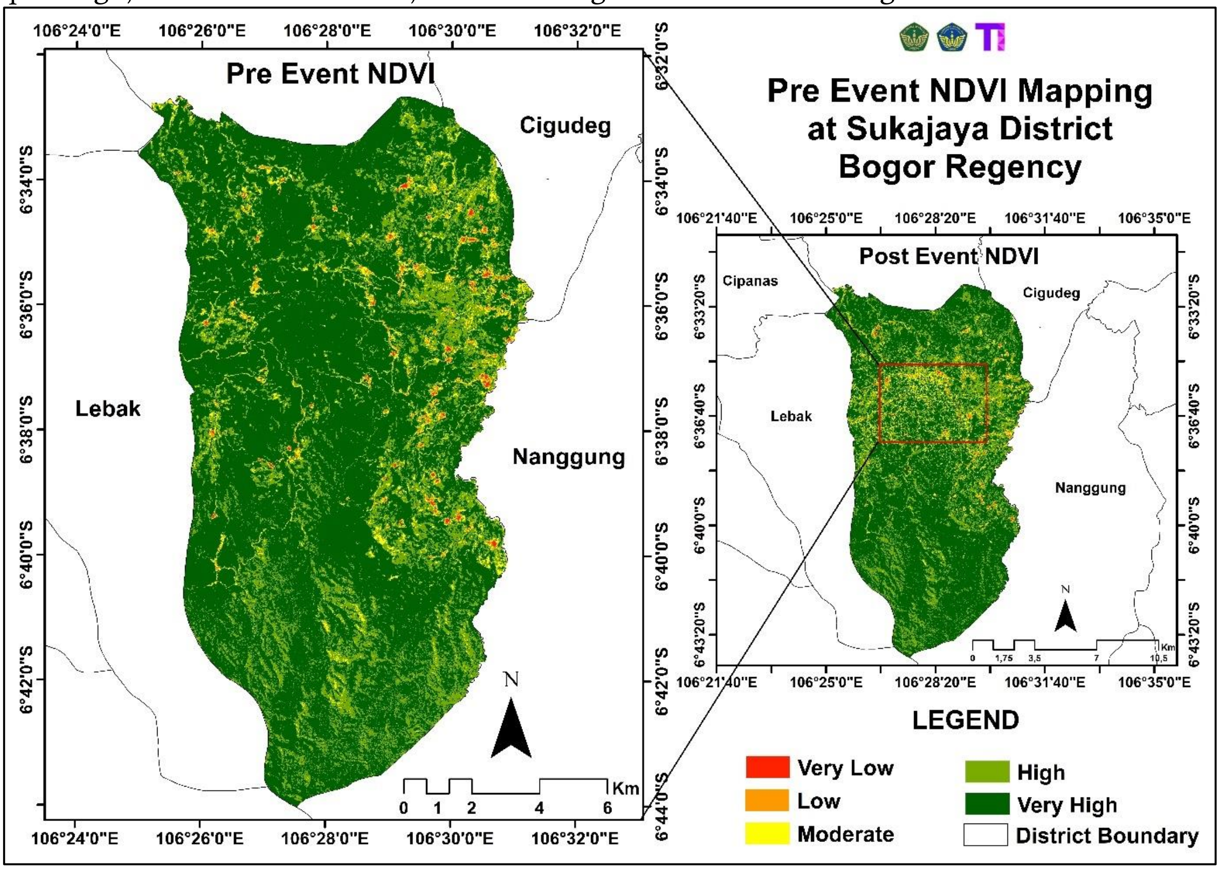

Figure 4. Comparison Landslide Pre-event NDVI at Sukajaya District, Bogor Regency

