e-JURNAL PENYELIDIKAN DAN INOVASI
ISLAMIC INNOVATION CENTER FOR TECHNOLOGY, UIS
https://ejpi.uis.edu.my
e-ISSN 2289-7909

VOL. 12 NO. 5, SPECIAL EDITION, (DECEMBER, 2025): page 296-311
DOI: 10.53840/ejpi.v12i5.325

Received: October 27, 2025 Accepted: December 2, 2025 Published: December 31, 2025

Spatial Analysis of Landslide Detection Using The Relative Different NDVI (rdNDVI) Method Through The Google Earth Engine Platform (Case Study of Sukamakmur District, Bogor Regency)

Analisis Spasial Deteksi Longsor Menggunakan Metode Relative Different NDVI (rdNDVI) Melalui Platform Google Earth Engine (Kajian Kes Kecamatan Sukamakmur Kabupaten Bogor)

Mohamad Septiyanto Ismail [1], Iksal Yanuarsyah[2], Nurul Kamilah [3]
[1,2,3] Informatics Engineering, Faculty of Technology & Science, Universitas Ibn Khaldun Bogor
Jl. Sholeh Iskandar, RT.01/RW.10, Kedungbadak, Kec. Tanah Sereal, Bogor City, West Java
16162 Indonesia.
Email: [1]septiyantoismail@gmail.com,[2]iksal.yanuarsyah@ft.uika-bogor.ac.id· [3]nurul.kamilah@uika-bogor.ac.id

ABSTRACT

Sukamakmur District in Bogor Regency is one of the areas with a high level of vulnerability to landslides. From 2020 to 2023, there were 57 landslides that caused land damage, economic losses, and loss of people's homes. This condition shows the need for effective environmental monitoring to identify areas prone to and affected by landslides. Remote sensing technology offers the ability to obtain information on the earth's surface quickly, accurately, and sustainably, so that it can be used to analyze changes in land cover and vegetation conditions that are closely related to the potential for landslides. This study uses the Relative Difference NDVI (rdNDVI) method on the Google Earth Engine (GEE) platform by utilizing Sentinel-2A multitemporal images in 2019 and 2023. The research stages include pre-image processing, calculation of the Normalized Difference Vegetation Index (NDVI), and rdNDVI analysis to detect vegetation changes as an early indicator of landslides. This approach allows for the spatial identification of areas that have experienced significant vegetation degradation as a result of soil movement. The results of the study show that the areas that experienced the largest vegetation decline and were the most significantly affected by landslides in 2023 were Wargajaya Village and Sukawangi Village. The rdNDVI mapping manages to visualize the distribution of damage areas clearly, so that it can be used as a basis for decision-making in disaster mitigation. In addition, the results of the accuracy test based on the analysis of the slope threshold showed that the best level of accuracy was achieved at a 10% slope value of 86.6%, followed by a 15% slope with an accuracy of 86%. This value indicates that the combination of vegetation analysis and topographic parameters provides optimal results in identifying landslide-prone areas. Overall, this study confirms the effectiveness of the use of remote sensing data and rdNDVI methods in supporting monitoring of vegetation changes and early detection of landslides. These findings are expected to contribute to local governments and stakeholders in disaster risk mitigation efforts and more sustainable environmental management.

Keywords: *"Landslide, rdNDVI, Remote Sensing, Sentinel-2A, Google Earth Engine,."*

ABSTRAK

Kecamatan Sukamakmur di Kabupaten Bogor merupakan salah satu wilayah dengan tingkat kerawanan bencana longsor yang tinggi. Dalam kurun waktu 2020 hingga 2023, tercatat sebanyak 57 kejadian longsor yang menyebabkan kerusakan lahan, kerugian ekonomi, serta hilangnya tempat tinggal masyarakat. Kondisi ini menunjukkan perlunya pemantauan lingkungan yang efektif untuk mengidentifikasi area rawan dan terdampak tanah longsor. Teknologi penginderaan jauh menawarkan kemampuan untuk memperoleh informasi permukaan bumi secara cepat, akurat, dan berkelanjutan, sehingga dapat digunakan untuk menganalisis perubahan tutupan lahan serta kondisi vegetasi yang berkaitan erat dengan potensi terjadinya longsor. Penelitian ini menggunakan metode Relative Difference NDVI (rdNDVI) pada platform Google Earth Engine (GEE) dengan memanfaatkan citra multitemporal Sentinel-2A tahun 2019 dan 2023. Tahapan penelitian meliputi pra-pemrosesan citra, perhitungan Normalized Difference Vegetation Index (NDVI), serta analisis rdNDVI untuk mendeteksi perubahan vegetasi sebagai indikator awal terjadinya longsor. Pendekatan ini memungkinkan identifikasi spasial area yang mengalami degradasi vegetasi signifikan sebagai dampak dari pergerakan tanah. Hasil penelitian menunjukkan bahwa wilayah yang mengalami penurunan vegetasi terbesar sekaligus terdampak paling signifikan oleh kejadian longsor pada tahun 2023 adalah Desa Wargajaya dan Desa Sukawangi. Pemetaan rdNDVI berhasil memvisualisasikan distribusi area kerusakan secara jelas, sehingga dapat digunakan sebagai dasar pengambilan keputusan dalam mitigasi bencana. Selain itu, hasil uji akurasi berdasarkan analisis ambang batas kemiringan lahan menunjukkan bahwa tingkat akurasi terbaik dicapai pada nilai kemiringan 10% sebesar 86,6%, diikuti oleh kemiringan 15% dengan akurasi 86%. Nilai tersebut mengindikasikan bahwa kombinasi analisis vegetasi dan parameter topografi memberikan hasil yang optimal dalam mengidentifikasi area rawan longsor. Secara keseluruhan, penelitian ini menegaskan efektivitas penggunaan data penginderaan jauh dan metode rdNDVI dalam mendukung pemantauan perubahan vegetasi dan deteksi dini tanah longsor. Temuan ini diharapkan dapat memberikan kontribusi bagi pemerintah daerah dan pemangku kepentingan dalam upaya mitigasi risiko bencana serta pengelolaan lingkungan yang lebih berkelanjutan.

Kata kunci: Tanah Longsor; rdNDVI; Penginderaan Jauh; Sentinel-2A; Google Earth Engine

INTRODUCTION

Indonesia is one of the countries that has a high level of vulnerability to natural disasters, especially landslides. Landslides often occur due to a combination of geological, topography, and land cover conditions that affect slope stability. One of the areas that consistently experiences landslides is Bogor Regency, especially Sukamakmur District. Geographically, Sukamakmur District is located at the coordinates of 6°31'8.72" – 6°39'23.2" South Latitude and 106°54'37.2" – 107°4'3.6" East Longitude, with an area of 16,982.65 hectares and divided into 10 villages. The topography of this region is in the form of plateaus surrounded by mountains and hills, making it very vulnerable to landslide disasters (Saputra et al., 2020).

