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GIS-Based Multi-Hazard Disaster Risk Mapping in The Indonesian Capital City (IKN) Area

Auliah Mujahidah*, Najma Nur Mawaddah, Aisyah Trees Sandy, Yulian Widya Saputra
Geography Education, Faculty of Teacher Training and Education,
Universitas Mulawarman, Indonesia
auliahmujahidah2446@gmail.com

Abstract

This study employs a quantitative approach to comprehensively map and analyze multi-hazard disaster risks in the Indonesian Capital City (IKN) area, with a primary focus on flood and landslide threats. The research involved extensive data collection through field surveys, direct observations, documentation, and the acquisition of geospatial datasets to ensure accurate representation of the study area. The collected data were analyzed using a combination of scoring techniques, map overlays, and disaster risk classification methods. All analyses were conducted using Geographic Information System (GIS) software to produce a detailed thematic risk map. In accordance with the Regulation of the Head of BNPB Number 2 of 2012 concerning general guidelines for disaster risk assessment, the study classified hazard risks into three categories: low, medium, and high. Spatial analysis results indicate that low-risk areas occupy 76,576.37 hectares, approximately 57.47% of the total study area. Moderate-risk areas cover 11,131 hectares or 7.63%, while high-risk areas account for 58,236.45 hectares, approximately 39.90%. These findings highlight significant variations in vulnerability and hazard exposure across the IKN region. The produced multi-hazard map serves as a crucial tool for development planning and disaster risk mitigation, providing essential information for local authorities, urban planners, and policymakers. By identifying areas with different levels of risk, this study contributes to enhancing community safety, protecting critical infrastructure, and supporting sustainable development in the IKN area. The comprehensive spatial approach ensures that disaster preparedness strategies are grounded in scientific analysis and real-world data, offering a foundation for proactive risk management and long-term resilience.

Keywords: Multi-hazard; Geospatial mapping; Disaster risk; Geographic Information System

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1. Introduction

Indonesia is one of the countries prone to natural disasters, this can be seen from the geographical conditions of Indonesia which consists of many archipelagos that have the potential for disasters and have different levels. In addition to the geographical conditions of Indonesia in the form of an archipelago, the climate in Indonesia is a tropical climate and has two seasons, namely the dry

season and the rainy season. This can affect extreme weather changes so that it can cause several bad consequences such as flooding and landslides (Aksha et al., 2020; Arrighi et al., 2023; Heo et al., 2024; Sharma & Miyazaki, 2019). Problems related to disasters are problems that are included in the priority, this is due to the high number of disasters and the vast area that is a priority for handling (Moch et al., 2022; Anastasia et al., 2021).

Indonesia is one of the countries with a high level of vulnerability to natural disasters due to its location at the convergence of three major tectonic plates (Indo-Australian, Eurasian, and Pacific) and its tropical climate, which makes it prone to extreme weather events and flooding (Mandal et al., 2022; Nachappa et al., 2020; Rezvani et al., 2023; Tempa & Yuden, 2023). Every year, Indonesia experiences various types of disasters, including earthquakes, tsunamis, floods, landslides, and forest fires (Monardo, 2022) . Among these, meteorological disasters such as floods, storms, and extreme rainfall are increasingly frequent and cause substantial socio-economic losses (Hussain et al., 2023; Martín-Raya et al., 2024). In Kalimantan, meteorological disasters pose a particular risk. Data from the Indonesian National Board for Disaster Management (BNPB, 2024) show that East Kalimantan has experienced frequent floods and landslides, especially during the rainy season, while forest fires are a recurrent threat during dry periods. The combination of intense rainfall, peatland areas, and human activities such as deforestation and land conversion increases the vulnerability to meteorological hazards. These conditions highlight the need for detailed multi-hazard risk assessments in the region.

The new Capital City of the Archipelago (IKN), currently under development in East Kalimantan, is planned to be a resilient city. However, this area faces potential multi-disaster threats, including floods, forest fires, landslides, and the impacts of climate change, which may exacerbate disaster risks in the future (Sukapti & Nanang, 2022) . Therefore, mapping multi-hazard risks is crucial to support effective planning, development, and mitigation policies (Chicaiza-Fuentes et al., 2025; Koudoumakis et al., 2024; Yagoub & Al Yammahi, 2022).

