JURNAL GEOGRAFI DOI : https://doi.org/10.26740/jggp.v23n1.p223-238
Geografi dan Pengajarannya
ISSN : 1412 - 6982
e-ISSN : 2443-3977
Volume 23, Number 1, June 2025
https://journal.unesa.ac.id/index.php/jg

SPATIAL ANALYSIS OF URBAN FLOOD VULNERABILITY USING WEIGHTED OVERLAY TECHNIQUE FOR IDENTIFICATION OF HAZARD ZONES IN GREATER JAKARTA

Ikhlas Nur Muhammad*[1], Sarpono Sarpono[2], Agus Wibowo[3], Rachmat Setiawibawa[1], Anwar Kurniadi[1]
[1]Master Department of Disaster Management Program, Indonesia Defense University, Bogor, Indonesia
[2]Directorate of Census and Survey Methodology Development at the Central Bureau of Statistics, Indonesia
[3]Directorate of Disaster Management System of the Indonesia Disaster Management Agency, Indonesia

ARTICLE INFO

Article history:
Received 18 May 2025
Revised 22 May 2025
Accepted 27 May 2025

***Keywords*:**
Flood Hazard Mapping, Geospatial Analysis, Climate Resilience

ABSTRACT

This study assessed flood hazards in the Greater Jakarta area, Indonesia, using geospatial analysis and the weighted overlay method in a Geographic Information System (GIS). There are variables used, which are vegetation index, wetness index, Topographic Position Index (TPI), distance to water bodies, and altitude. The classification results showed five levels of hazards: very low (0.48%), low (1.60%), medium (28.70%), high (48.96%) and very high (20.26%). A total of 69.22% of the study area of 6,724.18 km² was classified as high to very high. The findings emphasise the need for risk-based zoning and mitigation strategies, such as improved drainage and land use regulation. This research highlights the role of geospatial technology in supporting climate adaptation planning, in line with Sustainable Development Goal (SDG) 13, to increase the resilience of coastal-urban areas to increased flood threats due to climate change.

A. INTRODUCTION

Floods are one of the most frequent natural disasters in Indonesia, totalling at least 55% of the total disasters in Indonesia in 2024 (BNPB, 2024). Flooding is defined as the overflowing of water from water bodies such as rivers, lakes, or seas that inundate normally dry land. This phenomenon can occur due to various factors, both natural and anthropogenic (Malik, 2022). A comprehensive understanding of the spatial patterns of flood vulnerability is crucial for decision-making and strategic planning in the context of disaster mitigation in complex urban areas.

Greater Jakarta is the largest metropolitan area in Indonesia with a high vulnerability to floods. As the economic, political and cultural centre of Indonesia, Greater Jakarta is experiencing rapid population growth and urbanisation, which has a significant impact on land use change and hydrological system. Massive land development (Han et al., 2020) and inadequate drainage systems that cannot

*Correspondence address: ikhlasnurmuhammad@gmail.com

effectively handle stormwater discharge (Bibi et al., 2023; Iftikhar & Iqbal, 2023) are the primary factors driving the increased frequency and severity of flooding in urban areas like Greater Jakarta.

The physical conditions of Greater Jakarta that are very favourable for flooding include a very low topography and slopes that tend to be flat (Marfai et al., 2015). The National Disaster Management Agency (BNPB) notes that flooding is the most frequent natural disaster in Greater Jakarta. Greater Jakarta faced floods almost routine occurrences every year, especially during the rainy season. Historical data shows that major floods have hit Jakarta and its surroundings in 1996, 2002, 2007, 2013, 2020, and most recently in early 2025.

Floods in the Greater Jakarta area have a major impact on several sectors, including the economy. According to BNPB information, the loss of economic value in the 2025 Jabodetabek Flood is estimated at 1.69 trillion rupiah (Bisnis.com, 2025). This loss has not included the loss of community activities, such as education, health and so on. In the environmental ecosystem, this flood also has an impact on erosion in the water catchment area which is dangerous for settlements, and also siltation in rivers which has an impact on higher vulnerability in the upcoming flood (Siswanto & Francés, 2019).

This highlights the need for accurate flood hazards maps to aid mitigation and adaptation. The development of geographic information system and remote sensing opened up opportunities accurate and comprehensive flood vulnerability analysis (Amiri et al., 2024; Zhang et al., 2022). GIS enables better and more effective integration of spatial data from multiple sources, multi-criteria analysis, and visualisation of results in rapid decision-making (Mohammed et al., 2024; Muhammad et al., 2023; Nofirman et al., 2024).

One of the commonly used methods in GIS-based flood vulnerability analysis is the Weighted Overlay method. This method has proven effective in various environmental and urban studies (Alharbi, 2024; Nainggolan et al., 2024). Previous research on the study area by Safitri et al., (2023) studied the Tangerang area, Ariyani et al., (2024) who studied the focus on flooding in the Ciliwung watershed, and Puspitasari et al., (2024) who studied specifically in the South Jakarta area with the weighted overlay method.

In contrast to previous studies that focused on limited areas such as Tangerang, the Ciliwung watershed or South Jakarta, this study examines the Greater Jakarta area as a whole, which has a wider and more complex spatial coverage using a biophysical approach. In addition, this study also compares the results of the vulnerability mapping with official maps from BNPB to see how relevant and appropriate the analysis results are with existing institutional references. The results are also more detailed and therefore more targeted as they support specific disaster mitigation policy interventions in high-risk locations.