Landslides are the movement of the mass of soil, rocks, or a mixture of both that move down the slope due to the disruption of the stability of the materials that make up the slope (Anifam, Bhakti, & Nugroho, 2021). The impact of this disaster is very significant, ranging from land damage, loss of community housing, to economic losses that affect the welfare of the local community. Based on data from the Bogor Regency Regional Disaster Management Agency (BPBD), 57 landslide incidents were recorded in Sukamakmur District during the period 2020 to 2023 (Masnur, Alam, & Muhammad, 2021), confirming that this area is one of the high-risk areas.

To overcome these problems, remote sensing technology can be used as an important tool to obtain information about the condition of the earth's surface in an accurate and sustainable manner. This technology allows spatial analysis to map areas with the potential for landslides and areas affected by disasters (Pasmah, Lubis, & Usman, 2021). Previous research, such as by Davide Notti et al. (2022), has shown that the use of remote sensing data, particularly through the greenest pixel composite technique and NDVI Relative Difference (rdNDVI) calculations, is effective in detecting potential landslides. This method has been successfully applied in various locations, including the Tanarello and Gavi valleys, to identify vegetation changes associated with soil movement.

In addition, the combination of vegetation index (NDVI) and geomorphological analysis has proven to be very useful in mapping landslide-prone areas. Changes in vegetation cover are often an early indicator of slope instability, so multitemporal monitoring using satellite imagery can provide critical information for disaster mitigation (Ningsih, Wiharta, & Sastra, 2019). Thus, an integrative approach that combines remote sensing technology and topographic analysis makes a significant contribution to landslide risk mitigation planning and community protection in vulnerable areas.

PROBLEM STATEMENT

Based on the above background description, the formulation of the problem in this study is as follows:

1. How does the landslide disaster identification method use remote sensing technology?
2. How to conduct an accuracy test on the detection of landslides in Sukamakmur Regency?
3. How to design a geographic information system to visualize the distribution of landslide detection maps in Sukamakmur Regency?

LITERATURE REVIEWS

Table 1: Literature reviews

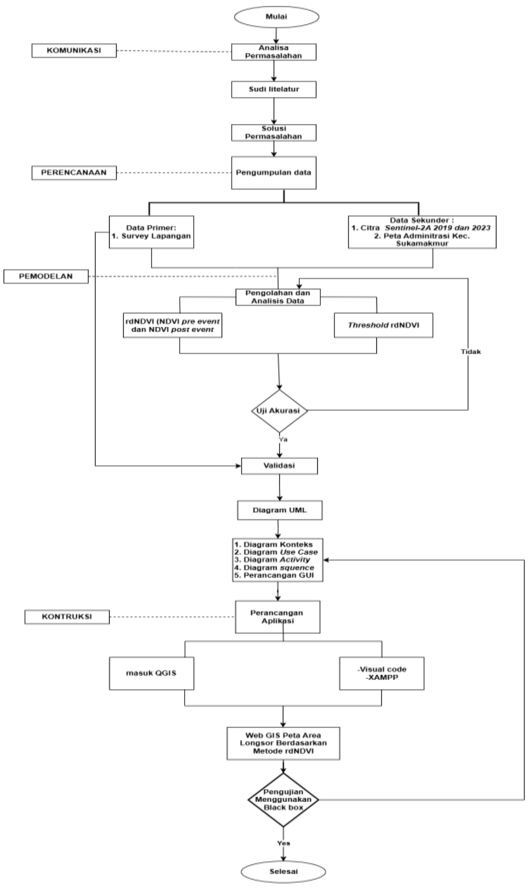
No	Title	Result	Relationship
1	Daisuke Komori. 2023 "A combination of optical images and SAR images to detect landslide scars, using classification and regression trees" (Alhady, Supratman, & Darma, 2022).	The study uncovered a semi-automated method using Sentinel-2 satellite imagery and NDVI time series analysis to detect landslides.	Landslides are classified into two types (deep and shallow landslides) using differential spectral index thresholds (rdNDVI, dBSI, and dBI).
2	The Syifa Putri, et al. 2021 Utilization of Sentinel Image-2 for Vegetation Density Analysis in the Mount Maglayang Area Patimah et al., 2022.	Remote sensing technology can be used to assist in human work, including to analyze This analysis can be done with a variety of images including Sentinel-2 imagery. Based on the results that have been made, this image produces the results of vegetation analysis quite well.	Explains the use of multi-source data such as Sentinel-2 imagery, NDVI
3	Erin Lindsay, et al. 2022 Composite Multi-Temporal Satellite Images in Google Earth Engine to Improve Landslide Visibility: A Glacial Landscape Case Study (Santoso et al.,	This study seeks to investigate a satellite-based change detection approach for landslide detection, in order to improve spatial bias and completeness of landslide inventory. The initial inventory of landslides was carried out using a conventional change detection approach based on NDVI, which	Explains the use of multi-source data such as Sentinel-2A, NDVI satellite imagery

	2020).	was then verified with helicopters, drones, and field observations.	
4	Corey M. et al. "HazMapper: global open-source natural disaster mapping applications in Google Earth Engine" (Scheip et al., 2021).	This study discusses the use of remote sensing data. The results of the study explain that natural disaster risk mitigation globally through the use of Google Earth Engine technology uses the rdNDVI method to detect changes in vegetation cover.	Describe the NDVI Relative Difference method for detecting changes in vegetation land cover.
5	Valeria Satriano, et al. "Landslide Detection and Mapping with Advanced Multi-Temporal Satellite Optical Techniques" (Satriano et al., 2023).	Water has a lower NDVI value than vegetation so significant land cover variations caused by landslides are slowly paving the way for land cover reform.	Landslide detection of fixed threshold changes in NDVI land cover index

METHODOLOGY

The stages of this research method can be seen in Figure 1 below.

Figure 1: Frame of mind



The methodology of this research is described in the form of a systematic flow chart, consisting of several main stages: Communication, Planning, Modelling, and Construction.

Communication Stage

This stage starts with:

- Problem Analysis: Identify the main problems related to the landslide disaster in Sukamakmur Regency.
- Literature Study: Collect information and references related to remote sensing technology, NDVI, rdNDVI, and GIS mapping.
- Problem Solving: Determining the appropriate approach and method to detect and map landslides.

Planning Stage

- Data Collection: Data is collected from two main sources:
  - Primary Data: Field survey results to obtain information on real conditions at the location.
  - Data Seconds:
    - Sentinel-2A satellite imagery in 2019 and 2023.
    - Map of the administrative area of Sukamakmur District.