One of the main challenges in disaster risk management in the IKN is the limited availability of comprehensive spatial data related to the potential and distribution of multi-hazard risks. Geographic Information Systems (GIS) offer a solution by enabling the analysis and visualization of spatial distributions of disaster threats, producing information that can support policy-making and decision-making (Clar et al., 2021). Despite its potential, there has been limited research specifically mapping multi-hazard risks in the IKN area using a GIS approach. This study aims to map the risk of multi-hazard disasters in the IKN area using GIS technology, with a focus on meteorological disasters such as floods and forest fires. By conducting this study in the IKN, it is expected to identify areas with high disaster risk, providing critical information to support disaster mitigation policies and sustainable urban development in the new capital.

2. Method

This research was conducted over a period of approximately four months, from November 2024 to February 2025, in the Indonesian Capital Region (IKN), East Kalimantan. The study applies a quantitative approach to map and analyze multi-hazard disaster risks, with a particular focus on floods and landslides. Data collection was carried out through field surveys, observations, and documentation, complemented by the acquisition of geospatial data. Primary data were obtained directly from the research site, including topography, drainage conditions, land use, and other local features affecting disaster vulnerability. Secondary data were sourced from governmental agencies, previous research reports, and geospatial datasets available from the National Disaster Management Agency (BNPB).

In measuring disaster risk, the study considers both hazard and vulnerability factors. Hazard variables for floods include rainfall intensity, proximity to rivers, slope gradient, and land use patterns, while landslide hazards are assessed based on slope steepness, soil stability, rainfall, and land cover. Vulnerability indicators include population density, presence of critical infrastructure,

and socio-economic conditions. These variables and indicators collectively provide a comprehensive representation of the potential impact of natural disasters in the IKN area.

The analysis of disaster risk involves a scoring and weighting system. Each variable is assigned a score according to its severity or contribution to risk and multiplied by a weight reflecting its relative importance. The total score is then used to classify areas into risk categories, ranging from low to high. The scoring process follows standards set by BNPB and is integrated using GIS map overlay techniques. This allows for the combination of multiple hazard layers into comprehensive multi-hazard maps, providing a spatial understanding of disaster-prone areas. To ensure the accuracy of the analysis, the GIS-based risk maps are validated against historical disaster records and local field observations. Additionally, sensitivity analysis is conducted by adjusting variable weights to test the robustness of the resulting classifications. Microsoft Excel is also utilized to process scores, calculate percentages, and summarize data prior to mapping. By integrating hazard, vulnerability, and spatial analysis, this study aims to produce reliable and detailed multi-hazard risk maps. These maps serve as an essential tool for disaster mitigation planning and decision-making in the IKN, supporting the development of effective strategies to reduce potential losses from floods and landslides in the region.

