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Identification of Flood Prone Areas in Sumatra Barat Province Using Remote Sensing Data and Geographic Information System Based on Machine Learning

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Abstract
This research aims to identify flood-prone areas in West Sumatra Province using remote sensing data and Machine Learning-based Geographic Information System. By utilizing variables such as distance from the river, Normalized Difference Water Index (NDWI), elevation, Topographic Position Index (TPI), Normalized Difference Vegetation Index (NDVI), and Rainfall Data, this research was conducted on the Google Earth Engine platform. This analysis method supports resource optimization, public education, increased environmental safety, and the development of new technologies and research. The results of the research are expected to assist in mitigation and adaptation to future flood disasters, as well as provide more accurate and comprehensive insights for local governments, disaster management agencies, and communities. With this approach, it is expected to reduce flood risk and increase community resilience to natural disasters.

Abstrak
Penelitian ini bertujuan untuk mengidentifikasi daerah rawan banjir di Provinsi Sumatera Barat menggunakan data penginderaan jauh dan Sistem Informasi Geografis berbasis Machine Learning. Dengan memanfaatkan variabel seperti jarak dari sungai, Normalized Difference Water Index (NDWI), elevasi, Topographic Position Index (TPI), Normalized Difference Vegetation Index (NDVI), dan Data Curah Hujan, penelitian ini dilakukan di platform Google Earth Engine. Metode analisis ini mendukung pengoptimalan sumber daya, edukasi masyarakat, peningkatan keamanan lingkungan, serta pengembangan teknologi dan penelitian baru. Hasil penelitian diharapkan dapat membantu dalam mitigasi dan adaptasi terhadap bencana banjir di masa depan, serta memberikan wawasan yang lebih akurat dan komprehensif bagi pemerintah daerah, lembaga penanggulangan bencana, dan masyarakat. Dengan pendekatan ini, diharapkan dapat mengurangi risiko banjir dan meningkatkan resiliensi masyarakat terhadap bencana alam.

Kata Kunci : Banjir, Penginderaan Jauh,Machine Learning, Sistem Informasi Geografis

INTRODUCTION

Flooding is one of the natural disasters that often occurs in various regions in Indonesia, including West Sumatra Province (BNPB 2023). This disaster can cause huge losses, both in terms of material and casualties. Therefore, the identification of flood-prone areas is very important to be carried out as a mitigation effort and targeted development planning. On Saturday, May 11, 2024, flash floods and landslides hit several regencies and cities in West Sumatra, causing casualties and considerable material losses (Sanjaya 2024). South Sulawesi and West Sumatra provinces were the areas most severely affected by this natural disaster during May this year (Taufani 2024). The areas affected by cold lava floods and landslides in West Sumatra are Agam, Tanah Datar, Padang Panjang, Padang Pariaman, and Padang City. The cause of the floods and landslides in West Sumatra was moderate to heavy rainfall and cold lava material from the eruption of Mount Marapi that was carried away by the water (Utama 2024).

Coordinating Minister for Human Development and Culture Muhadjir Effendy said that West Sumatra is a disaster-prone area. He continues to coordinate with relevant parties to find a permanent solution to floods and landslides in West Sumatra. "West Sumatra is the province with the highest risk among other provinces in Indonesia, because in 2023 alone, out of 5,400 disaster events in Indonesia, 460 of them occurred in West Sumatra (Sanjaya 2024). Head of the Rehabilitation and Reconstruction Division of the West Sumatra Regional Disaster Management Agency (BPBD) Ilham Wahab said that the

death toll of West Sumatra's flash floods and landslides had reached 57 people. The distribution of the victims of flash floods and landslides in West Sumatra was in Agam as many as 21 people, Tanah Datar as many as 21 people, Padang Panjang as many as two people, Padang Pariaman as many as eleven people, and Padang as many as two people. In addition, BPBD West Sumatra also noted that 32 people were reported missing. The missing victims came from Agam as many as two people, Tanah Datar as many as 20 people, and Padang Pariaman as many as ten people. Meanwhile, 16 people in Agam and 20 people in Tanah Datar were reported injured (Sanjaya 2024). A total of 4,491 residents are still displaced due to flash floods and landslides that hit West Sumatra. The number of refugees is spread in Agam as many as 2,039 residents and in Tanah Datar as many as 2,452 residents (Main 2024). BPBD West Sumatra also noted that the death toll that had been identified was six residents in Agam, 15 residents in Tanah Datar, one resident in Padang Panjang, and eight residents in Padang Pariaman. The number of death victims who have not been identified is three people, all of whom came from Padang Pariaman. To address this issue, it is important for the government and researchers to have a better understanding of flood-prone areas in the province. One effective way to obtain this information is through the use of technologies such as remote sensing and geographic information systems (GIS), which can be combined with machine learning for analysis and prediction (Rakuasa 2023; Wang et al. 2023).