This stage ensures that the research has a complete database for further analysis.

Modelling Stage

- Data Processing and Analysis: Image data and survey results are processed to calculate:
  - NDVI (pre-event and post-event): Measuring vegetation cover before and after landslides.
  - rdNDVI (Relative Difference NDVI): Identifies vegetation changes as an indicator of landslide-affected areas.
  - Threshold rdNDVI: Specifies a threshold for detecting significant changes.
- Accuracy Test: Assess the reliability of the mapping results by comparing the prediction with field data. If accuracy is eligible, proceed to the validation stage.
- UML Validation and Diagrams: The results of the mapping and analysis of the data are validated, then UML diagrams are generated, including:

  Diagram Context
  Diagram Use Case
  Diagram Activity
  Diagram Sequence
  GUI (application interface) design

Construction / Implementation Stage

- Application Design: Geographic information systems (GIS) are created by utilizing:
  QGIS for spatial mapping.
  Visual Code + XAMPP for GIS web application development.
- Web GIS Landslide Area Map Based on rdNDVI: The system displays an interactive web-based map of the landslide-affected area.
- Testing (Black Box): Testing the functionality and performance of the application to ensure that all features work according to the user's needs.

Final Stage

After the test is successful, the research process is considered **complete**, and the results in the form of a web GIS landslide detection map are ready to be used for mapping, mitigation, and others.

FINDINGS AND DISCUSSION

Communication

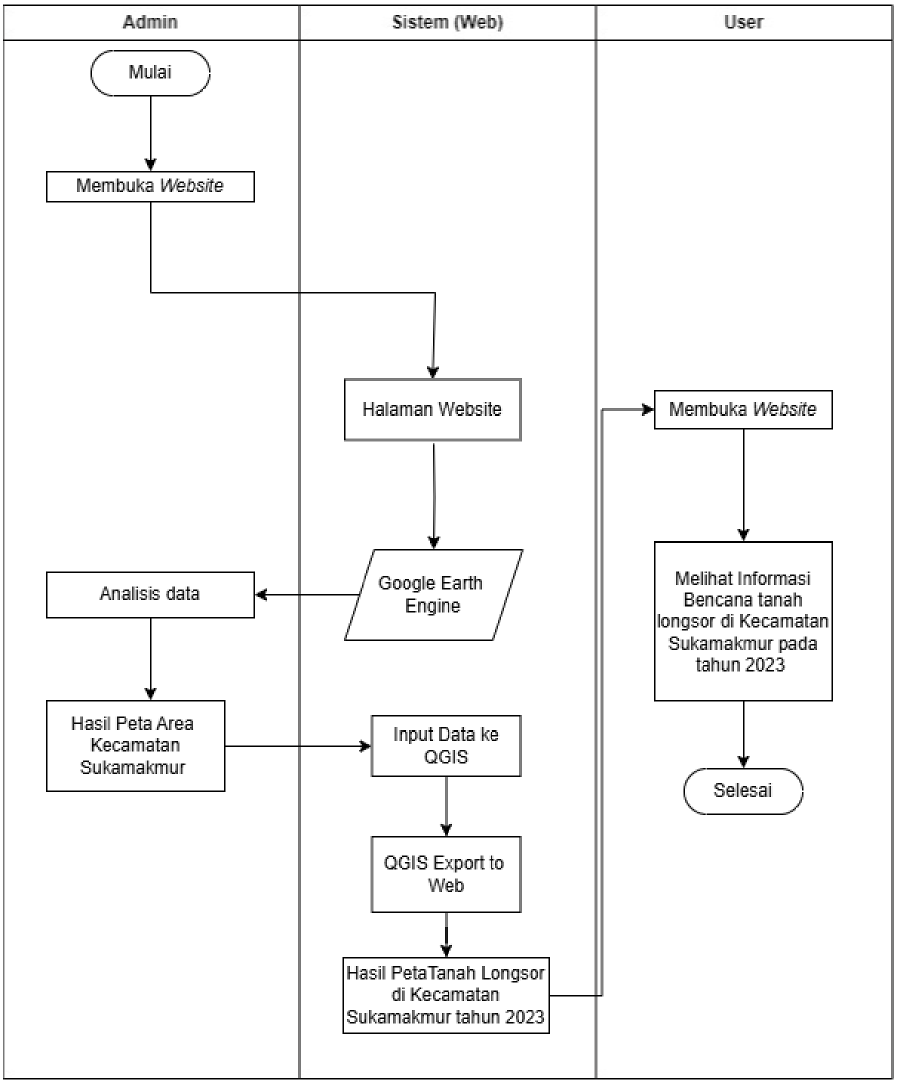
Problem Analysis

Analysis of the problems that occurred was known to have occurred a landslide disaster in Sukamakmur Regency which resulted in material and non-material losses.

Troubleshooting

Creating an information system about post-landslide disasters in Sukamakmur Regency in 2023 with analysis using the GEE platform.

Figure 2: Troubleshooting



Planning

Data Collection

At this stage, a data search is performed. The data required are primary data and secondary data. Primary data is data collected directly from the original source. Meanwhile, secondary data is data that already exists and has been collected by other parties or from other sources. The following data were obtained in this study.

1. **Landslide Survey**
   Landslide data collection activities in Sukamakmur use a survey method that combines direct observation methods (field surveys) and the use of secondary data from related agencies (BPBD).
2. **Bogor Regency Administrative Map**
   The results of the existing Bogor Regency Administrative Map were obtained from GEE for event data mapping.
3. **Citra Sentinel- 2A 2019 and 2023**