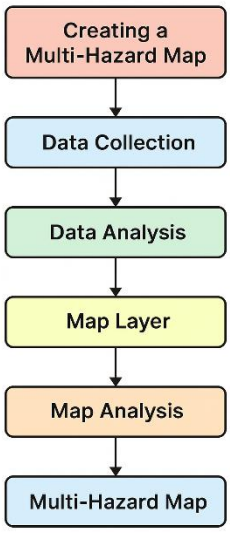

Figure 1. Flowchart for creating a multi-hazard map

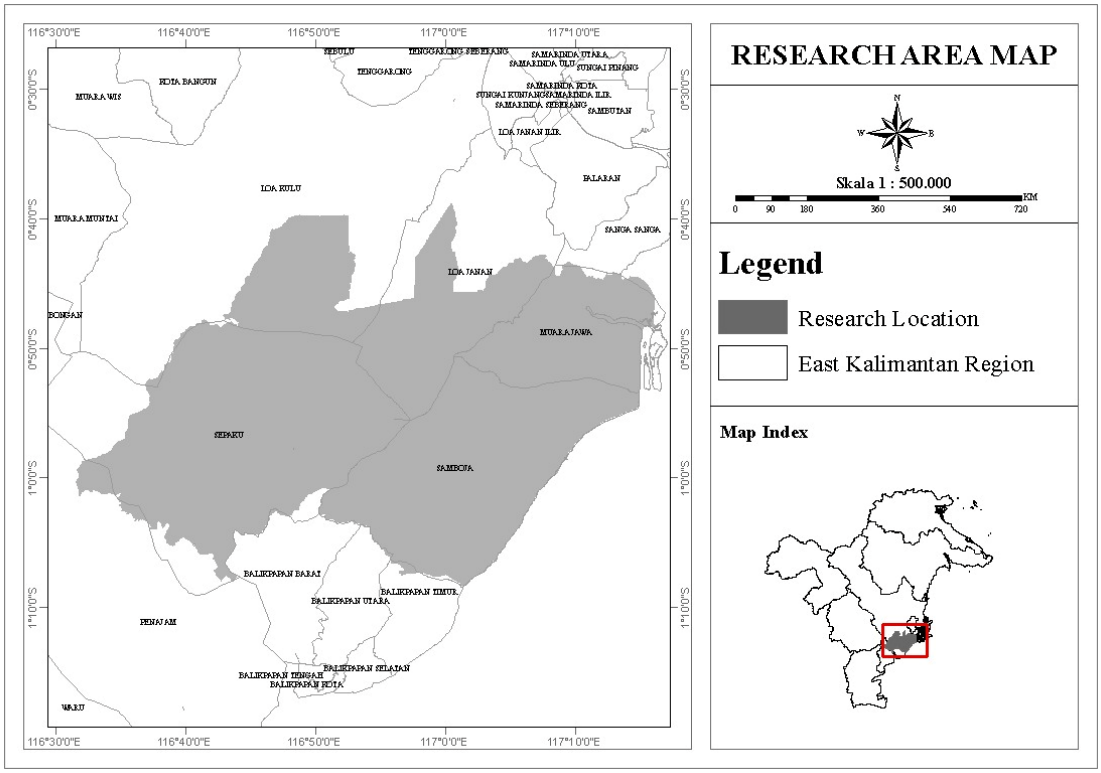

Figure 2. Research Location Map

3. Result and Discussion

A. Landslide Risk Map

The Indonesian Capital Region (IKN) is one of the areas that has various disaster problems, one of which is landslides. Landslide disaster risk mapping is a systematic effort to understand, identify, and manage areas that are vulnerable to landslides. Landslides are a type of geological disaster that is influenced by various factors, including rainfall, topography, soil type, land use, and human activities. This risk mapping aims to provide clear and accurate information on the level of vulnerability of an area to the threat of landslides, so that it can be used for mitigation, spatial planning, and data-based policy making.

Based on the results of the research that has been carried out, the results or output of the map are in the form of regional classifications with different levels of risk. The classification of landslide disaster risks in the IKN area consists of three classes. These classes include low class, medium class, and high class.