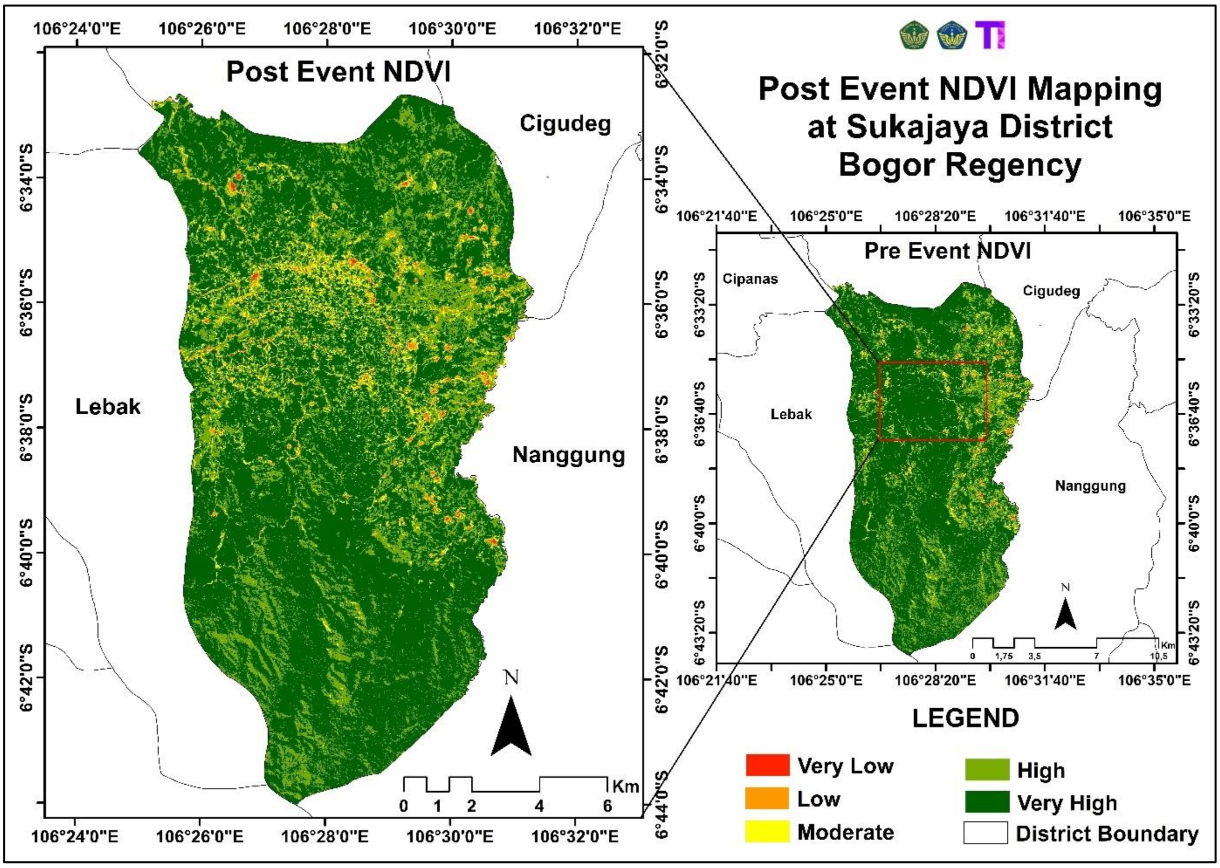

Figure 5. Comparison Landslide Post-event NDVI at Sukajaya District, Bogor Regency

Calculation of normalized difference vegetation index (NDVI) can help identify vegetation changes associated with landslide potential. These vegetation changes can be measured by calculating the relative difference in NDVI (rdNDVI) between the images before and after the landslide (Dahigamuwa et al., 2016). rdNDVI is calculated by subtracting the NDVI value after the landslide from the NDVI value before the landslide. A threshold value of rdNDVI can be set based on statistical analysis to determine areas that are likely to experience landslides, making the process of detecting landslides much more feasible based on changes in vegetation in landslide-indicated areas. Landslide areas can be visualized by displaying rdNDVI values that exceed the threshold value according to the predefined parameters (Scheip & Wegmann, 2021).

The process of identifying and detecting landslides using several slopes to produce landslide areas aims to compare several slopes that produce landslides and areas that have the potential for landslides, in the use of slope converted from slope degree into slope percent, the slope used in detecting landslides is slope 10, 15, 20, and 25, by using different slope variations it will be possible to see the possibility of landslides occurring, in which dryness the most landslides occur and in which areas are the most impacted of the 11 villages affected by landslides, thus producing a comparison between regions, especially between villages (Liu et al., 2021).

The visualization results of each slope are part a) is a slope of 10 percent using a threshold which is completed by comparing field survey data of 30 field survey points, while part b) is a slope of 15 percent using a threshold by comparing field survey data of 30 field survey points, then part c) is a slope of 20 percent using a threshold by comparing field survey data of 30 field survey points, and the last part d) is a slope of 25 percent by comparing field survey data of 30 field survey points, each slope will produce accuracy based on the accuracy of the field survey data comparison.