The development of machine learning technology opens up new opportunities in improving the accuracy and efficiency of mapping flood-prone areas (Rahman et al. 2019). With its ability to learn patterns from large and diverse data, machine learning can identify factors that cause flooding more comprehensively and predict risk areas more accurately (Sugandhi & Rakuasa 2023). West Sumatra Province has a varied topography, from lowlands to mountains, and is influenced by tropical climate conditions. The characteristics of this region make some areas prone to flood disasters, both those caused by high rainfall and sea tides. Identifying flood-prone areas in the province is crucial to protect communities and infrastructure from the impacts of disasters (Rakuasa et al., 2022; Latue & Rakuasa 2023). By integrating remote sensing data, GIS, and machine learning, a more accurate and comprehensive mapping of flood-prone areas in West Sumatra Province is expected. This will help the local government and related institutions in planning disaster mitigation strategies, early warning, and post-disaster management more effectively.

In addition, the results of this mapping can also be utilized for spatial planning and infrastructure development that considers flood vulnerability factors (Rakuasa et al., 2022; Muin & Rakuasa 2023). Thus, losses due to disasters can be minimized, and development can be carried out sustainably by taking into account community safety aspects (Latue et al., 2023). In this research, machine learning will be implemented to analyze various factors that cause flooding, such as rainfall, topography, soil type, land cover, and proximity to rivers or the sea (Muin, A., & Rakuasa 2023). Methods such as Random Forest or Artificial Neural Networks will be used to learn patterns from historical flood data and generate accurate prediction models (Rakuasa et al., 2023).

Remote sensing data, such as multispectral satellite images and digital elevation data, will be utilized to extract information related to land cover, slope, and other hydrological characteristics (Muin et al., 2023). Meanwhile, GIS will be used to integrate and analyze spatial data from various sources, and present the mapping results in the form of interactive and easily accessible digital maps (Rakuasa and Latue 2023). With this approach, it is expected to obtain more accurate and comprehensive information about flood-prone areas in West Sumatra Province. The results of this research will be very useful for local governments, disaster management agencies, and communities in mitigation and adaptation efforts to flood disasters in the future. Based on the above background, this research aims to identify flood-prone areas in West Sumatra Province using remote sensing data and machine learning-based geographic information systems.

METHOD

This research was conducted in West Sumatra Province, Indonesia. The variables used in this study consisted of distance from the river, Normalized Difference Water Index (NDWI), elevation, Topographic Position Index (TPI), Normalized Difference Vegetation Index (NDVI) and Rainfall Data which were all analyzed on the Google Earth Engine (GEE) platform; https://earthengine.google.com. A free cloud

computing platform provided by Google to access, manipulate and analyze geospatial data from various sources, including satellite imagery, maps and other data (Muntaga 2019). GEE is a petabyte-scale data-driven tool for open geospatial data analysis and archiving (Gorelick et al. 2017). Its computing infrastructure is built for geospatial data processing and visualization of spatial analysis from satellite images. GEE allows users to access large amounts of geospatial data from various sources such as Landsat, Sentinel, MODIS, and others. This facilitates remote sensing analysis such as change detection, trend mapping, and quantification of differences on the Earth's surface. GEE provides programming interfaces (APIs) in Python and JavaScript, as well as a web-based code editor for interactive algorithm development with instant access to petabytes of data (Manakane et all., 2023). Flood-prone areas in West Sumatra Province are classified into 5 classes, namely low, medium, high and very high. The results of the flood potential analysis are then overlaid with data on the distribution of built-up land in West Sumatra Province to determine the built-up land affected by flooding.

RESULT AND DISCUSSION

Flood-prone areas are areas that have a high risk of flooding, which can result in various negative impacts such as fatalities and injuries, property damage, economic losses, environmental damage, and clean water crisis (Sugandhi et all., 2023). Prevention and preparedness are essential in reducing the impact of floods, including early warning, flood infrastructure development, public education, and weather monitoring. Flooding is a natural disaster that is often devastating and can affect human life, the economy, and the environment, so appropriate mitigation and adaptation efforts are needed to protect communities and their assets (Rakuasa et al., 2023).