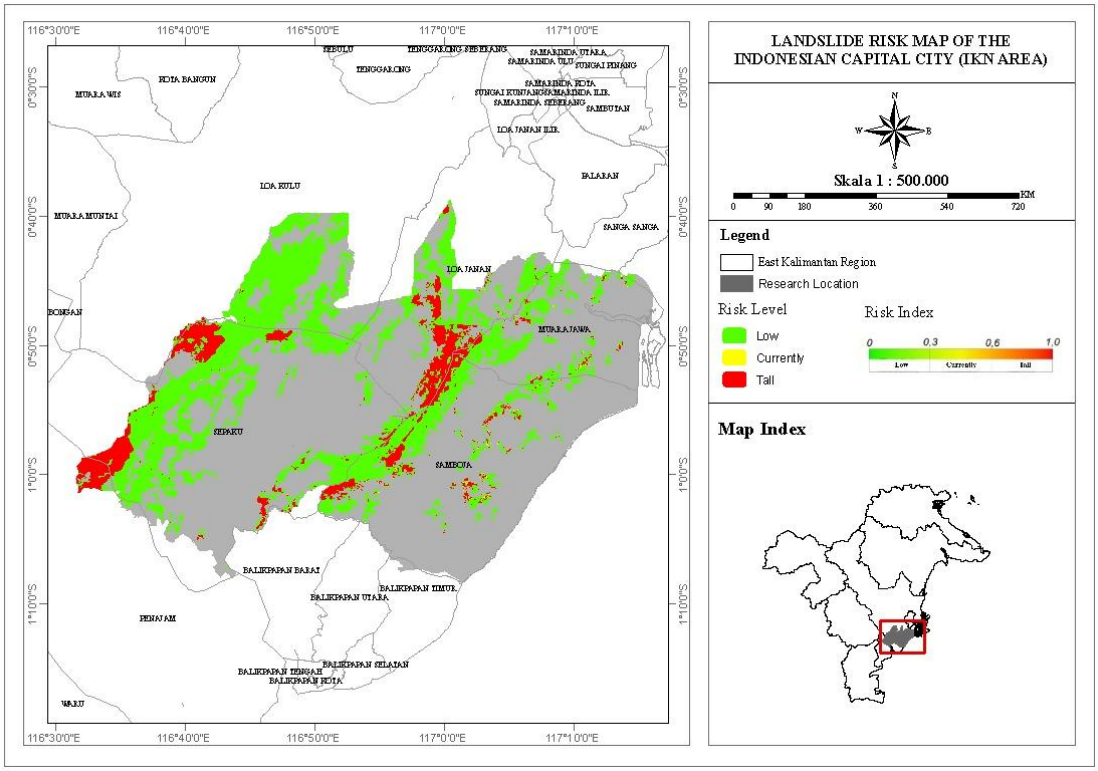

Figure 3. Landslide Risk Map

In figure 3 above shows the distribution of landslide risks in the Indonesian Capital Region (IKN) which is grouped into three main classifications, namely low, medium, and high risk. Visually, areas with low risk are marked in green, medium risk by yellow, and high risk by red. This risk distribution describes the level of landslide vulnerability based on various parameters such as slope gradient, soil type, rainfall, and land use.

The red areas, which are located mainly in the central and eastern parts of the IKN area, indicate the need for special attention in development planning in the area. Areas with low risk (green) tend to be in lowlands with relatively gentle topography. These areas are safer for infrastructure development, especially housing and public facilities. However, good spatial management is still needed to minimize the potential for secondary impacts, such as flooding that can worsen geotechnical conditions around the area.

This map shows that most of the areas around Balikpapan and other buffer areas are in the low to medium risk category, providing greater potential for safe regional development. High landslide risks (red) tend to be concentrated in areas with steep topography, such as the hilly areas in the Sepaku area. This condition indicates that the area requires intensive mitigation, such as slope management, reforestation, and erosion control. In addition, infrastructure development in this area must be carried out with careful planning, including considering in-depth geotechnical analysis.

The use of this map can help determine no-development zones to prevent material losses and casualties due to landslides. This map also reflects the importance of spatial data integration in supporting disaster risk management policies in the IKN. By utilizing this risk map, the government and stakeholders can determine the priority of mitigation interventions in the most vulnerable areas.

In addition, this map provides a basis for sustainability-oriented spatial planning, so that the development of the IKN can take place by prioritizing the safety and welfare of the community. Integration of this map with GIS-based multi-hazard analysis can enrich disaster risk management

in the future. Data on the area at risk of landslides in the IKN area is presented in Table 1

Table 1. Area of Landslide Disaster Risk Level

No	Classification	Area (Ha)	Percentage (%)
1	Low	69933.51 Ha	82.20%
2	Currently	361.23 Ha	0.42%
3	Tall	14787.33 Ha	17.38%
Total		85082.07 Ha	100.00%

Source: Research results

Based on the table 1, the area with a low risk level is 69,933.51 hectares or equivalent to 82.20% of the total area. This dominant percentage shows that the majority of areas in the study are relatively safe from the threat of landslides. However, it is important to continue monitoring in this area because environmental changes, such as deforestation or infrastructure development, can increase the risk.