These studies integrated various spatial factors and produced flood vulnerability maps with a high level of accuracy. However, these studies are limited to smaller areas and have not covered the entire Greater Jakarta area, which has more complex hydrological and anthropogenic characteristics. The flood problem itself is not only generated by one area, but the combined neighbouring areas also have a contribution in creating vulnerability (D'Ayala et al., 2020; Kaźmierczak & Cavan, 2011; Sayers et al., 2018). This research examines the broader area of how flood vulnerability is distributed.

The purpose of this research is to identify and map the spatial flood vulnerability level in the Greater Jakarta area using a geospatial approach based on the weighted overlay method. This research specifically aims to evaluate the contribution of each physical environmental variable such as vegetation, soil moisture, Topographic Position Index (TPI), distance to water bodies, and elevation in forming flood vulnerability zones.

By integrating remote sensing data and cloud-based geographic information systems through the Google Earth Engine or GEE platform, this research produces flood hazard maps at a more detailed scale and broader coverage, and enables a faster and more efficient analysis process. The results are expected to support the formulation of disaster risk mitigation policies and spatial planning that are responsive to climate change, especially in vulnerable coastal urban areas such as Jabodetabek.

B. METHOD

B.1. STUDY AREA

This research focuses on assessing the vulnerability and mapping the distribution of flood hazards in the Greater Jakarta (Jakarta, Bogor, Depok, Tangerang and Bekasi) region that experienced major flooding in early March 2025. Greater Jakarta has diverse physical conditions, and has vulnerabilities that are contributed by many variables. This study aims to identify and map areas that have different levels of flood risk based on the physical and environmental characteristics of the area.

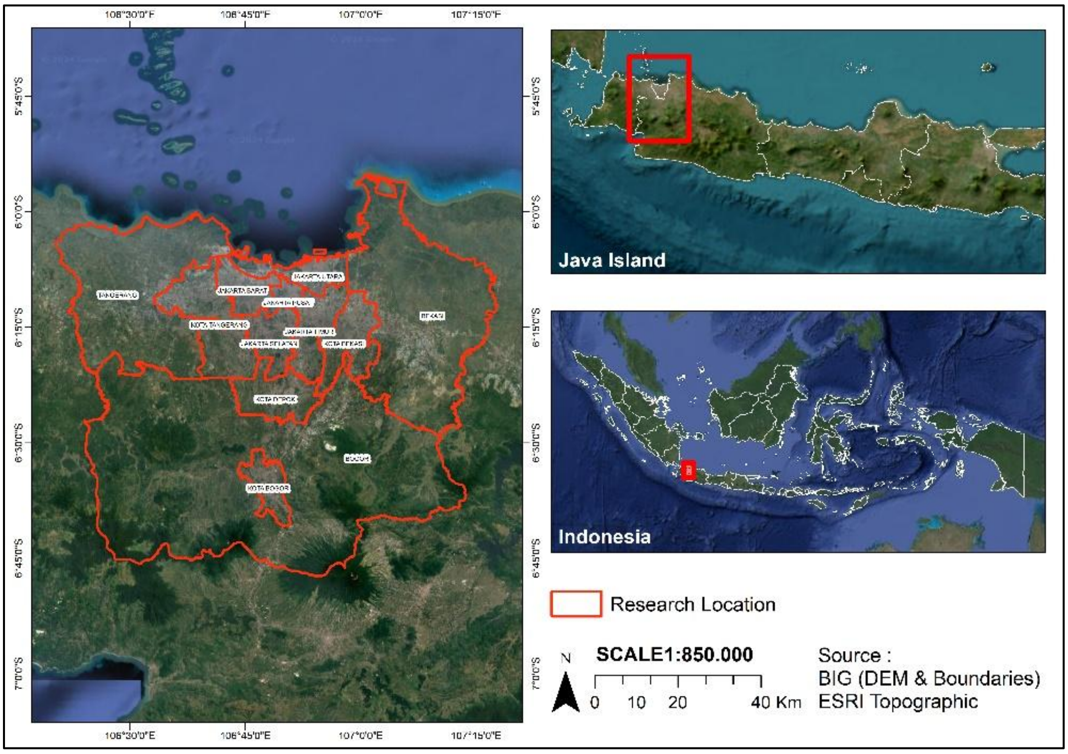

Figure 1. Greater Jakarta.
(Source: author, 2025)

B.2.WEIGHTED OVERLAY

This research adopts a quantitative descriptive approach, where data from mapping and spatial processing are systematically analysed and presented in the form of a comprehensive narrative to describe the level of flood hazard in the study area. The assessment of flood hazard levels was conducted through the application of the Weighted Overlay method, which is a multi-criteria weighting technique that allows the incorporation of several key variables that influence flood risk.

Proportionally weighting each variable based on its level of influence, this method is able to produce representative and spatially accurate flood hazard maps. Using a spatial analysis approach, this study integrates variables such as distance to water, topography, elevation, vegetation cover, and soil moisture to produce flood hazard maps that comprehensively illustrate the spatial distribution of flood hazards in the Greater Jakarta area. This approach facilitate integration of physical data to providing a comprehensive picture of the distribution and vulnerability level of flood hazards in the Greater Jakarta area. The results of the analysis are then interpreted descriptively to support a deeper understanding of the spatial patterns and factors of study areas.