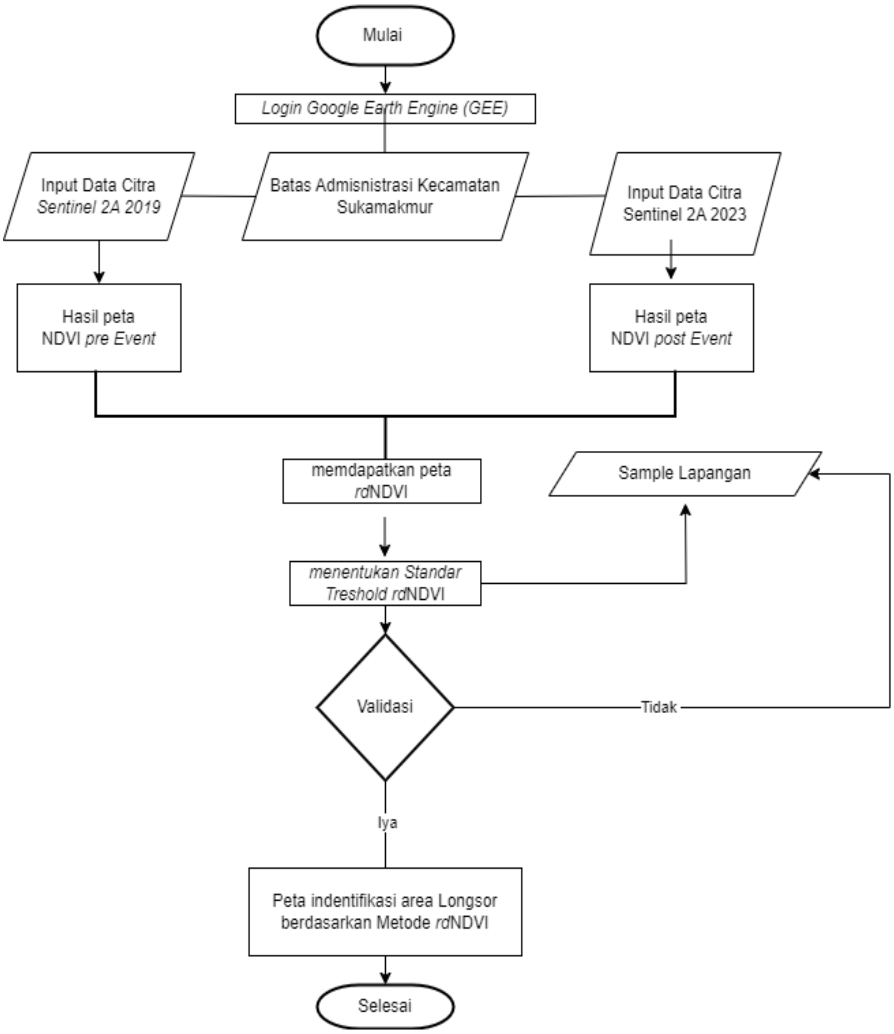
is spatial data, including Sentinel-2A images from 2015-2019 for pre-disaster data (pre-event) while 2020-2023 data is post-disaster data (post event) and administrative boundaries of Sukamakmur Regency, Bogor Regency.

Modelling

Data Processing and Analysis

Data management and analysis are spatial data, including Sentinel-2A images from 2015-2019 for pre-disaster data (pre-event) while 2020-2023 data is post-disaster data (post event) and administrative boundaries of Sukamakmur Regency, Bogor Regency. This is what is shown in figure 3.

Figure 3: Data Processing and Analysis



This research has a planning stage consisting of data processing and analysis. The data used are the 2019 Sentinel-2A Pre-event images, the 2023 Sentinel-2A Post-Event Images, and the administrative boundaries of Sukamakmur District. The methods used are Relative Difference NDVI (rdNDVI), and field surveys to validate the data produced. Criteria for detecting landslides.

Table 2: Criteria for detecting landslides

Type	Featured	Regulation
Spectral and Temporal	rdNDVI	$m_{rdNDVI} \pm \sigma_{rdNDVI}$
Spatial	Slope	> 10 percent

The calculation of the NDVI Relative Difference method is carried out using the following formula:

Figure 4: NDVI Relative Difference Method

$$rdNDVI = \left(\frac{NDVI_{post} - NDVI_{pre}}{\sqrt{NDVI_{pre} + NDVI_{post}}}\right) x\ 100$$

Calculating the percentage change of rdNDVI can take the NDVI value before (NDVI_pre) and after (NDVI_post) and then subtract the NDVI_post value by NDVI_pre. Then add NDVI_post at a NDVI_pre, and take the square root from the amount. Next, multiply the NDVI difference by the square root and multiply the result by 100. The results show whether there was an increase or decrease in NDVI pixel values in the time span before and after the event.

Figure 5: NDVI pixel values

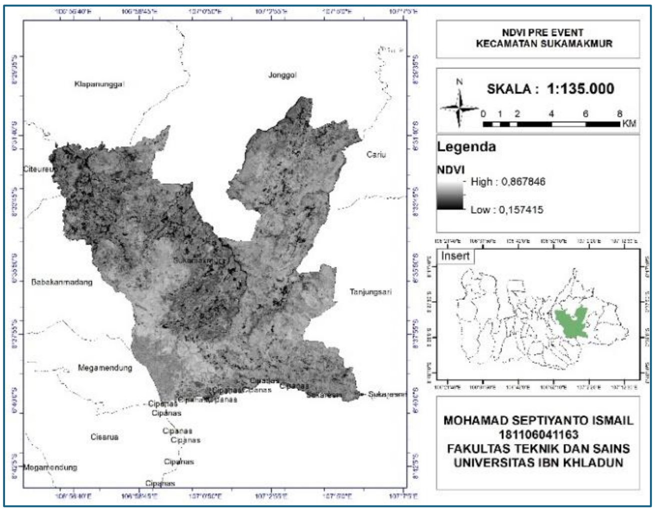
$$Th_{rdNDVI} = m_{rdNDVI} \pm \sigma_{rdNDVI}$$

Then using the standard deviation and the mean value of the percentage change, we can determine the landslide threshold by using the formula:

Landslide Detection Results in Google Earth Engine

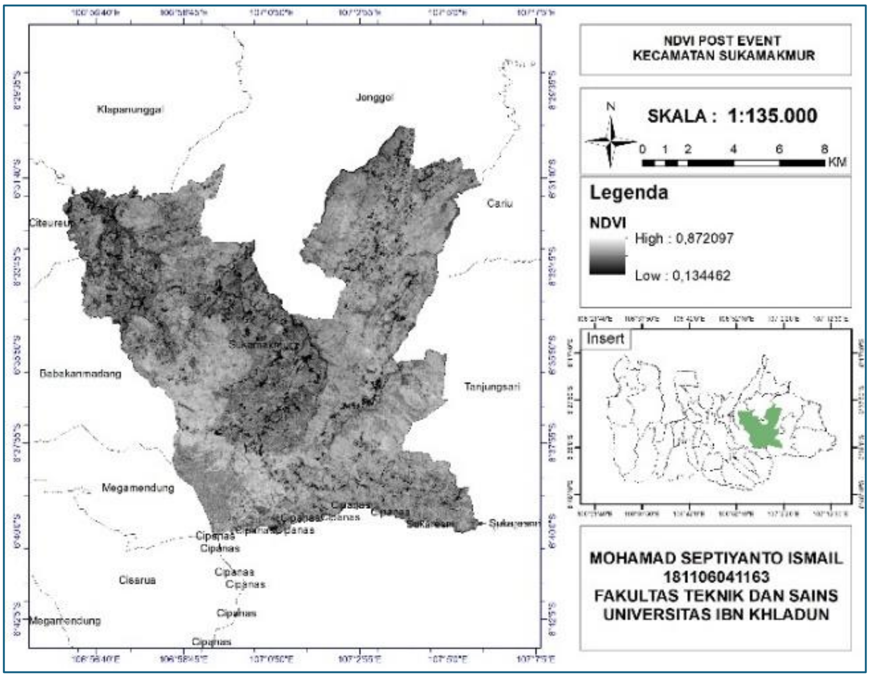
The processing of NDVI Pre-Event in Google Earth Engine (GEE) is to measure the health of vegetation and land, the darker the warning, the better the vegetation condition, while the whiter the color, the less vegetation conditions.

