Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 24 | No. 4 | Article ID D1756 | 2025

Original Research Paper

https://doi.org/10.46488/NEPT.2025.v24i04.D1756

Open Access Journal

Flood Risk Modelling Based on Machine Learning Using Google Earth Engine in Hulu Sungai Utara Regency

Krisna Aditya, Ichsan Ridwan† and Nurlina
Department of Geophysics, Lambung Mangkurat University, Indonesia
†Corresponding author: Ichsan Ridwan; ichsanridwan@ulm.ac.id

Abbreviation: Nat. Env. & Poll. Technol.
Website: www.neptjournal.com

Received: 18-12-2024
Revised: 05-02-2025
Accepted: 27-02-2025

Key Words:

Flood risk modelling
Machine learning
Google Earth Engine
Remote sensing
Flood susceptibility mapping

Citation for the Paper:

Aditya, K., Ridwan, I. and Nurlina, 2025. Flood risk modelling based on machine learning using Google Earth Engine in Hulu Sungai Utara Regency. *Nature Environment and Pollution Technology*, 24(4), D1756. https://doi.org/10.46488/NEPT.2025.v24i04.D1756

Note: From 2025, the journal has adopted the use of Article IDs in citations instead of traditional consecutive page numbers. Each article is now given individual page ranges starting from page 1.

ABSTRACT

Flood risk modeling is essential for effective disaster mitigation, particularly in flood-prone areas such as Hulu Sungai Utara Regency, Indonesia. This study leverages Google Earth Engine (GEE) to integrate multi-source satellite data and machine learning techniques for flood susceptibility mapping. Key geospatial variables, including the Normalized Difference Vegetation Index (NDVI), elevation, distance from rivers, and the Topographic Position Index (TPI), were analyzed using a weighted overlay method within GEE. A supervised classification approach was employed to enhance accuracy, and validation was performed using historical flood event data. The results indicate that 51.66% (47,875.86 ha) of the study area falls into the low-risk category, 42.90% (39,763.08 ha) is at moderate risk, and 5.44% (5,040.36 ha) is highly susceptible to flooding. This study highlights the advantages of GEE in large-scale flood risk assessments by enabling real-time processing, high computational efficiency, and seamless integration of geospatial datasets. The findings provide critical insights for local governments and disaster management agencies to develop proactive flood mitigation strategies.

INTRODUCTION

Flooding is a natural phenomenon that significantly disrupts communities, causing property damage, economic loss, and threats to human life (Rafiei-Sardooi et al. 2021). Defined as the overflow of water into normally dry areas, flooding can result from increased water levels in reservoirs, streams, canals, and coastal regions (Chan et al. 2022). In Hulu Sungai Utara Regency, flooding is a persistent issue, affecting nearly all parts of the region annually (Radani et al. 2024). These floods severely impact local livelihoods, inundating agricultural lands, settlements, and economic zones. Among the key contributing factors are land cover changes in the Barito watershed, which have led to soil degradation and increased flood frequency (Muin & Rakuasa 2023, Suwaji & Anisari 2024). The socio-economic consequences of these floods continue to escalate, making it crucial to understand the underlying causes and develop effective mitigation strategies (Di Mauro et al. 2022). Analyzing flood risk in Hulu Sungai Utara Regency requires an integrated approach that considers land use changes, precipitation patterns, and hydro-meteorological characteristics (Rakuasa et al. 2023).

Hulu Sungai Utara Regency's high susceptibility to flooding is largely due to its low-lying topography and proximity to rivers. Additional contributing factors include rising sea levels, increased river discharge, and extreme rainfall events (Hossain & Meng 2020). Identifying vulnerable areas, predicting flood impacts, and developing mitigation strategies are essential for reducing flood risks through flood risk modeling (DeVries et al. 2020, Muin et al. 2023b). Hydrological modeling provides a systematic method for flood hazard assessment (Cea & Costabile 2022). Moreover, integrating artificial intelligence (AI) technologies, such as those available through Google Earth Engine (GEE), enhances the accuracy and efficiency of flood risk modeling (Yang et al. 2022).