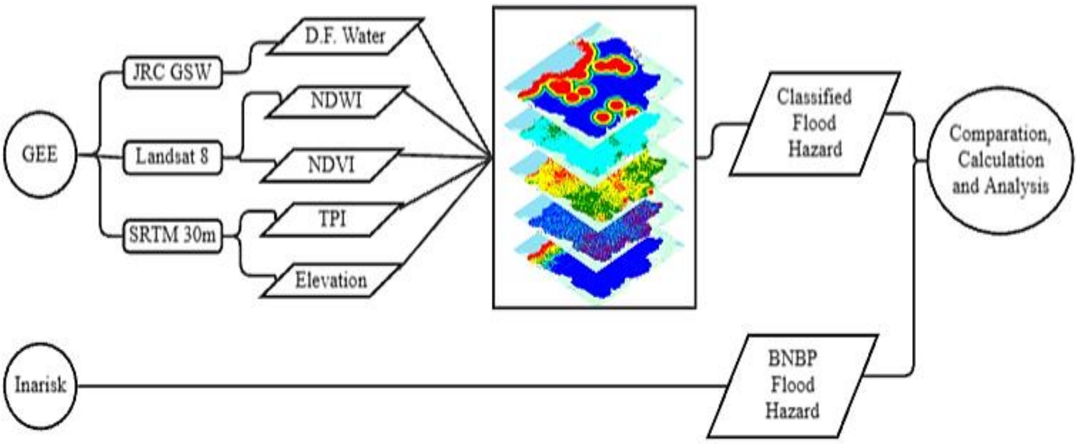

Figure 1. Research Workflow.
(Source: author, 2025)

This study adopted the weighting variables previously applied by Bello et al., (2024) in mapping flood hazards in Nigerian regions. In its application, this study uses a number of variables that play an important role in determining the level of vulnerability and flood hazard. The satellite imagery utilized in this study is Sentinel-2 data acquired in 2024, selected with a maximum cloud cover threshold of 10%. This filtering ensures optimal image clarity by minimizing atmospheric interference, thereby enhancing the accuracy of spectral information extraction.

This study integrates geospatial variables to model flood vulnerability including permanent water bodies, terrain morphology, elevation, vegetation index and moisture index. The JRC Global Surface Water Dataset, presence water in influence flood vulnerability (Agrawal et al., 2024; Babaei et al., 2018). The Topographic Position Index (TPI) characterises the landscape, where negative values are valleys and positive values (hills), which correspond to runoff accumulation (Seif, 2014). Elevation data from SRTM is used to identify low-lying areas, which are more vulnerable to flooding (Diriba & Karuppannan, 2024).

The vegetation index provides where areas with high vegetation density have the ability to absorb more water and can reduce flood risk (Soltani et al., 2021; Xue & Su, 2017). The Wetness Index highlights water-saturated zones and creates a higher risk (Khalifeh Soltanian et al., 2019; Muhammad et al., 2023). These parameters collectively inform the spatial framework for flood hazard assessment in this study. The following is a breakdown of the variables and the weighting of the assessment that occurred in Table 1.

Table 1. Flood hazard Variable

Variable	Score	Conditions	Data Source
Distance From Water (m)	1	> 4000	JRC Global Surface Water
	2	3000 - 4000	
	3	2000 - 3000	
	4	1000 - 2000	
	5	≤ 1000	
Topography Position Index	1	> 0	DEM SRTM 30m
	2	-0.2 to 0	
	3	-0.4 to -2	
	4	-0.6 to -0.4	
	5	≤ -0.8	
Elevation Score	1	> 20	DEM SRTM 30m
	2	15 - 20	
	3	10 - 15	
	4	5 - 10	
	5	≤ 5	
Vegetation Score	1	NDVI > 0.8	Sentinel 2
	2	0.6 < NDVI ≤ 0.8	
	3	0.4 < NDVI ≤ 0.6	
	4	0.2 < NDVI ≤ 0.4	
	5	NDVI ≤ 0.2	
Wetness Score	1	NDWI > 0.6	Sentinel 2
	2	0.2 < NDWI ≤ 0.6	
	3	-0.2 < NDWI ≤ 0.2	
	4	-0.6 < NDWI ≤ -0.2	
	5	NDWI ≤ -0.6	

(Source: Bello et al, 2024)

B.3.Product Accuracy

Validation in this study was conducted by comparing the results of flood hazard mapping produced officially by the National Disaster Management Agency (BNPB). The method used was statistical correlation analysis to measure the level of agreement between the two maps. Due to limitations in conducting direct field accuracy tests due to the vastness of the study area, field validation was replaced with a spatial approach based on raster data that was compared with the mapping results by the official institution, BNPB.

Correlation values were calculated through the extraction of raster data into point form. This process involved converting both hazard maps into raster format with the same resolution, then extracting their pixel values at identical locations. The values were then compared using statistical methods such as Pearson or Spearman tests to determine the level of correlation. This approach allows for objective evaluation without relying on time- and cost-consuming field surveys, and comparing with mappings that have been previously tested for validation.