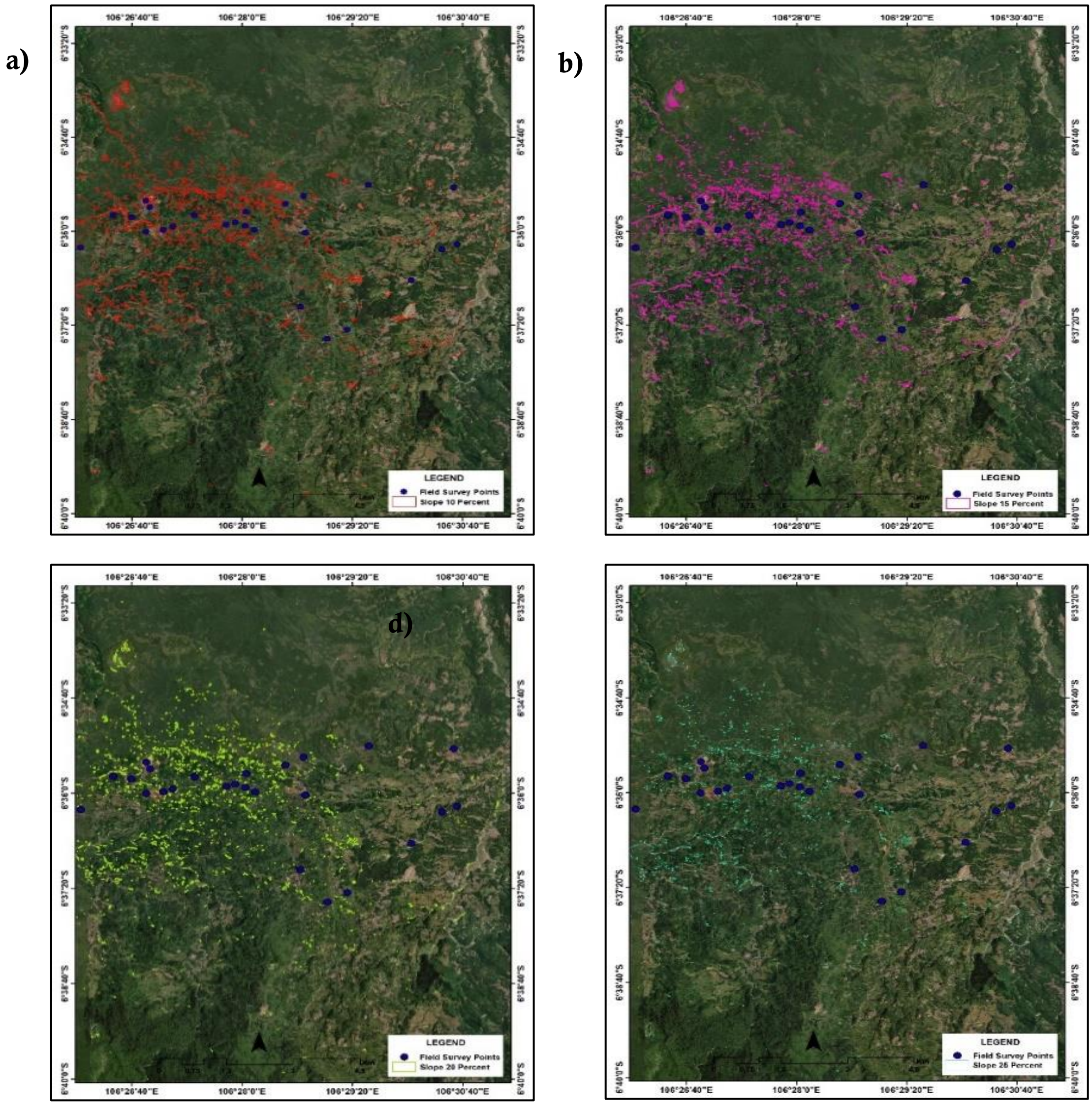

Figure 6. Result Detection of Landslide a) Slope 10 Percent, b) Slope 15 Percent, c) Slope 20 Percent, d) Slope 25 Percent

3.2. Data Analysis

Analysis of the landslide extent of the most affected areas in Sukajaya Sub-district shows that Cileuksa Village and Pasir Madang Village are the most affected areas. Cileuksa Village detected a landslide area of 28.83 hectares before using a landslide threshold with a 10 percent slope. After using the landslide threshold with various slopes, the landslide area in Cileuksa Village increased to 45.26 hectares (10 percent slope), 36.78 hectares (15 percent slope), 27.17 hectares (20 percent slope), and 19.30 hectares (25 percent slope).

Pasir Madang Village detected a landslide area of 23.32 hectares before using a landslide threshold with a 10 percent slope. After using landslide threshold with various slopes, the landslide area in Pasir Madang Village increased to 47.61 hectares (10 percent slope), 40.08 hectares (15 percent slope), 30.38 hectares (20 percent slope), and 20.34 hectares (25 percent slope).

Overall the landslide area in Sukajaya District before using the landslide threshold with 10 percent slope was 72.32 hectares. After using the landslide threshold with various slopes, the landslide area increased to 132 hectares (10 percent slope), 107 hectares (15 percent slope), 80 hectares (20 percent slope), and 55 hectares (25 percent slope). The results of the landslide detection analysis above can be seen in table 1.