Advancements in geospatial technology over the past decade have improved flood vulnerability assessments (Rinaldi & Rakuasa 2023). Google Earth Engine (GEE) has emerged as a powerful platform for large-scale earth science data analysis, leveraging temporal Earth Observation (EO) datasets, including Landsat imagery. GEE has been widely applied in various global and regional studies, such as mapping surface water, land cover, population distribution, food security, and elevation modeling (Mehmood et al. 2021). The ability of GEE to process vast amounts of geospatial data in real time allows researchers, governments, and policymakers to conduct detailed flood risk analyses with unprecedented precision (Manakane et al. 2023).

By leveraging GEE for flood risk assessment, this study aims to enhance understanding of flood patterns, potential inundation areas, and their impacts on communities and ecosystems (Manakane et al. 2023). Integrating multiple geospatial and hydrological variables provides a comprehensive assessment of flood susceptibility in Hulu Sungai Utara Regency (Ermida et al. 2020). This research contributes new insights by demonstrating the effectiveness of GEE in flood modeling and how its integration with hydrological data can improve flood risk analysis. The findings will help inform local policies, disaster preparedness strategies, and sustainable urban planning efforts, ultimately strengthening resilience against future flood events (Sugandhi & Rakuasa 2023).

MATERIALS AND METHODS

This study was conducted in Hulu Sungai Utara Regency, located in South Kalimantan Province, Indonesia. The research utilized various datasets, including the JRC Global Surface Water Mapping Layers v1.4, NASA SRTM Digital Elevation data (30m resolution), USGS Landsat 8 Level 2, Collection 2, Tier 1 data, and boundary data for the study area. The variables analyzed in this study include elevation data, NDVI and NDWI indices, permanent water presence, and proximity to water sources. Additional variables such as land elevation and the Topographic Position Index (TPI), which indicates whether a pixel is higher or lower relative to its surroundings, can be derived by further processing the data.

To model flood risk in Hulu Sungai Utara, a composite value is generated by integrating various factors contributing to flooding. For example, proximity to rivers or permanent water bodies is considered; areas closer to these features are more likely to flood. Elevation is a crucial element, as low-lying regions are more susceptible to flooding than higher altitudes. However, elevation alone is insufficient, as additional topographic factors, such as the Topographic Position Index (TPI), provide insight into a location's position relative to the surrounding terrain. Vegetation also plays a role, as areas with dense vegetation are generally less susceptible to flooding than barren or water-resistant regions. This makes NDVI a useful tool for modeling vegetation coverage. By combining these variables, the area can be marked to indicate its degree of flood susceptibility using all of these factors (Table 1) (Phongsapan et al. 2019, Sugandhi & Rakuasa 2023).

Table 1: Flood Susceptibility Variables Ranking Score.

No.	Variables	Description	Score
1	Distance From Water	> 200 meters	1
		150 – 200 meters	2
		100 – 149 meters	3
		50 – 99 meters	4
		< 50 meters	5
2	Elevation	> 20 meters	1
		15 – 20 meters	2
		10 – 14 meters	3
		5 – 9 meters	4
		< 5 meters	5
3	TPI	> 0	1
		0 – -0,25	2
		-0,25 – -0,5	3
		-0,5 – -0,75	4
		< -0,75	5
4	NDVI	> 0,8	1
		0,8 – 0,6	2
		0,6 – 0,4	3
		0,4 – 0,2	4
		< 0,2	5
5	NDWI	< -0,6	1
		-0,6 – -0,2	2
		-0,2 – 0,2	3
		0,2 – 0,6	4
		> 0,6	5

Table 2: Flood Susceptibility Scores.

No.	Total Variable Score	Flood Susceptibility Score	Description
1	< 8	1	Low Susceptibility
2	9 - 12	2	Medium Susceptibility
3	13 - 16	3	High Susceptibility