C. RESULT AND DISCUSSION

C.1. RESULT

Flood hazard risk assessment measures the level of threat and likelihood of flooding by analysing factors that contribute to the vulnerability of an area. In this research, the assessment is conducted by combining geographical parameters such. The parameter contribute to vulnerability as hydrological patterns, topography, land cover type, soil permeability and history of flood events. Each parameter is weighted based on its influence on flood vulnerability, and then mathematically calculated to produce a composite risk score.

The analysis results visualised in Figure 2 category of the flood hazard scores classified in five categories based on the risk scale, namely Very Low, Low, Medium, High and Very High, using a specific statistical classification method. This categorisation simplifies the interpretation of complex data.

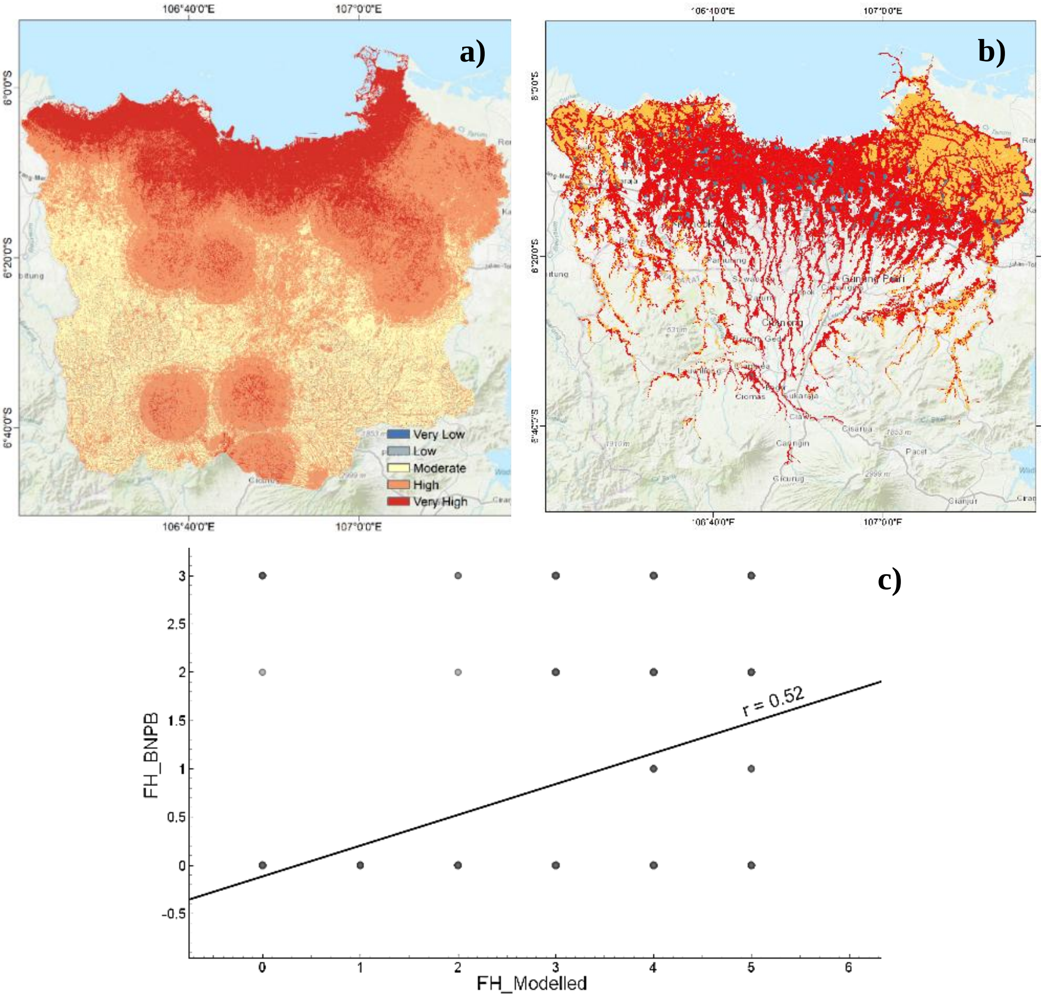

Figure 2. a) Modelled Flood Hazard, b) BNPB Flood Hazard, c) Map Correlation.
(Source: author, 2025)

Figure 2 is spatial representation of flood risk levels in the form of thematic maps provides a more detailed picture of the distribution of an area's hazard to flooding. The analysis shows that areas with low topographic heights are more likely to risker from flooding. Landscapes especially those near major water sources such as rivers and coastlines are at higher risk. The mapping not only illustrates the spatial distribution of hazard zones, but also includes a quantitative estimate of the area affected for each risk category.

Based on the correlation analysis conducted, the modelled flood hazard map (FH_Modelled) compared to the official flood hazard map from the National Disaster Management Agency (BNPB) showed a correlation coefficient (r) of 0.52. To obtain this value, the data from the two raster maps was first extracted into a set of points that represented the hazard values at the same geographical locations. Subsequently, these two point data sets were analysed for correlation using Orange Data Mining software. The value of r = 0.52 indicates a moderate positive relationship between the modelled map and the BNPB output map.

This suggests that there is a general trend whereby areas identified as having higher flood hazard levels on the modelled map also tend to have higher hazard levels on the BNPB map, although the correlation is not perfect and implies that there are some differences or variations between the two maps. The calculation of the area is done automatically through spatial data processing based on Google Earth Engine. More information on the area distribution of each flood hazard class is presented in Table 2.