Table 1. Results of Landslide Detection Area at Sukajaya District Using Slope 10, 15, 20 and 25

Village	Before Threshold (Ha)	10 Percent (Ha)	15 Percent (Ha)	20 Percent (Ha)	25 Percent (Ha)
Cileuksa	28,83	45,26	36,78	27,17	19,30
Cipayung	0,13	0,29	0,22	0,06	0,04
Cisarua	0,57	2,01	1,62	1,31	1,08
Harkatjaya	0,86	1,69	1,20	0,76	0,43
Jayaraharja	8,72	17,37	14,52	11,34	8,34
Kiarapandak	6,44	11,32	8,27	5,56	4,05
Kiarasari	0,18	0,61	0,37	0,31	0,17
Pasir Madang	23,32	47,61	40,08	30,38	20,34
Sukajaya	1,24	2,31	1,50	0,92	0,52
Sukamulih	1,50	2,42	1,71	1,22	1,05
Urug	0,54	1,35	1,23	1,02	0,67
Total	**72,32**	**132,25**	**107,49**	**80,05**	**55,99**

Analysis of the landslide slope class in Sukajaya district shows that 8-15% (skewed) slope is the most dominant class, with a percentage of 45%. The 15-25% (Slightly Steep) slope class follows with a percentage of 29%. This can occur because the Sukajaya district is a hilly area with a fairly high slope. The results of the total slope analysis can be seen in table 2.

Table 2. Slope Class Detected of Landslides at sukajaya District, Bogor Regency

Slope Class	Point Detected	Persen
>45	55	0,2 %
0-8%	4212	18 %
15-25%	6588	29 %
25-45%	1803	8 %
8-15%	10270	45 %
Grand Total	**22928**	

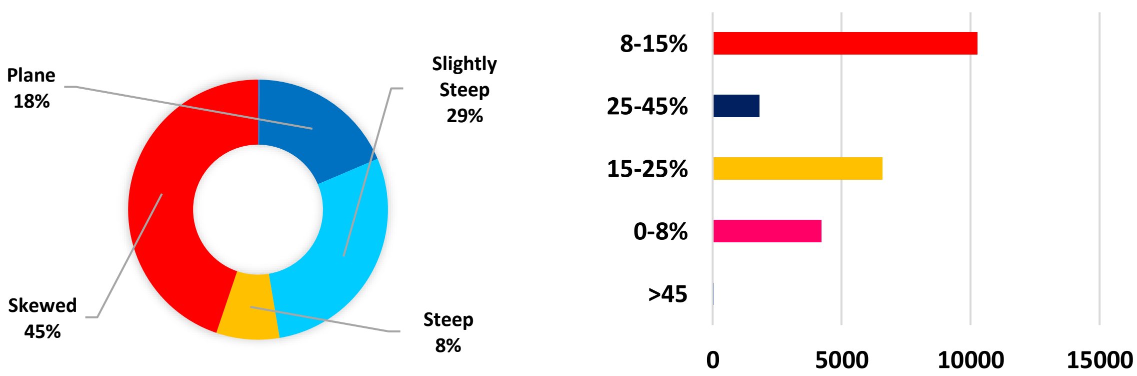

Figure 7. Percentage of Slope Class That Detected Landslide at Sukajaya District

Landslide detection accuracy showed that the use of 10 percent and 15 percent slope thresholds resulted in the highest accuracy of 90%. This is because out of 30 field survey points, 27 of them were detected correctly and the other 3 points were detected incorrectly. The accuracy rate of using a 20 percent threshold slope was 86%, with 26 points detected correctly and 4 points detected incorrectly. The accuracy rate of using a 25 percent slope threshold is 80%, with 24 points detected correctly and 6 points detected incorrectly and the lowest accuracy rate is before using the threshold of 66.7%, with 20 points detected correctly and 10 points detected incorrectly. The results of the landslide detection accuracy test are listed in Table 3.

Table 3. Result of Accuracy Test Assessment of Landslide Detection at Sukajaya District

Slope	Total Point Survey	Match Point	Non-Conforming Points	Accuracy
Before Threshold	30	20	10	66.7 %
10 Percent	30	27	3	90 %
15 Percent	30	27	3	90 %
20 Percent	30	26	4	86.7 %
25 Percent	30	24	6	80 %

4. CONCLUSIONS

Based on the analysis results of this research, it can be concluded that the landslide disaster in Sukajaya District shows that Cileuksa Village and Pasir Madang Village are the villages most affected by landslides that occurred in 2020. The results of the landslide detection accuracy test using the Relative Difference NDVI (rdNDVI) method show that the use of 10 percent and 15 percent slope thresholds produces the highest accuracy, which is 90%. Meanwhile, before using the threshold, it produces the lowest accuracy, which is 66.7%. This conclusion is expected to provide useful information for parties involved in landslide mitigation efforts in Sukajaya Sub-district. This information can be used to improve the effectiveness of mitigation efforts, thus reducing the risk of casualties and material losses.

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