The moderate risk area covers 361.23 hectares or 0.42% of the total area. Although the percentage is small, this area requires special attention because it has a higher landslide potential than low-risk areas. Mitigation activities such as planting vegetation and drainage control can be applied in this area. High-risk areas cover 14,787.33 hectares or 17.38% of the total area. These areas are the main priority in disaster mitigation strategies. Steps such as reducing human activity in vulnerable zones, building terracing, and strengthening slopes with environmentally friendly technology can reduce the impact of disasters.

The risk distribution shows that most areas are classified as low risk, which provides great opportunities for safe regional development. However, the existence of high-risk areas that reach almost one-fifth of the total area requires special attention. Focusing on mitigation in high and medium risk areas, along with sustainable management in low risk areas, is essential to minimize the impact of landslides. This information can be used by the government, stakeholders, and communities in designing more effective risk management strategies.

B. Flood Risk Map

Flooding is an event or condition in which an area or land is submerged due to increased water volume (Aedla et al., 2025; Saravanan et al., 2023). Flooding is a condition in which water overflows and covers areas that are not usually submerged by water (Kalaycıoğlu et al., 2023; Karymbalis et al., 2021; Udoh, 2015). Flooding can be caused by high rainfall without sufficient soil absorption, this can occur for various reasons, including heavy rain and overflowing rivers or Abdelkarim et al., (2020). Mapping flood-prone areas helps identify areas at high risk of flooding (Agrawal et al., 2021).

Based on the results of the research that has been carried out, the results or output of the map in the form of Flood disaster risk classification in the IKN area consists of three classes. These classes include low class, medium class, and high class, can be seen in Figure 4 below.

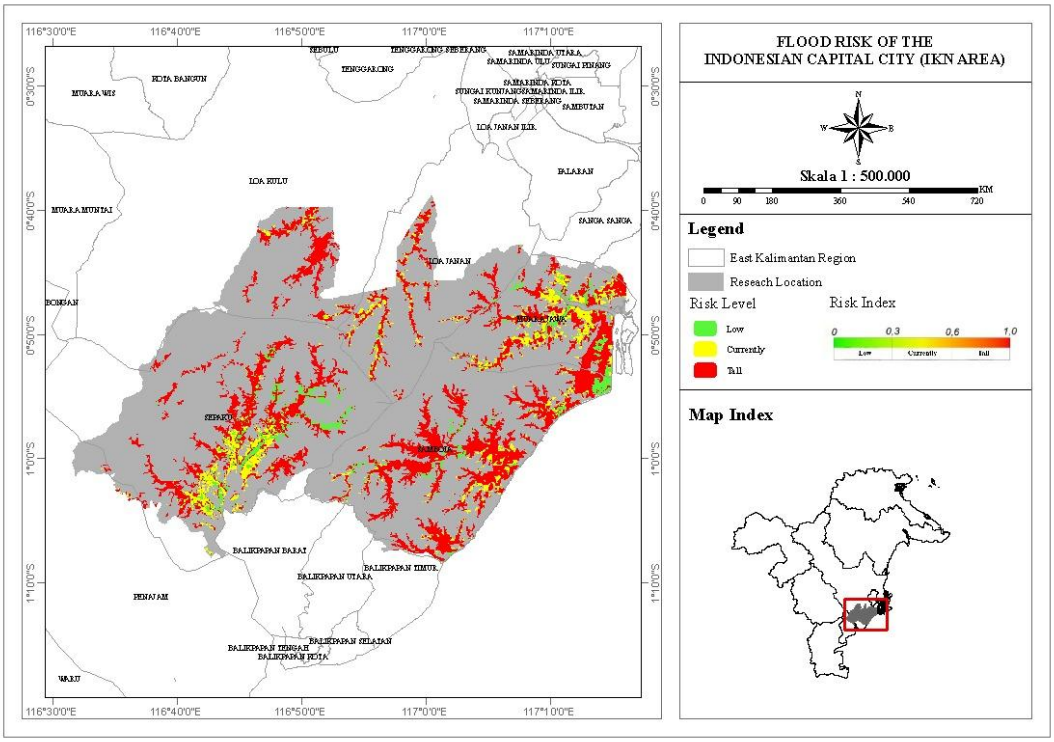

Figure 4. Flood Risk Map

In figure 4 above illustrates the distribution of flood risk in the Indonesian Capital Region (IKN). This map groups areas based on flood risk classification into three main classifications, namely low class (green), medium class (yellow), and high class (red). Meanwhile, areas that are not affected by flood risk are marked in blue. This information is important because IKN is planned as the new center of government of Indonesia which requires a resilient and adaptive spatial plan to the threat of natural disasters, including floods. This risk distribution illustrates the level of flood vulnerability based on various parameters such as Rainfall, Land height, Slope gradient, Soil type, Land form, Drainage density, Land use.