Figure 6: Pre-Event NDVI



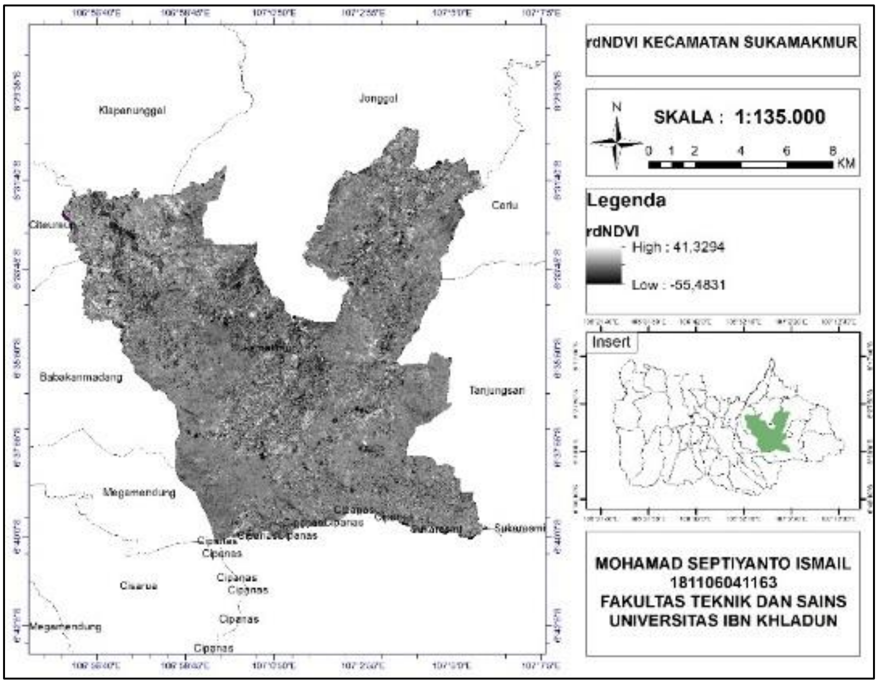
The processing of NDVI Post-Event in Google Earth Engine (GEE) is to measure the health of vegetation and land, the darker the colour, the better the vegetation condition, while the whiter the colour, the less vegetation conditions.

Figure 7: Post-NDVI Events



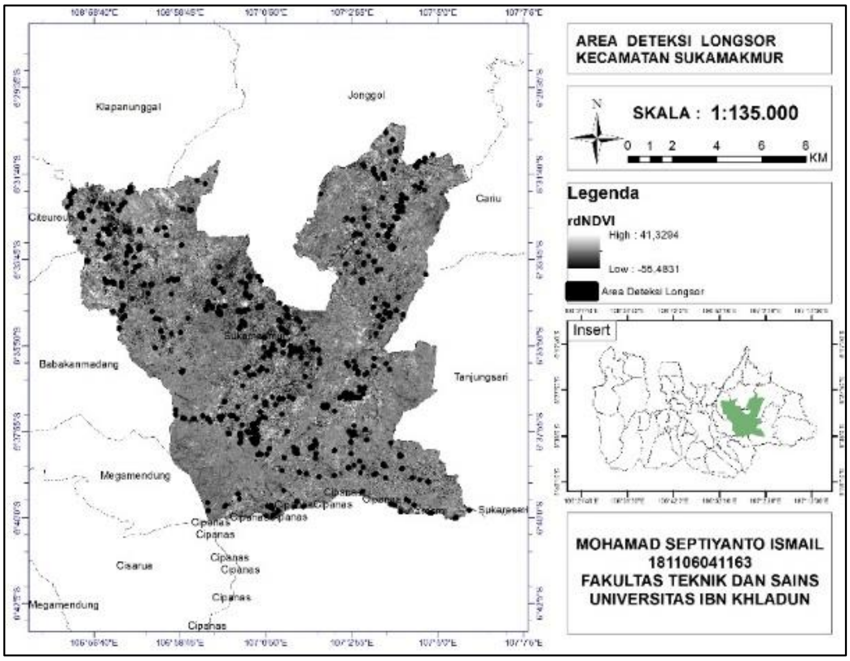
Processing rdNDVI results in Google Earth Engine (GEE) is the process of extracting valuable information from NDVI (Normalized Difference Vegetation Index) data that has been previously processed. NDVI is a vegetation index used to measure the health and condition of vegetation.

Figure 8: reNDVI Sukamakmur Regency



Visualization of Landslide Binaries after the landslide event, where in the image you can see the location of the landslide detected in certain areas which covers the total area of Sukamakmur Regency.

Figure 9: Landslide location detected



Landslide Area Analysis

The analysis of landslide-prone areas in Sukaharja District focused particularly on Wargajaya Village, which is identified as the most affected area. Prior to applying the slope threshold method, using a 10 percent slope criterion, approximately 49.03 hectares of land were identified as potentially susceptible to landslides. After applying a series of slope thresholds at 10, 15, 20, and 25 percent, the areas classified as landslide-prone decreased significantly, with approximately 16.52 hectares at 10 percent, 9.54 hectares at 15 percent, 5.18 hectares at 20 percent, and 2.58 hectares at 25 percent. This progressive reduction in the identified landslide areas with increasing slope thresholds demonstrates how slope plays a critical role in landslide susceptibility, highlighting the importance of incorporating slope-based analysis in disaster risk assessment and land-use planning. The results also provide valuable insights for local authorities and stakeholders in implementing targeted mitigation strategies and prioritizing areas for preventive measures.