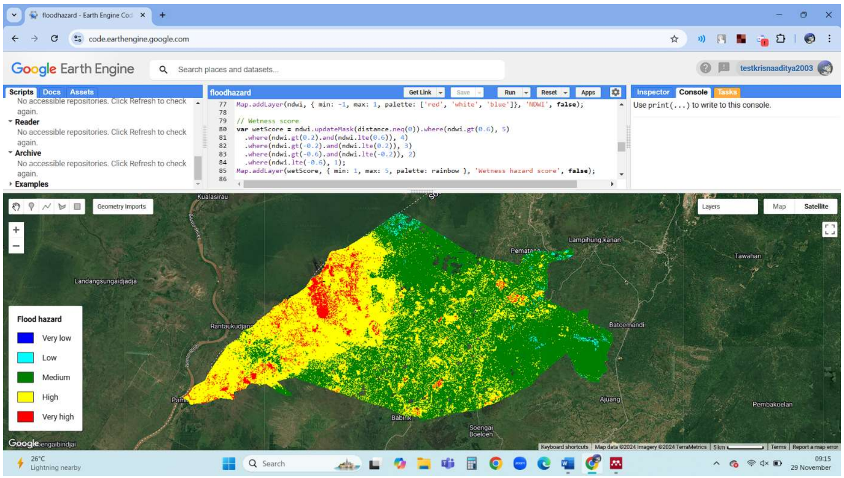

Fig. 1: Display of Flood Risk Modeling Process in Google Earth Engine.

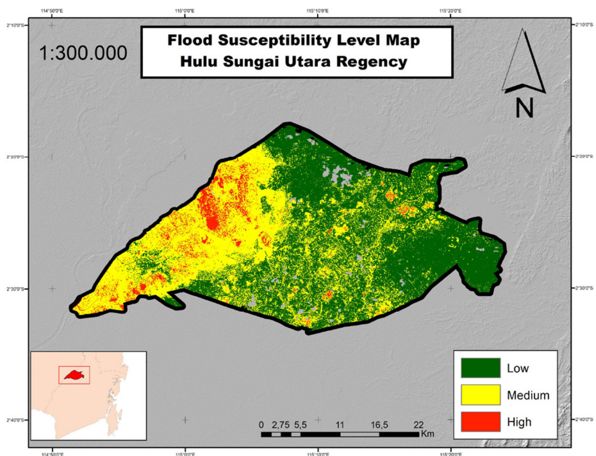

Fig. 2: Flood susceptibility level map in Hulu Sungai Utara Regency.

Once every variable has been evaluated. Flood susceptibility can then be modeled by adding up all variable values and recalculating them to calculate the level of susceptibility. The hierarchy of flood susceptibility is outlined in Table 2. A modified script from earlier researchers is used to process and analyze study data entirely in the Google Earth Engine (https://earthengine.google.com/) (Fig. 1). Following the analysis of flood-prone locations in Hulu Sungai Utara Regency, the results were divided into three categories: low, medium, and high susceptibility.

RESULTS AND DISCUSSION

The findings revealed that the area vulnerable to floods in the low-risk category is 47,875.86 hectares, constituting 51.66%; the area in the moderate-risk category is 39,763.08 hectares, representing 42.90%, and 5,040.36 hectares, or 5.44%, are classified as high risk for flooding. The detailed distribution of flood susceptibility levels is illustrated in Fig. 2.

A critical aspect of flood risk analysis is understanding the role of elevation in determining flood-prone areas. Elevation is defined as the height of a region above sea level or the nearest riverbank. The extent to which a region can be impacted by flooding depends largely on elevation. Lower elevations are more susceptible to flooding, resulting in possible infrastructure damage, property loss, and fatalities (Rinaldi & Rakuasa 2023). The elevation of a river also influences flood danger. Rivers with lower beds are more susceptible to flooding with intense rainfall (Latue & Latue 2023). When river water ascends and inundates elevated regions, low-lying places adjacent to rivers may suffer from significant flooding. Comprehending the interplay between elevation and elements such as precipitation, river dynamics, soil conditions, and drainage systems is crucial for efficient flood risk management (Muin et al. 2023a). By acknowledging these relationships, governments and communities can implement suitable measures to safeguard particularly sensitive regions from flood risks.

Flood risk analysis in Hulu Sungai Utara Regency provides several critical advantages for flood hazard management and impact mitigation. Firstly, it enables the precise identification of areas prone to flooding, helping governments and stakeholders focus their disaster management efforts on regions with the greatest need. This targeted approach ensures that resources and interventions are deployed where they are most effective, minimizing potential damage and loss of life (Shankar 2024). Secondly, the analysis provides deeper insights into the various factors contributing to floods, such as land use, terrain characteristics, river flow dynamics, and rainfall patterns. By understanding these interrelated factors, policymakers and researchers can identify the root causes of flooding and prioritize long-term solutions tailored to the local context.