Low-risk areas (green) indicate areas that are relatively safe from the threat of flooding. However, it is important to maintain environmental conditions in this zone so that they are not degraded by uncontrolled development. This zone can be used as a priority location for settlements, public facilities, and critical infrastructure, but must still pay attention to the principles of sustainable spatial planning. Management of water runoff from the surrounding area is also a priority so that the risk does not increase in the future.

Medium risk areas (yellow) are in the transition between high and low risk areas. These areas are also important because they have the potential to act as buffer zones that can reduce water flow to high risk areas. Handling in medium areas requires approaches such as better management of water catchments, planting vegetation to increase water absorption, and implementing modern water management technologies. Appropriate policies in these areas can reduce pressure on high risk areas and strengthen environmental resilience.

High flood risk areas (red) are generally located along large rivers and lowlands. Most of these areas are in areas prone to water runoff, possibly due to high rainfall, lack of water-retaining vegetation, or river sedimentation that reduces water flow capacity. Infrastructure in these areas, such as roads, residential buildings, and public facilities, require special mitigation, such as the construction of embankments, river dredging, and efficient drainage systems. The main focus is to protect people and assets in these zones from major flood losses.

This flood risk map is an important tool to support data-based spatial planning in the IKN Area. The geospatial information displayed provides a detailed picture of potential flood risks, so that the government can formulate evidence-based policies. For example, high-risk zones can be a priority for mitigation by planting vegetation, developing green open spaces, or building flood-resistant infrastructure. Meanwhile, low-risk zones can be developed to support development activities without ignoring the principles of environmental sustainability.

Based on this map, there are several strategic recommendations that can be taken. First, optimizing the function of natural ecosystems, such as mangrove forests and swamps, to absorb water runoff. Second, building flood-resistant infrastructure in high-risk areas, such as embankments and retention ponds. Third, educating the public about flood risks and evacuation steps to increase preparedness. Fourth, using technology, such as sensor-based flood monitoring systems, to detect risks in real time.

As the future center of government, the development of the IKN must consider environmental risk aspects as shown in this map. Integration of flood risk maps into planning will help create a safe, resilient, and sustainable area. It also shows the importance of collaboration between government, academics, and the community to achieve development goals that are harmonious with the environment.

Table 2. Area of Flood Disaster Risk Level

No	Classification	Area (Ha)	Percentage (%)
1	Low	6642.86 Ha	10.91%
2	Currently	10770.40 Ha	17.70%
3	Tall	43449.12 Ha	71.39%
Total		60862.39 Ha	100.00%

Source: Research results

From table 2 above, it can be seen that areas with high flood risk cover 43,449.12 Ha or 71.39% of the total area. This shows that most areas are in the category of being very vulnerable to the impacts of flood disasters. This area requires special attention in development planning and risk mitigation. Flood-resistant infrastructure, such as embankments, retention ponds, and adequate drainage systems, should be a priority in this area. In addition, it is important to control human activities that can exacerbate risks, such as deforestation or land conversion.

Areas with moderate flood risk cover 10,770.40 Ha or 17.70% of the total area. As a transition zone, this area has a moderate risk but still requires good management to prevent increased risk. Replanting water-retaining vegetation and watershed management can be done to maintain ecosystem balance. In addition, measures such as the construction of small embankments or water diversion canals can also be implemented to strengthen environmental resilience to flood threats.

Areas with low flood risk only cover 6,642.86 Ha or 10.91% of the total area. Although this area is relatively safe from the threat of flooding, good management is still needed to maintain environmental stability. This area has the potential to be an ideal location for the development of important infrastructure, such as housing, public facilities, and economic centers, as long as it is designed with attention to the principles of sustainable spatial planning. Management of water runoff from surrounding areas must also be a priority so as not to increase the risk in this zone.