Table 3: Landslide Area Analysis

		Luas (Ha)					
No	Desa	*Before Threshold Slope*	*Threshold slope 10*	*Threshold slope 15*	*Threshold slope 20*	*Threshold slope 25*	Total
1	Cibadak	1,08	0,65	0,42	0,25	0,09	2,49
2	Pabuaran	4,03	2,29	0,81	0,34	0,14	7,61
3	Sinarjaya	1,9	1,25	0,7	0,39	0,24	4,48
4	Sukadamai	4,54	2,08	1,1	0,64	0,46	8,82
5	Sukaharja	4,12	2,77	1,62	1,05	0,32	9,88
6	Sukamakmur	0,57	0,21	0,09	0,06	0,03	0,96
7	Sukamulya	2,35	1,87	0,99	0,37	0,2	5,78
8	Sukaresmi	0,88	0,6	0,32	0,11	0,02	1,93
9	Sukamakmur	3,18	1,89	1,1	0,6	0,39	7,16
10	Wargajaya	26,38	2,91	2,39	1,37	0,69	33,74
Total		49,03	16,52	9,54	5,18	2,58	82,79

Accuracy Test Results

Accuracy Test Results The results of the landslide analysis accuracy test can be seen that by using the highest threshold of 10 percent with an accuracy value of 86.6% with 26 matching points and 4 inappropriate points compared to others, where the lowest accuracy is before using the 10 percent Threshold Slope with an accuracy value of 66.7% from 30 survey points with 20 matching points and 10 unsuitable points.

Table 4: Accuracy Test Results

No	Threshold	Account
1	Before the 10 percent slope threshold	= x 100% = 66.7% $\frac{20}{30}$
2	Threshold Slope 10 Percent	= x 100% = 86.6% $\frac{26}{30}$
3	Threshold Slope 15 Percent	= x 100% = 80% $\frac{24}{30}$
4	Threshold Slope 20 Percent	= x 100% = 73% $\frac{22}{30}$
5	25 percent threshold slope	= x 100% = 33% $\frac{10}{30}$

Accuracy test results with kappa

Based on the results of the field survey, 30 survey points were taken. The results of the analysis showed as many as 26 landslide points and 4 non-landslide points with the results in accordance with field surveys. For as many as 3 survey points, it was found that the results were not in accordance with the interpretation of the image and the results of the field survey. The Kappa accuracy test shows the level of accuracy in the numbers
84% with an Overall Accuracy of 92%.

Table 5: Accuracy Test Result with Kappa

<table>
<tr><th rowspan="2"></th><th rowspan="2">Land Cover</th><th colspan="2">Field Verification Results</th><th rowspan="2">Total</th><th rowspan="2">User Accuracy</th><th rowspan="2">UA %</th></tr>
<tr><th>Avalanche</th><th>No Landslides</th></tr>
<tr><td rowspan="2">Interpretation Results</td><td>Avalanche</td><td>26</td><td>0</td><td>26</td><td>1</td><td>100%</td></tr>
<tr><td>No Landslides</td><td>1</td><td>3</td><td>4</td><td>0.75</td><td>75%</td></tr>
<tr><td colspan="2">Total</td><td>27</td><td>3</td><td>30</td><td></td><td></td></tr>
<tr><td colspan="2">Producer Accuracy</td><td>0.96</td><td>1,00</td><td colspan="2">Overall Accuracy</td><td>92%</td></tr>
<tr><td colspan="2">PA%</td><td>96%</td><td>100%</td><td colspan="2">Kappa Accuracy</td><td>84%</td></tr>
</table>

Based on the results of the field survey, 30 survey points were taken. The results of the analysis contained as many as 24 landslide points and 6 non-landslide points with the results in accordance with field surveys. For as many as 4 survey points, it was found that the results were not in accordance with the interpretation of the image and the results of the field survey. The Kappa accuracy test shows an accuracy level of 80% with an Overall Accuracy of 89%.

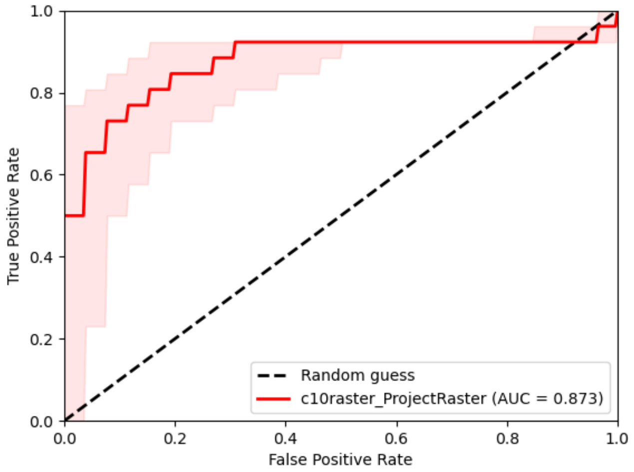
AUC/ROC Accuracy Test Results

Table 6: AUC/ROC Accuracy Test Results

	Land Cover	Field Verification Results		Total	User Accuracy	UA %
		Avalanche	No Landslides			
Interpretation Results	**Avalanche**	24	0	24	1	100%
	No Landslides	2	4	6	0.67	67%
Total		26	4	**30**		
Producer Accuracy		0.92	1,00	**Overall Accuracy**		89%
PA%		92%	100%	**Kappa Accuracy**		80%

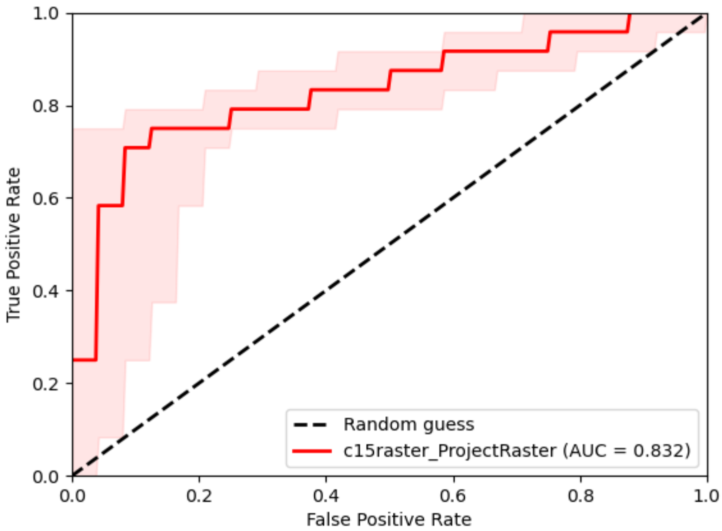
Based on the accuracy assessment using the AUC/ROC curve, an AUC value of 0.837 was obtained, indicating that the developed model demonstrates a strong ability to effectively differentiate between positive and negative classes. This relatively high AUC value suggests that the model has a substantial predictive performance, allowing it to classify instances with a relatively low probability of error. Consequently, the results highlight that the modelling approach and methods employed are effective in capturing the underlying patterns within the data, thereby enabling a clear distinction between the two classes. Furthermore, this outcome underscores the reliability of the model for practical applications, as it reflects not only the model's discriminative power but also its potential to provide meaningful insights and support informed decision-making in the context under study.