Despite the advantages of using Google Earth Engine (GEE) for flood risk analysis, certain limitations and potential errors in data processing must be considered. One primary concern is the resolution of satellite imagery, which may not always provide the fine-scale detail required for localized flood assessments. The accuracy of elevation data, such as that derived from the Shuttle Radar Topography Mission (SRTM), is subject to inherent errors, particularly in areas with dense vegetation or significant topographical variations. Additionally, Normalized Difference Vegetation Index (NDVI) and other indices used for vegetation analysis may be influenced by seasonal changes, leading to inconsistencies in flood vulnerability assessments. The automated classification processes in GEE, while efficient, may introduce biases due to algorithmic assumptions that do not always align with real-world conditions. Addressing these limitations requires integrating higher-resolution datasets, validation with ground truth data, and continual refinement of analytical methodologies.

Flood risk analysis in Hulu Sungai Utara Regency provides several critical advantages for flood hazard management and impact mitigation. Firstly, it enables the precise identification of areas prone to flooding, helping governments and stakeholders focus their disaster management efforts on regions with the greatest need. This targeted approach ensures that resources and interventions are deployed where they are most effective, minimizing potential damage and loss of life (Shankar 2024). Secondly, the analysis provides deeper insights into the various factors contributing to floods, such as land use, terrain characteristics, river flow dynamics, and rainfall patterns. By understanding these interrelated factors, policymakers and researchers can identify the root causes of flooding and prioritize long-term solutions tailored to the local context.

The results of this study have direct implications for local policy and urban planning in Hulu Sungai Utara Regency. The identification of high-risk areas provides an evidence-based foundation for zoning regulations, ensuring that new developments avoid flood-prone zones. Policymakers can use the findings to prioritize infrastructure improvements, such as constructing flood barriers, improving drainage networks, and reinforcing embankments in vulnerable regions. Additionally, the data can guide the implementation of nature-based solutions, including reforestation and wetland restoration, to enhance natural flood mitigation. The study also underscores the need for robust early warning systems and disaster preparedness programs, which can be integrated into local emergency response strategies. By incorporating these findings into regional planning and governance, authorities can enhance resilience against future flood events while promoting sustainable development in flood-affected areas.

CONCLUSIONS

The use of Google Earth Engine to analyze flood susceptibility in Hulu Sungai Utara Province demonstrates the future potential of geospatial technology for managing flood risks in susceptible locations. This technology allows real-time access to high-quality satellite data and comprehensive mapping capabilities, enabling the government and interested parties to manage flood problems more effectively. The findings revealed that 47,875.86 hectares (51.66%) of the area fall into the low flood risk category, 39,763.08 hectares (42.90%) are classified as moderate risk, and 5,040.36 hectares (5.44%) are considered high-risk areas. This would help Hulu Sungai Utara improve spatial planning, flood management, and preventative measures to safeguard citizens and crucial resources in the region.

ACKNOWLEDGMENTS

Thank you to the Regional Development Planning, Research and Development Agency of Hulu Sungai Utara Regency for cooperating in this research. Thank you to the Ministry of Education, Culture, Research, and Technology, which has funded this study with a National Competitive Applied Research Grant [Number 056/ E5/PG.02.00.PL/2024].

REFERENCES

Cea, L. and Costabile, P., 2022. Flood risk in urban areas: modelling, management and adaptation to climate change: a review. *Hydrology*, 9(3), pp. 150-165. DOI

Chan, S.W., Abid, S.K., Sulaiman, N., Nazir, U. and Azam, K., 2022. A systematic review of the flood vulnerability using a geographic information system. *Heliyon*, 8(3), pp. 320-335. DOI

DeVries, B., Huang, C., Armston, J., Huang, W., Jones, J.W. and Lang, M.W., 2020. Rapid and robust monitoring of flood events using Sentinel-1 and Landsat data on the Google Earth Engine. *Remote Sensing of Environment*, 240, p. 111664. DOI

Di Mauro, C., Hostache, R., Matgen, P., Pelich, R., Chini, M., van Leeuwen, P.J., Nichols, N. and Blöschl, G., 2022. A tempered particle filter to enhance the assimilation of SAR-derived flood extent maps into flood forecasting models. *Water Resources Research*, 58(8), pp. e2022WR031940. DOI