Table 2. Flood Hazard Area

Class	Area (km²)	Percentage (%)
Very Low	32.40	0.48
Low	107.70	1.60
Moderate	1930.32	28.70
High	3292.02	48.96
Very High	1361.72	20.26

(Source: author, 2025)

Based on the results of the flood hazard mapping analysis using the weighted overlay method in the Greater Jakarta area, a wide distribution of areas with varying levels of vulnerability was obtained. Areas with a very low flood hazard category cover an area of 32.40 km² (0.48%), while the low category covers 107.70 km² (1.60%). The medium category shows a significant coverage of 1,930.33 km² (28.70%).

The high flood hazard level is the most dominant, covering 3,292.03 km² (48.96%). followed by the very high category covering 1,361.72 km² (20.26%). Overall, the total area analysed in this study covers 6,724.18 km². These results show that almost 70% of the Greater Jakarta area is in the high to very high flood hazard category. This indicates a serious level of vulnerability to flood hazards in the metropolitan area. Therefore, a planned and risk-zoning-based mitigation strategy is needed to effectively reduce disaster impacts, especially in areas with the highest hazard levels.

The spatial distribution of flood hazards indicates the physical environmental factors used in the modelling. Areas with very low to low hazard levels are generally located in the southern part of Jabodetabek, such as Bogor, which has a fairly high vegetation cover, low wetness index, and relatively large elevation and distance from water bodies. While areas with moderate categories are scattered in the transition zone between highlands and lowlands, with vegetation cover starting to decline and moderate wetness.

Meanwhile, high to very high hazard areas are concentrated in the lowlands and northern coastal areas of Jabodetabek, covering most of North Jakarta, Bekasi and Tangerang. These areas are characterised by low vegetation cover, high wetness, low elevation, and proximity to water bodies such as major rivers and coastlines. The topographic position in the floodplain area is prone to inundation. This condition is exacerbated by high spatial utilisation, which leads to a decrease in water infiltration capacity. The results of this classification reflect the combination of biophysical environmental conditions that influence vulnerability.

C.2. DISCUSSION

The results showed that 69.22% of the Jabodetabek area falls into the high to very high flood hazard category. This distribution shows a concentration of risk in urban areas with high population density and land use change. According to urban ecology theory, massive land cover changes such as the conversion of infiltration areas to built-up areas significantly increase the potential for surface runoff, thus exacerbating flood risk (Huq & Abdul-Aziz, 2021; Tang et al., 2024). Soil moisture and distance to water bodies are also key determinants in the distribution of vulnerability, in line with the findings of Kaźmierczak & Cavan, (2011) that areas with low infiltration capacity and proximity to water sources are more vulnerable to inundation.

Based on the results of this study, we learnt that the Greater Jakarta area has a high risk and vulnerability to flooding. The major flood in March 2025 showed how this event had a significant impact that halted the economic activities of the community (Bloomberg, 2025). The utilisation of Geographic Information Systems (GIS) helps in providing rapid analysis in decision making in understanding spatially complex problems (Hussain et al., 2023). GIS needs to be applied in regional planning for mitigation and risk reduction from the start of development (Muhammad et al., 2024).

According to Greve, (2016), sustainable development supported by integrated regional planning plays an important role in minimising disaster impacts. This approach enables early identification of disaster-prone areas and the implementation of risk-adaptive spatial policies. The weighted overlay method has been widely applied in the development of disaster risk maps due to its ability to integrate multiple spatial variables. It has proven effective in assessing various types of hazards, such as floods (Lestari et al., 2021), tsunamis (Shit et al., 2016), and landslides (Sambah & Miura, 2014).

Apart from its effective application in disaster-related fields, geospatial technology widely used in areas such as urban planning, environmental monitoring, and determining the location of the agro-fishery industry (Adii et al., 2019), as well as for determining developing areas (Kuru & Terzi, 2018). Weighted Overlay offers high accuracy, which is one of the key reasons it is frequently applied in spatial analysis and disaster risk mapping. Its ability to combine multiple criteria with assigned weights allows for more precise identification of vulnerable areas.

Previous research shows a high accuracy AUC (Area Under Curve) value that tests the model with predictions showing a value of 0.98 in the study by Bui et al., (2023) in Quang Binh, Vietnam, 0.89 by Lukose & Sunilkumar, (2024) in Kuttanad, India, and 0.94 by Wardana et al., (2023) in South Jakarta. The vulnerability of urban areas requires cooperation between policy makers to create sustainable and resilient areas that prone to disasters (Peters et al., 2024). The year 2025 has reminded us that disasters have a major impact on inhibiting the movement of economic activities by the community (Bloomberg, 2025). Spatial information technology provides an understanding of how conditions are occurring in our environment, this role has helped provide the right decisions in policy making(Roche, 2014). Dynamic changes demand further development of this technology (Dold & Groopman, 2017).

This research compare the results of flood hazard mapping with data from institutions such as BNPB, to see the extent to which the geospatial modelling results are in line with official vulnerability maps. By utilising the Google Earth Engine platform, mapping can be done quickly and efficiently, potentially supporting the process of validating or updating data by relevant institutions. This approach is not intended to replace institutional data, but rather complement it to enrich spatial information and support faster and higher-scale decision-making in the context of flood disaster mitigation.