The results of the analysis show that areas that have the potential to experience flooding with different levels of intensity. The low flood potential level covers an area of 2,496,434.17 hectares, which represents 59.22% of the total area mentioned. This indicates that most areas in West Sumatra are within a relatively safe zone from flooding, although there are still risks to be aware of. The moderate flood potential level covers an area of 1,018,107.15 hectares, which represents 24.15% of the total area. This indicates that there are a number of areas within the moderate flood risk zone, which require special attention in planning and mitigation. The high flood potential level covers an area of 658,966.82 hectares, which represents 15.63% of the total area. These areas are within the high flood risk zone and require more intensive intervention and mitigation planning. The very high flood potential level covers an area of 42,370.24 hectares, which represents 1.01% of the total area.

From the analysis of flood-prone areas, it can be concluded that while most of West Sumatra is within the low to moderate flood risk zone, there are a number of areas that are within the high to very high flood risk zone. This highlights the importance of comprehensive flood planning and mitigation, including risk assessment, development of appropriate infrastructure, and community education on flood hazards and how to deal with them. These areas are the highest flood risk zones and require quick and effective mitigation measures to reduce flood risks and impacts.

The flood-prone areas were then overlaid with settlement data. Settlements potentially affected by flooding at the low flood potential level cover an area of 32,040.23 hectares of affected settlements, which represents 61.81% of the total area of affected settlements. This indicates that most settlements in West Sumatra are within a relatively safe zone from flooding, although there are still risks that must be considered. Flood-affected settlements in areas with moderate flood potential cover an area of 3,268.56 hectares, which represents 6.31% of the total area. This indicates that there are a number of settlements within the moderate flood risk zone, which require special attention in planning and mitigation. Flood-affected settlements in areas with a high potential flood level cover an area of 13,066.04 hectares, which represents 25.21% of the total area. These settlements are within high flood risk zones and require more intensive intervention and mitigation planning. Flood-affected settlements

in areas with a very high level of flood potential cover an area of 3,459.09 hectares, which represents 6.67% of the total area. These settlements are the highest flood risk zones and require quick and effective mitigation measures to reduce flood risks and impacts. The flood-prone areas of West Sumatra Province can be seen in Figure 1.