The data in this table provides a solid basis for policymakers in developing flood disaster mitigation strategies. The main focus should be directed at high-risk areas, which cover more than 70% of the area, to minimize the impacts. Mitigation-based spatial planning policies, such as land use zoning, are essential to reduce potential future losses. On the other hand, medium and low-

risk areas can be utilized as buffers or safe development zones, as long as they still pay attention to ecological impacts and environmental sustainability.

This table also emphasizes the importance of quantitative data in supporting development planning. By understanding the extent and percentage of each risk level, the government can set clear priorities in allocating the disaster mitigation budget. In addition, the community can also be involved in environmental management, such as forest rehabilitation programs and education related to flood risks. Collaboration between the government, academics, and the community is essential to ensure that disaster mitigation can run effectively and efficiently.

C. Multi-Hazard Risk Map

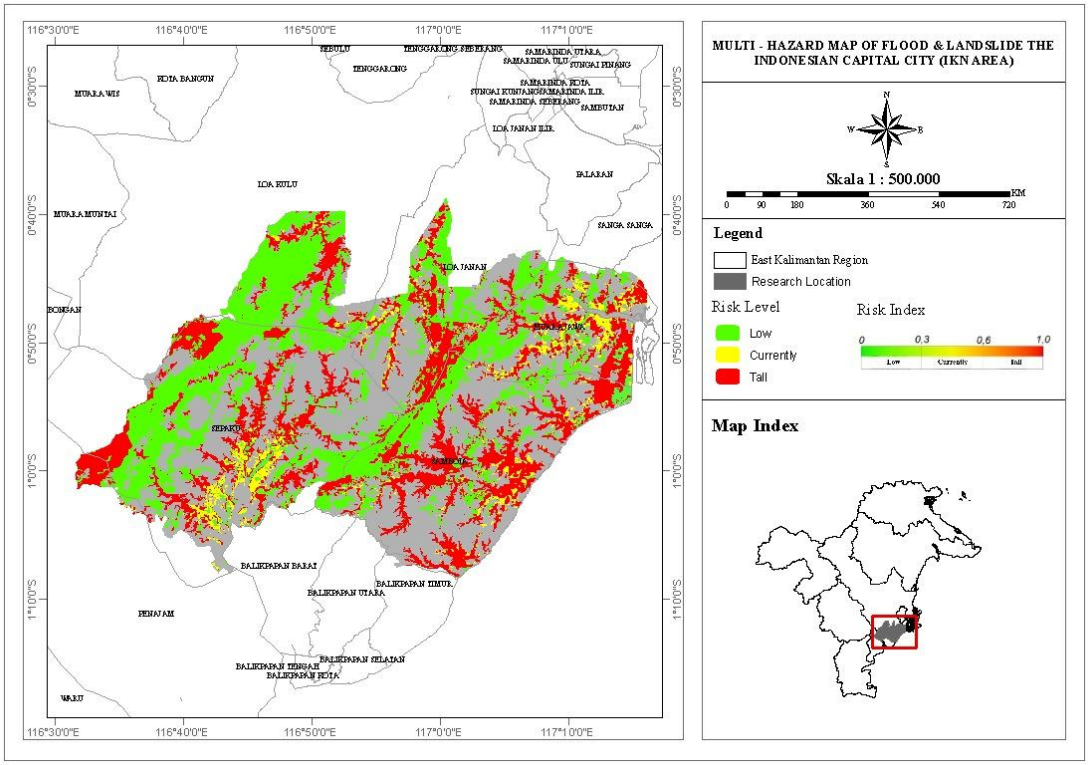

Figure 5. Multi-Hazard Map of the IKN Area

Based on the overlay results of the Landslide Risk Map with the Flood Risk Map in the IKN area, 3 classifications were obtained, namely low which is marked in green, medium with yellow, and high which is marked in red. The risk index used is 0 - 0.3 (Low), 0.3 - 0.6 (Medium) and 0.6 - 1.0 (High). (7.63% = 11131.64 Ha) of the area of the IKN area has a moderate risk level, the high risk level is 39.90% (58236.45 Ha) of the area, and the low risk level is 57.47% (76576.37 Ha) of the area of the IKN area. Table 3 below shows the area of the area at risk of landslides and flooding in the IKN area.