D. CONCLUSION

This research illustrates how geospatial technology is applied in measuring and assessing flood hazards in the Greater Jakarta area. The mapping results provide valuable information to help prioritize areas with high flood hazard vulnerability, enabling more targeted and effective mitigation efforts. The major floods that occurred in 2025 have had a very significant impact on the community, not only damaging vital infrastructure such as roads, bridges, and waterways, but also disrupting widespread economic activities and damaging residential neighbourhoods.

This catastrophic event further underscores the importance of implementing comprehensive risk management, especially in areas of high hazard and vulnerability to natural disasters. Image data integration of hydrological, land cover and topographic data resulted in visualised vulnerability distribution values, based on the mapping there is an area of 3,292.03 Km² in the high flood hazard risk class.

This research supports the Sustainable Development Goals, and specifically point 13 related to climate action, which highlights the application of geospatial technology in improving information accumulation in disaster strategy and preparedness. This research has a limitation where accuracy testing with field data is not applied in this research. It is necessary to apply field data testing and testing on a smaller scope to see the accuracy of the map with existential conditions in future researchers.

ACKNOWLEDGE

I would like to thank several parties who contributed to the results of this study, including researchers, data providers, reviewers and editors who have helped in improving quality of this manuscript.

BIBLIOGRAPHY

Adii, J., Kusumawati, D., Falevi, C., Teniwut, W. A., Hamid, S. K., & Makailipessy, M. M. (2019). Using Spatial Analysis with weighted overlay on selecting area for fisheries agroindustry in Southeast Maluku, Indonesia. *Journal of Physics: Conference Series*, *1424*(1), 012016. https://doi.org/10.1088/1742-6596/1424/1/012016

Agrawal, R., Singh, S. K., Kanga, S., Sajan, B., Meraj, G., & Kumar, P. (2024). Advancing Flood Risk Assessment through Integrated Hazard Mapping: A Google Earth Engine-Based Approach for Comprehensive Scientific Analysis and Decision Support. *Https://Doi.Org/10.3233/JCC240007*, *10*(1), 47–60. https://doi.org/10.3233/JCC240007

Alharbi, T. (2024). A Weighted Overlay Analysis for Assessing Urban Flood Risks in Arid Lands: A Case Study of Riyadh, Saudi Arabia. *Water 2024, Vol. 16, Page 397*, *16*(3), 397. https://doi.org/10.3390/W16030397

Amiri, A., Soltani, K., Ebtehaj, I., & Bonakdari, H. (2024). A novel machine learning tool for current and future flood susceptibility mapping by integrating remote sensing and geographic information systems. *Journal of Hydrology*, *632*, 130936. https://doi.org/10.1016/J.JHYDROL.2024.130936

Ariyani, D., Purwanto, M. Y. J., Sunarti, E., Perdinan, & Juniati, A. T. (2024). Integrated flood hazard assessment using multi-criteria analysis and geospatial modeling. *Journal of Degraded and Mining Lands Management*, *11*(4), 6121–6134. https://doi.org/10.15243/JDMLM.2024.114.6121

Babaei, S., Ghazavi, R., & Erfanian, M. (2018). Urban flood simulation and prioritization of critical urban sub-catchments using SWMM model and PROMETHEE II approach. *Physics and Chemistry of the Earth, Parts A/B/C*, *105*, 3–11. https://doi.org/10.1016/J.PCE.2018.02.002

Bello, M., Singh, S., Singh, S. K., Pandey, V., Kumar, P., Meraj, G., Kanga, S., & Sajan, B. (2024). Geospatial Analysis of Flood Susceptibility in Nigeria’s Vulnerable Coastal States: A Detailed Assessment and Mitigation Strategy Proposal. *Climate 2024, Vol. 12, Page 93*, *12*(7), 93. https://doi.org/10.3390/CLI12070093

Bibi, T. S., Reddythta, D., & Kebebew, A. S. (2023). Assessment of the drainage systems performance in response to future scenarios and flood mitigation measures using stormwater management model. *City and Environment Interactions*, *19*, 100111. https://doi.org/10.1016/J.CACINT.2023.100111

Bisnis.com. (2025). *Nilai Kerugian Banjir Jabodetabek Tembus Rp1,69 Triliun*. Bisnis.Com. https://hijau.bisnis.com/read/20250328/651/1865562/nilai-kerugian-banjir-jabodetabek-tembus-rp169-triliun

Bloomberg. (2025). *Floods in Indonesia’s Capital Displace Thousands, Shut Factories - Bloomberg*. Bloomberg. https://www.bloomberg.com/news/articles/2025-03-05/floods-in-indonesia-s-capital-displace-thousands-shut-factories?utm_source=chatgpt.com

BNPB. (2024). *Data Informasi Bencana Indonesia*. Badan Nasional Penanggulangan Bencana. https://dibi.bnpb.go.id/peta_korban_dan_kerusakan

Bui, Q. D., Luu, C., Mai, S. H., Ha, H. T., Ta, H. T., & Pham, B. T. (2023). Flood risk mapping and analysis using an integrated framework of machine learning models and analytic hierarchy process. *Risk Analysis*, *43*(7), 1478–1495. https://doi.org/10.1111/RISA.14018; PAGE:STRING:ARTICLE/CHAPTER