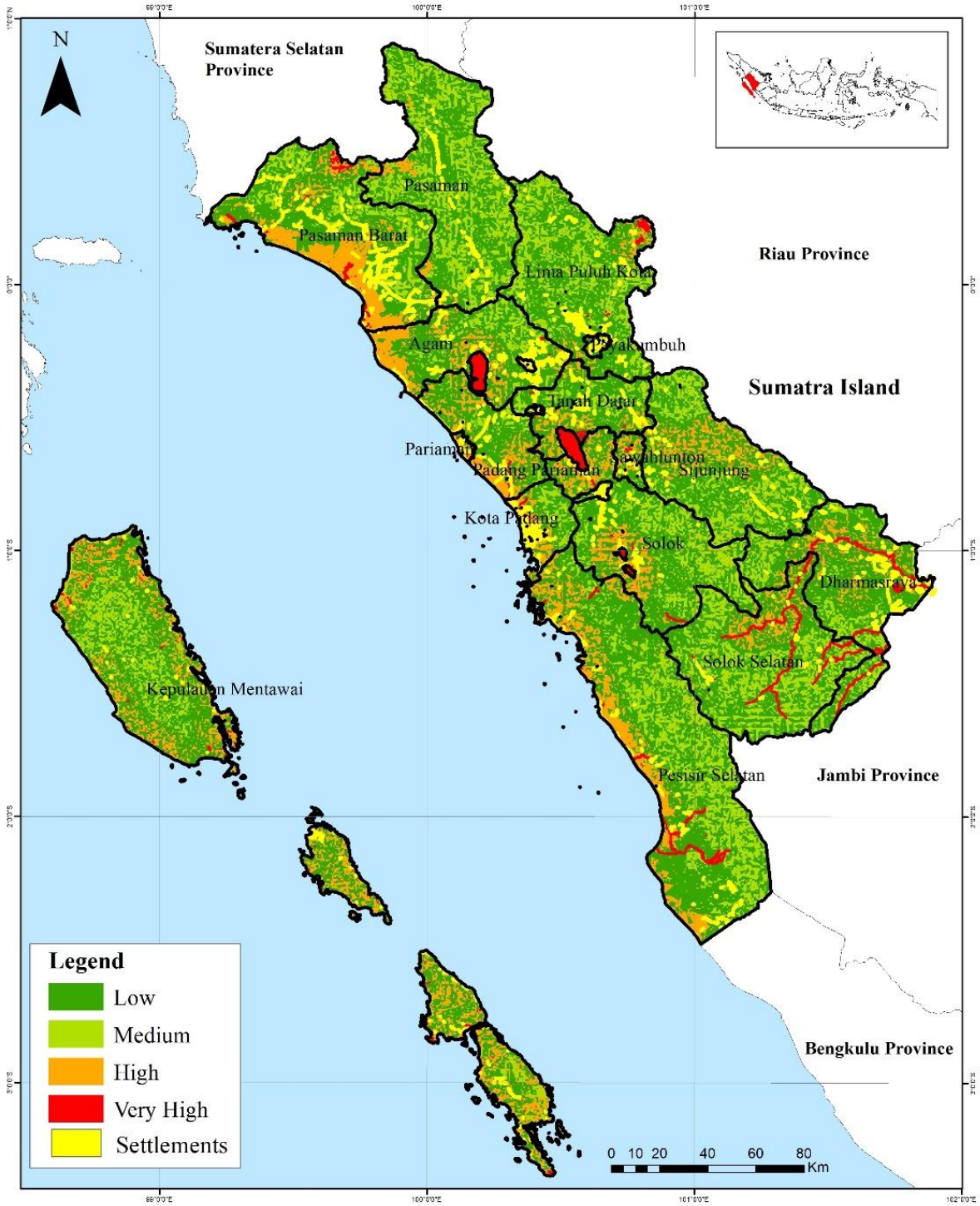

Figure 1: Flood-prone areas of Sumatra Barat Province

From these results, it can be concluded that while most settlements in West Sumatra are within low to moderate flood risk zones, there are a number of settlements that are within high to very high flood risk

zones. This highlights the importance of comprehensive flood planning and mitigation, including risk assessment, development of appropriate infrastructure, and community education on flood hazards and how to overcome them. Identifying Flood Prone Areas in West Sumatra Province using remote sensing data and machine learning-based geographic information systems provides significant benefits in dealing with and reducing flood risks. Here are some of the key benefits:

1) Flood Risk Prediction: This method makes it possible to predict the areas most vulnerable to flooding with a high degree of accuracy. These predictions are crucial for flood planning and mitigation, allowing governments and communities to take preventive actions before a disaster occurs (Muin & Rakuasa 2023b).
2) Resource Optimization: With the identification of flood-prone areas, the government can optimize resource allocation for flood infrastructure development and drainage system improvement. It also helps in more efficient completion of development priorities (Agustina 2017).
3) Public Education and Awareness: Information on flood-prone areas can be used to raise public awareness about the dangers of flooding and the importance of planning and preparation. This education can help communities to take precautions and be prepared for flooding (Kodoatie 2021).
4) Improved Neighborhood Safety: By understanding the areas most vulnerable to flooding, steps can be taken to safeguard and sustain local ecosystems. This includes the preservation of forests and natural habitats that contribute to the water cycle and flood mitigation (Sitorus et al., 2021).
5) Technology Development and Research: The implementation of this method also supports the development of new technologies and research in remote sensing, geographic information systems, and machine learning (Aziza et al., 2021). This can open up new opportunities for research and innovation in dealing with other natural disasters.

Overall, the identification of flood-prone areas in West Sumatra Province using remote sensing data and machine learning-based geographic information systems offers an integral solution to reduce flood risk and improve community resilience to natural disasters.

CONCLUSION

This research shows that the use of remote sensing data and Machine Learning-based Geographic Information Systems can provide more accurate and comprehensive mapping of flood-prone areas in West Sumatra Province. By integrating machine learning technology, information from various variables such as distance from river, NDWI, elevation, TPI, NDVI, and rainfall data can be used to identify factors that cause flooding more comprehensively. The results of this mapping can help local governments and related agencies plan disaster mitigation strategies, early warnings, and post-disaster management more effectively. In addition, the identification of flood-prone areas can also support resource optimization, community education, environmental safety improvement, and the development of new technologies and research in remote sensing, GIS, and machine learning. Overall, this research makes an important contribution to reducing flood risk and increasing community resilience to natural disasters in West Sumatra Province.

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