Figure 10: AUC/ROC accuracy test



Based on the AUC/ROC accuracy test, an AUC curve value of 0.832 was obtained, which showed that the modelling could effectively distinguish between positive and negative classes.

Figure 11: AUC/ROC accuracy test



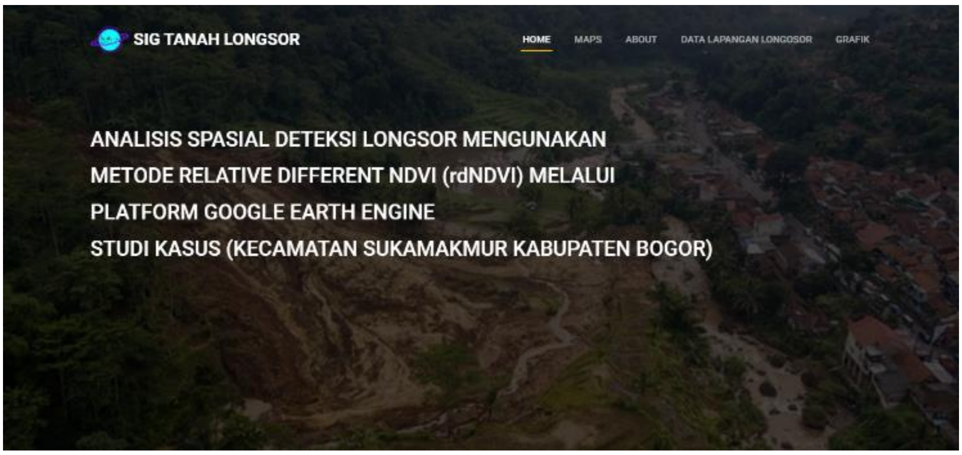
Application Design

After completing the modelling step, the next step is to implement the pre-designed design into the system through coding and testing. The results of coding and testing of the information system used for the promotion of tourism events are as follows.

1. Home Page View

The home page interface display displays the website page that contains the title of the website. For the Home page interface display.

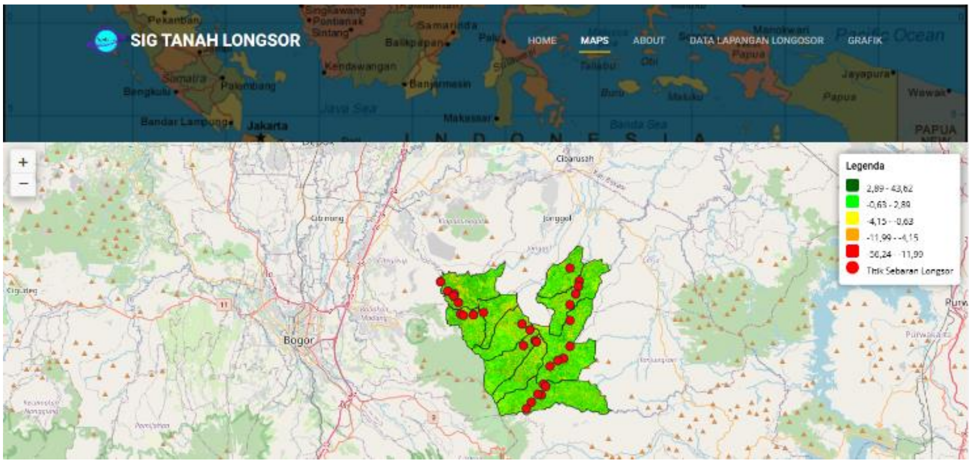
Figure 12: Home Page View



2. Maps Page View

The interface display of the Maps page, displaying the website page containing information about the landslide. For the Maps page interface display.

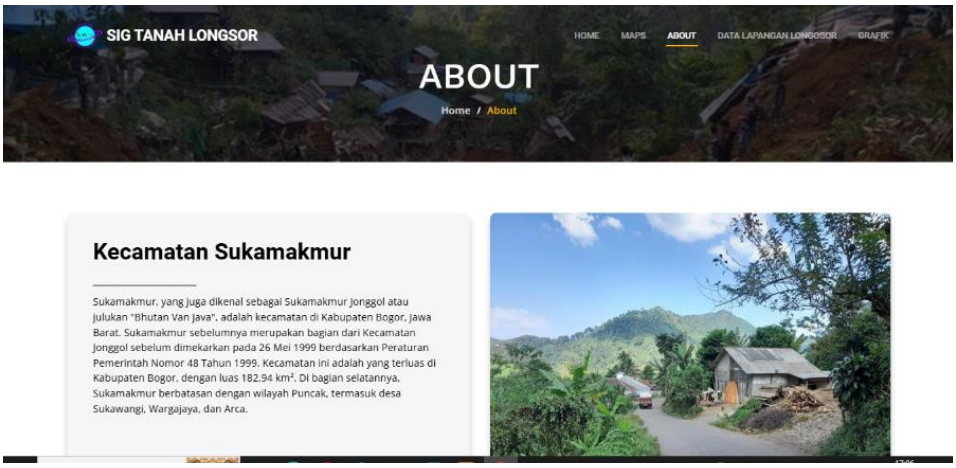
Figure 13: Maps Page View



3. About Page Views

The interface display of the Maps page, displaying the website page containing information about the landslide. For the interface display of the About page.

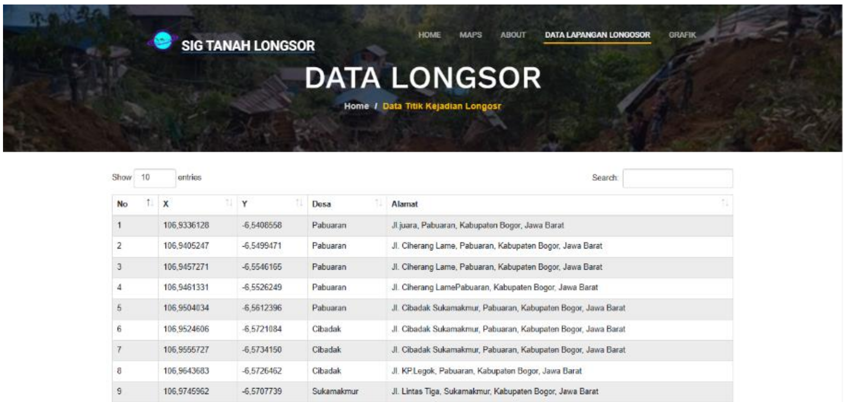
Figure 14: About Page View



4. Landslide Data Page View

The interface display of the Landslide Data Page, displays the website page that contains the Landslide Data information. For the interface display of the Avalanche Data page.