D’Ayala, Di., Wang, K., Yan, Y., Smith, H., Massam, A., Filipova, V., & Jacqueline Pereira, J. (2020). Flood vulnerability and risk assessment of urban traditional buildings in a heritage district of Kuala Lumpur, Malaysia. *Natural Hazards and Earth System Sciences*, *20*(8), 2221–2241.

https://doi.org/10.5194/NHESS-20-2221-2020

Diriba, D., & Karuppannan, S. (2024). An integrated approach to identify flood hazard and risk areas in Melka Soda district, Southern Ethiopia. *Quaternary Science Advances*, *15*, 100211. https://doi.org/10.1016/J.QSA.2024.100211

Dold, J., & Groopman, J. (2017). The future of geospatial intelligence. *Geo-Spatial Information Science*, *20*(2), 151–162. https://doi.org/10.1080/10095020.2017.1337318;WGROUP:STRING:PUBLICATION

Greve, A. I. (2016). *Sustainable Development, Climate Change Adaptation and Disaster Management*. 13–36. https://doi.org/10.1007/978-4-431-55078-5_2

Han, Y., Huang, Q., He, C., Fang, Y., Wen, J., Gao, J., & Du, S. (2020). The growth mode of built-up land in floodplains and its impacts on flood vulnerability. *Science of The Total Environment*, *700*, 134462. https://doi.org/10.1016/J.SCITOTENV.2019.134462

Huq, E., & Abdul-Aziz, O. I. (2021). Climate and land cover change impacts on stormwater runoff in large-scale coastal-urban environments. *Science of The Total Environment*, *778*, 146017. https://doi.org/10.1016/J.SCITOTENV.2021.146017

Hussain, A., Masood, T., Munir, H., Habib, M. S., & Farooq, M. U. (2023). Developing resilience in disaster relief operations management through lean transformation. *Production Planning and Control*, *34*(15), 1475–1496. https://doi.org/10.1080/09537287.2022.2026671;PAGE:STRING:ARTICLE/CHAPTER

Iftikhar, A., & Iqbal, J. (2023). The Factors responsible for urban flooding in Karachi (A case study of DHA). *International Journal of Disaster Risk Management*, *5*(1), 81–103. https://doi.org/10.18485/IJDRM.2023.5.1.7

Kaźmierczak, A., & Cavan, G. (2011). Surface water flooding risk to urban communities: Analysis of vulnerability, hazard and exposure. *Landscape and Urban Planning*, *103*(2), 185–197. https://doi.org/10.1016/J.LANDURBPLAN.2011.07.008

Khalifeh Soltanian, F., Abbasi, M., & Riyahi Bakhtyari, H. R. (2019). Flood Monitoring using NDWI And MNDWI Spectral Indices: A Case Study Of Aghqala Flood-2019, Golestan Province, Iran. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-4-W18*(4/W18), 605–607. https://doi.org/10.5194/ISPRS-ARCHIVES-XLII-4-W18-605-2019

Kuru, A., & Terzi, F. (2018). Determination of New Development Area in Kırklareli by GIS Based Weighted Overlay Analysis. *International Journal of Environment and Geoinformatics*, *5*(3), 244–259.

https://doi.org/10.30897/IJEGEO.427330

Lestari, M., Mira, M., Prasetyo, S. Y. J., & Fibriani, C. (2021). Analisis Daerah Rawan Banjir Pada Daerah Aliran Sungai Tuntang Menggunakan Skoring dan Inverse Distance Weighted. *Indonesian Journal of Computing and Modeling*, *4*(1), 1–9. https://doi.org/10.24246/ICM.V4I1.4615

Lukose, N., & Sunilkumar, N. (2024). Risk Assessment and Categorization of Flood Risk Zones Using Geospatial Data and Multi-Criteria Decision Model in a Low-Lying Deltaic Region, Kuttanad, India. *Journal of the Indian Society of Remote Sensing*, *52*(5), 985–1002. https://doi.org/10.1007/S12524-024-01852-Y/METRICS

Malik, I. H. (2022). Anthropogenic causes of recent floods in Kashmir Valley: a study of 2014 flood. *SN Social Sciences*, *2*(8), 1–18. https://doi.org/10.1007/S43545-022-00463-Z/METRICS

Marfai, M. A., Sekaranom, A. B., & Ward, P. (2015). Community responses and adaptation strategies toward flood hazard in Jakarta, Indonesia. *Natural Hazards*, *75*(2), 1127–1144. https://doi.org/10.1007/S11069-014-1365-3/METRICS

Mohammed, Z. T., Hussein, L. Y., & Abood, M. H. (2024). Potential Flood Hazard Mapping Based on GIS and Analytical Hierarchy Process. *Journal of Water Management Modeling*, *32*. https://doi.org/10.14796/JWMM.C528

Muhammad, I. N., Astutik, S., Indarto, Mujib, M. A., Pangastuti, E. I., & Kurnianto, F. A. (2024). Evaluation of Groundwater Salinity And Suitability for Irrigation Purposes on South Coastal Jember Regency. *Water Conservation and Management*, *8*(3), 267–273. https://doi.org/10.26480/wcm.03.2024.267.273

Muhammad, I. N., Gemilang, R. G., Rosyidi, H. F., Khilmiah, E. K., Maulana, F., Andriyan, D., Syah, E. N., & Kurnianto, F. A. (2023). Analisis Dataran Banjir Menggunakan Spatial Computing MNDWI Dengan Sentinel 2 di Danau Rawa Pening. *MAJALAH PEMBELAJARAN GEOGRAFI*, *6*(2), 208. https://doi.org/10.19184/PGEO.V6I2.44509