Table 3. Area of Multi-Hazard Risk Level

No	Classification	Area (Ha)	Percentage (%)
1	Low	76576.37 Ha	57.47%
2	Currently	11131.64 Ha	7.63%
3	Tall	58236, 45 Ha	39, 90%
Total		145944, 47 Ha	100.00%

Source: Research results

Based on the overlay of landslide risk maps and flood risk maps in the Indonesian Capital City (IKN) area, a spatial overview of the multi-hazard vulnerability level is obtained, demonstrating three main classifications: low, medium, and high risk. Low-risk areas are indicated by green, medium-risk areas by yellow, and high-risk areas by red. This classification is based on a risk index value, which is divided into intervals of 0–0.3 for low risk, 0.3–0.6 for medium risk, and 0.6–1.0 for high risk. Overall, approximately 57.47% of the IKN area falls into the low-risk category, while 7.63% falls into the medium-risk category, and 39.90% falls into the high-risk category for multi-hazard flooding and landslides. The spatial analysis results indicate that the main causes of this risk variation are related to physiographic conditions, soil characteristics, and land-use patterns within the IKN area. Areas categorized as low-risk are generally located on plains with slight slopes, resulting in relatively little potential for air accumulation and soil mass movement. Furthermore, many of these areas are located in areas with stable vegetation cover, which supports air infiltration and maintains slope stability.

Conversely, areas with moderate and high risk levels tend to be located in areas with a more complex combination of geomorphological and hydrological factors. High-risk areas typically have undulating topography with moderate slopes, allowing rainwater to flow but also potentially being retained at points with low drainage capacity. This increases the likelihood of sedimentation, while the soil structure, which is partly composed of air-saturated material, potentially reduces slope stability. High-risk areas are dominated by areas with steep slopes and lithology that has undergone intensive weathering, making them susceptible to landslides during heavy rainfall. At the same time, these areas are also located close to river channels and sub-watersheds that flow towards coastal areas. The combination of large surface runoff, low infiltration capacity, and narrowing of river channels significantly increases the risk of flooding. Some areas even exhibit the potential for compound hazards, where landslides can occur upstream on slopes and be followed by flash floods downstream during extreme rainfall events.

This phenomenon is influenced by rapid land-use changes in the core development area of the New Capital City (IKN), including land clearing, vegetation changes, and infrastructure development that can alter natural drainage characteristics and increase hydrological pressure in certain areas. This aligns with the findings of various previous studies, which indicate that steep slope gradients, weathered lithology, and intense tropical rainfall are the dominant factors triggering landslides, while lowlands with poor drainage are the primary flooding hotspots. Therefore, the analysis of the multi-hazard maps provides a comprehensive overview of areas requiring stricter disaster risk management to ensure the safe and sustainable development of the New Capital City.

4. Conclusion

Based on the results of the research and discussion that has been carried out, it was found that areas at risk of multi-hazard disasters in the IKN area are located at certain points such as the Penajam, Sepaku, Samboja, Muara Jawa, Loa Kulu, and Loa Janan areas. With three classifications with, green (low risk level), yellow (moderate risk level), red (high risk). The resulting percentage results of the

Low class are 76,576.37 Ha or 57.47%, the moderate class is 11,131 Ha or 7.63%, and the high risk level is 58,236.45 or 39.90 area with the classification and also the percentage provides a clear picture of the level of vulnerability of the area. This study successfully mapped the risk of multi-hazard disasters in the Indonesian Capital City (IKN) area using a quantitative approach and Geographic Information System (GIS) technology and the data used is based on inaRISK data. The results of the analysis show that the IKN area has varying vulnerabilities to disasters, especially floods and landslides. This study emphasizes the importance of accurate information to support disaster mitigation planning and data-based decision making, and makes a significant contribution to building the resilience of the IKN area to disaster threats.

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