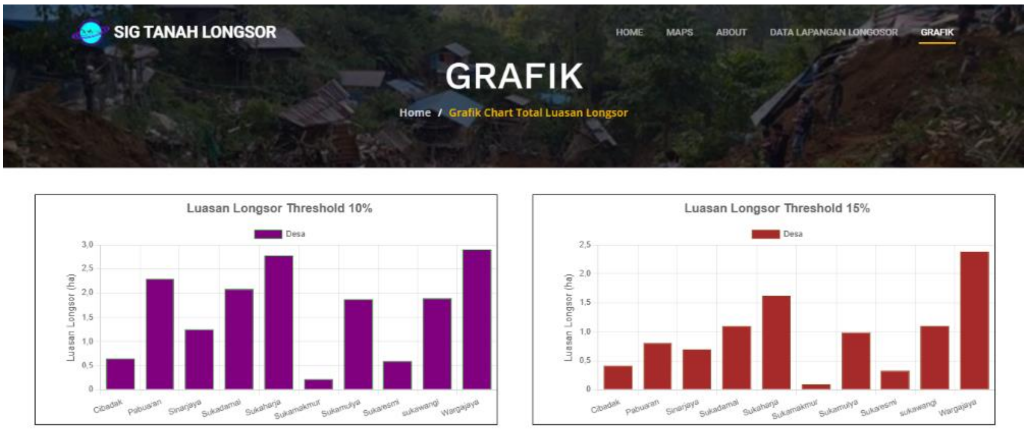
Figure 15: Landslide Data Page View



5. Chart Page View

Interface display of the Graph page, displaying the website page containing information about the landslide. For the interface display of the Graphics page.

Figure 16: Chat Page View



CONCLUSION

The results of the analysis of the landslide disaster that occurred in Sukamakmur District were two villages that were most affected by the landslide, namely Sukaharja Village and Wargajaya Village. The results of the landslide detection accuracy test using the NDVI (Normalized Difference Vegetation Index) method with the best accuracy using the Threshold slope of 10 percent got a score of 86.6% and 15 percent got a score of 80%, while the lowest accuracy before using the Threshold slope of 25 percent got a score of 33%. Display an information system in the form of NDVI before and after a WebGIS-based landslide by displaying some data from the NDVI Relative Difference method and knowing the areas that are most affected by landslides in Sukamakmur District.

ACKNOWLEDGEMENT

In this preparation, the author faced numerous difficulties and obstacles, but thanks to the support, encouragement, and enthusiasm from close ones, the author was able to complete it. Therefore, the author would like to express the deepest gratitude to Mother and Father for all the prayers and encouragement in completing this thesis. Dr. Iksal Yanuarsyah, S.Hut., M.Sc.IT as the main supervisor and Mrs. Nurul Kamilah, S.Kom., M.Kom as the co-supervisor Friends who have provided encouragement and motivation to the author to complete this research. The author realizes that there are

still many shortcomings in this thesis. Therefore, any constructive criticism and suggestions will be well received by the author.

REFERENCES

A. J. Viera and J. M. Garrett, "Understanding the Interobserver Agreement: Kappa Statistics," pp. 360–363, 2005.

BNPB, "Agile and resilient response to disasters," *Health. Mass.*, vol. 22, pp. 256–265, 2020, [Online]. Available: http://dx.doi.org/10.1016/j.tsc.2016.10.002

BPBD.bogorkab.go.id/, "Disasters, Data 665, 02-09-2020 2025, Disaster Occurrence Data 2011 -," *bpbd.bogorkab.go.id/*, 2020. https://bpbd.bogorkab.go.id/berita/data-bencana# (accessed Jan. 20, 2025).

C. M. Scheip and K. W. Wegmann, "HazMapper: A global open-source natural hazard mapping application in Google Earth Engine," *Nat. Hazards Earth Syst. Sci.*, vol. 21, no. 5, pp. 1495–1511, 2021, doi: 10.5194/nhess-21-1495-2021.

D. Afasel, R. Purnamasari, and Edwar, "Land Cover Classification Using Supervised Machine Learning on Satellite Imagery Using Google Earth Engine," *e-Proceeding Eng.*, vol. 8, no. 6, p. 3281, 2022.

D. Astari, W. F. Banggur, N. Santi, and N. Najib, "Mapping of Pyroclastic Flow Danger Zones of Mount Merapi, Central Java and Surrounding Areas using Titan2D Application," *J. Geoscience and Technology.*, vol. 5, no. 1, pp. 76–82, 2022, doi: 10.14710/jgt.5.1.2022.76-82.

D. Notti, M. Cignetti, D. Godone, and D. Giordan, "Semi-automated mapping of shallow landslides using the free Sentinel-2 and Google Earth Engine.," pp. 1–34, 2022.

E. Ihda, B. Sudarsono, and M. Awaluddin, "Analysis of the Order of Building Layout Towards River Boundaries in the Flood River of the East Canal of Semarang City (Case Study: Along the Flood of the East Canal from the Estuary to the Brig. Gen. Sudiarto Bridge (STA 0-

Fatimah and Nuryaningsih, *Textbooks*. 2018.

Firman F.M., Spi., M.sc REMOTE *SENSING*, UTMPRESS, Jl.RayaTelang, PO Box 2 Kamal, Bangkalan Madura, 2015

H. Muzaky and L. M. Jaelani, "Analysis of the Effect of Land Cover on Surface Temperature Distribution: An Urban Heat Island Study in Jakarta, Bandung and Surabaya," *J. Indonesian Remote Sensing.*, vol. 1, no. 2, pp. 45–51, 2019, [Online]. Available: http://jurnal.mapin.or.id/index.php/jpji/article/view/14

I. G. Indrayana, *Geographic Information System*, no. 140030655. 2017.

I. Komala Dewi, M. Yogie Syahbadar, and Muhammad Hatta Ope, "The Risk of Landslide Disasters on Space Utilization in Sukamakmur District, Bogor Regency," *J. Tek. | Maj. Ilm. Fak. Tech. UNPAK,* vol. 22, no. 2, pp. 17–25, 2021, doi: 10.33751/teknik.v22i2.4692.

N. Wakhidatus, A. L. Nugraha, and M. Awaluddin, "Threat Analysis of Floods and Landslides in Residential Areas in Jepara Regency,"

R. Baxter, *Software engineering is software engineering*. 2006. doi: 10.1049/ic:20040411.

T. Fawcett, "An introduction to ROC analysis," *Pattern Recognit. Lett.*, vol. 27, no. 8, pp. 861–874, 2006, doi: 10.1016/j.patrec.2005.10.010.

W. Zhang, B. Hu, and G. S. Brown, "Automatic surface water mapping using polarimetric SAR data for long-term change detection," *Water (Switzerland)*, vol. 12, no. 3, pp. 1–14, 2020, doi: 10.3390/w12030872.