Nainggolan, L., Ni, C. F., Darmawan, Y., Lo, W. C., Lee, I. H., Lin, C. P., & Hiep, N. H. (2024). Cost-Effective Groundwater Potential Mapping by Integrating Multiple Remote Sensing Data and the Index–Overlay Method. *Remote Sensing 2024, Vol. 16, Page 502*, *16*(3), 502. https://doi.org/10.3390/RS16030502

Nofirman, Ahmada, N. H., & Fauzan, T. R. (2024). Integration of Geographic Information Systems and Spatial Data Analysis in Location Decision Making for Manufacturing Industries. *International Journal Software Engineering and Computer Science (IJSECS)*, *4*(1), 196–209. https://doi.org/10.35870/IJSECS.V4I1.2027

Peters, M., Nimbalkar, S., Tutt, D., Carragher, V., Ishiwatari, M., Kawakami, H., Sasaki, D., Sakamoto, A., & Nakayama, M. (2024). Enhancing Disaster Resilience for Sustainable Urban Development: Public–Private Partnerships in Japan. *Sustainability 2024, Vol. 16, Page 3586*, *16*(9), 3586. https://doi.org/10.3390/SU16093586

Puspitasari, D., Hizbaron, D. R., & Mei, E. T. W. (2024). *An Integrated Urban Flood Risk Assessment into Development Plan of South Jakarta, Indonesia*. https://doi.org/10.2139/SSRN.4814130

Roche, S. (2014). Geographic Information Science I: Why does a smart city need to be spatially enabled? *Progress in Human Geography*, *38*(5), 703–711. https://doi.org/10.1177/0309132513517365;JOURNAL:JOURNAL:PHGB

Safitri, I., Ruhiat, Y., & saefullah, asep. (2023). Analysis of Flood Vulnerability Levels Using Overlay Method with System-Based Scoring Geographical Information (Case Study: District Tangerang). *Newton-Maxwell Journal of Physics*, *4*(2), 56–64. https://doi.org/10.33369/NMJ.V4I2.30354

Sambah, A. B., & Miura, F. (2014). Remote sensing and spatial multi-criteria analysis for tsunami vulnerability assessment. *Disaster Prevention and Management: An International Journal*, *23*(3), 271–295. https://doi.org/10.1108/DPM-05-2013-0082/FULL/XML

Sayers, P., Penning-Rowsell, E. C., & Horritt, M. (2018). Flood vulnerability, risk, and social disadvantage: current and future patterns in the UK. *Regional Environmental Change*, *18*(2), 339–352. https://doi.org/10.1007/S10113-017-1252-Z/METRICS

Seif, A. (2014). Using Topography Position Index for Landform Classification (Case study: Grain Mountain). *Bull. Env. Pharmacol. Life Sci*, *3*(11), 33–39.

Shit, P. K., Bhunia, G. S., & Maiti, R. (2016). Potential landslide susceptibility mapping using weighted overlay model (WOM). *Modeling Earth Systems and Environment*, *2*(1), 1–10. https://doi.org/10.1007/S40808-016-0078-X/FIGURES/6

Siswanto, S. Y., & Francés, F. (2019). How land use/land cover changes can affect water, flooding and sedimentation in a tropical watershed: a case study using distributed modeling in the Upper Citarum watershed, Indonesia. *Environmental Earth Sciences*, *78*(17), 1–15. https://doi.org/10.1007/S12665-019-8561-0/METRICS

Soltani, K., Ebtehaj, I., Amiri, A., Azari, A., Gharabaghi, B., & Bonakdari, H. (2021). Mapping the spatial and temporal variability of flood susceptibility using remotely sensed normalized difference vegetation index and the forecasted changes in the future. *Science of The Total Environment*, *770*, 145288.

https://doi.org/10.1016/J.SCITOTENV.2021.145288

Tang, J., Liu, D., Shang, C., & Niu, J. (2024). Impacts of land use change on surface infiltration capacity and urban flood risk in a representative karst mountain city over the last two decades. *Journal of Cleaner Production*, *454*, 142196. https://doi.org/10.1016/J.JCLEPRO.2024.142196

Wardana, M. W., Setiawan, C., & A'Rachman, F. R. (2023). Distribution of Buildings at Various Flood Hazard Levels In Kebon Baru Village, Tebetsub-District, South Jakarta. *JURNAL GEOGRAFI Geografi Dan Pengajarannya*, *21*(1), 59–68. https://doi.org/10.26740/JGGP.V21N1.P59-68

Xue, J., & Su, B. (2017). Significant Remote Sensing Vegetation Indices: A Review of Developments and Applications. *Journal of Sensors*, *2017*(1), 1353691. https://doi.org/10.1155/2017/1353691

Zhang, K., Shalehy, M. H., Ezaz, G. T., Chakraborty, A., Mohib, K. M., & Liu, L. (2022). An integrated flood risk assessment approach based on coupled hydrological-hydraulic modeling and bottom-up hazard vulnerability analysis. *Environmental Modelling & Software*, *148*, 105279. https://doi.org/10.1016/J.ENVSOFT.2021.105279