Ermida, S.L., Soares, P., Mantas, V., Göttsche, F.M. and Trigo, I.F., 2020. Google Earth Engine open-source code for land surface temperature estimation from the Landsat series. *Remote Sensing*, 12(9), pp. 1471–1485. DOI

Hossain, M.K. and Meng, Q., 2020. A fine-scale spatial analytics of the assessment and mapping of buildings and population at different risk levels of urban flood. *Land Use Policy*, 99, p. 104829. DOI

Latue, T. and Latue, P.C., 2023. Spatial modelling of flood-prone areas in Batu Merah watershed, Ambon city. *Buana Journal of Geography, Ecology and Disaster*, 1(1), pp. 1–13. DOI

Manakane, E., Latue, C., Somae, G., Rakuasa, H., Manakane, S.E. and Latue, P.C., 2023. Flood risk modeling in Buru Island, Maluku Province, Indonesia using Google Earth Engine. *MULTIPLE: Journal of Global and Multidisciplinary*, 1(2), pp. 80–87. https://journal.institercom-edu.org/index.php/multiple.

Mehmood, H., Conway, C. and Perera, D., 2021. Mapping of flood areas using Landsat with the Google Earth Engine cloud platform. *Atmosphere*, 12(7), pp. 866–881. DOI

Muin, A. and Rakuasa, H., 2023. Evaluation of spatial planning in Ambon City based on flood vulnerability aspects. *Multidisciplinary Scientific Journal*, 2(5), pp. 1727–1738.

Muin, A., Rakuasa, H. and Kunci, K., 2023a. Utilization of geographic artificial intelligence (Geo-AI) for flood-prone area identification in Ambon city. *Gudang Multidisciplinary Science Journal*, 1(2), pp. 58–63.

Muin, A., Somae, G. and Rakuasa, H., 2023b. Analysis of flood inundation potential in Siwalalat district, East Seram Regency, based on topographic wetness index. *Multidisciplinary Scientific Journal*, 2(5), pp. 1800–1806.

Phongsapan, K., Chishtie, F., Poortinga, A., Bhandari, B., Meechaiya, C., Kunlamai, T., Aung, K.S., Saah, D., Anderson, E., Markert, K., Markert, A. and Towashiraporn, P., 2019. Operational flood risk index mapping for disaster risk reduction using earth observations and cloud computing technologies: a case study on Myanmar. *Frontiers in Environmental Science*, 7, pp. 191–205. DOI

Radani, Arpandi and Saidah, H., 2024. Flood disaster management at regional disaster management agency (BPBD) Hulu Sungai Utara regency: case study of Amuntai Selatan and Amuntai Tengah. *Human Resource Management Journal*, 1(3), pp. 737–747.

Rafiei-Sardooi, E., Azareh, A., Choubin, B., Mosavi, A.H. and Clague, J.J., 2021. Evaluating urban flood risk using hybrid method of TOPSIS and machine learning. *International Journal of Disaster Risk Reduction*, 66, p. 102614. DOI

Rakuasa, H., Somae, G. and Latue, P.C., 2023. Mapping flood-prone areas in Batumerah village, Sirimau district, Ambon city, using geographic information systems. *Multidisciplinary Scientific Journal*, 2(4), pp. 1642–1653.

Rinaldi, M. and Rakuasa, H., 2023. Bogor regency uses DEMNAS data with the topographic wetness index method. *Multidisciplinary Scientific Journal*, 2(6), p. 2269.

Shankar, A., 2024. Dynamic impact-based heavy rainfall warning with multi-classification machine learning approaches. *Nature Environment and Pollution Technology*, 23(4), pp. 1885–1900. DOI

Sugandhi, N. and Rakuasa, H., 2023. Utilization of Google Earth Engine for flood hazard analysis in DKI Jakarta province. *Journal of Multidisciplinary Research and Technology Innovation*, 1(2), pp. 40–49. DOI

Suwaji and Anisari, R., 2024. Analysis of rain intensity calculation based on rainfall data from the rain station in Amuntai city, Hulu Sungai Utara district. *Multidisciplinary Madani Journal*, 4(7), pp. 1006–1016. DOI

Yang, L., Driscol, J., Sarigai, S., Wu, Q., Chen, H. and Lippitt, C.D., 2022. Google Earth Engine and artificial intelligence (AI): A comprehensive review. *Remote Sensing*, 14(14), pp. 3253–3275. DOI.