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Implementing GIS for Robust Disaster Mitigation in IKN, the Future Capital of Indonesia

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Abstract — This research focuses on the potential disasters at the Indonesian Capital City (IKN) located on the island of Kalimantan, which is set to be the future capital of Indonesia. East Kalimantan is prone to 13 different types of disasters, including floods, flash floods, forest fires, and landslides, particularly during heavy rainfall. To effectively mitigate these disasters, it is essential to remap evacuation routes using an accurate Geographic Information System (GIS). Measurements of height, slope, and width in the IKN area are necessary, along with an evaluation of existing evacuation routes. This will ensure that the community has access to safe and capable evacuation pathways. Additionally, research on the potential and distribution of earthquakes in East Kalimantan from 1900 to 2024 indicates that the earthquake risk in the Indonesian Capital City area is very low. Similarly, an assessment of forest fire occurrences from 2012 to 2021 reveals minimal fire risks in the IKN region. Thus, while some disasters need to be carefully monitored, the potential for significant forest fires appears limited.

Keywords — Disaster Mitigation; Geographic Information System; Indonesian Capital City (IKN); The Future Hub of Indonesia.

I. INTRODUCTION

Precise geographic information is crucial for evaluating measurements of height, slope, and width in the Indonesian Capital City (IKN) area. Additionally, it is important to assess existing evacuation routes to ensure that the community has safe and adequate options for evacuation.

According to the Law of the Republic of Indonesia Number 24 of 2007 [1] concerning disaster management, preparedness involves a series of activities aimed at anticipating disasters through organized, appropriate, and efficient measures. Mitigation consists of efforts to reduce disaster risk, which can be achieved through physical development as well as raising awareness and enhancing the community's ability to respond to disaster threats [2] . Emergency response actions take place immediately after a disaster occurs, focusing on managing the negative impacts, which include rescue and evacuation of victims, property protection, fulfillment of basic needs, management of refugees, and restoration of infrastructure and facilities. A key point in Article 45, paragraph 2, point e of the law emphasizes the importance of preparing evacuation locations.

The Capital City of the Nusantara (IKN) on the island of Kalimantan, Indonesia's future capital, has a distinctive topography that ranges from coastline to the hills of Bukit Soeharto Forest Park. Given the area's susceptibility to 13 potential disasters, including floods, flash floods, forest fires, and landslides—particularly during heavy rainfall—it is essential to remap evacuation routes specifically for disaster mitigation using a precise geographic information system (GIS). To enhance community preparedness, evacuation route signs must be prominently displayed along the southern route of IKN. This ensures that during a disaster, both local residents and newcomers can easily identify evacuation routes.

In this study, a survey will be conducted to reassess the feasibility of existing evacuation route signs. Following this, a spatial analysis will be performed using GIS tools to determine the suitability of these evacuation routes against risks such as earthquakes and tsunamis, taking into account factors like land characteristics, height, slope, residential areas, and proximity to tourist attractions.

The Indonesian government and society implemented a law on disaster management in 2007, a significant step that came too late—decades after independence—following devastating events. Notable disasters, such as the 2004 earthquake and tsunami in Nangroe Aceh Darussalam caused by the Sunda subduction megathrust, and the catastrophic events in Palu City, Sulawesi, in 2018 due to the Palu Koro fault, underscore the urgent need for effective disaster response. The staggering impact on Palu City, coupled with the tragic loss of life, reveals that this law has yet to be effective at the local level. It is imperative to focus on enhancing disaster preparedness and mitigation, particularly in regions at high risk for major disasters. The safety and well-being of communities depend on it.

II. RELATED WORK

The National Disaster Management Agency (BNPB) has established a comprehensive National Disaster Management Plan as part of its critical 2020-2024 master strategy [3]. It is essential that this policy document is not just read but fully understood and effectively implemented by regional authorities at both the provincial and district/city levels, which have already founded numerous Regional Disaster Management Agencies (BPBD). These agencies play a vital role in equipping local governments and communities to remain vigilant and proactive in the face of disasters, ensuring their safety and resilience.

The National Earthquake Study Center (Pusgen) has published the latest Indonesian Earthquake Source and Hazard Map in 2017 [4] . This essential document empowers all Indonesian governments and citizens to stay informed about their residential areas. By using this map as a guiding resource, they can make informed decisions for development and spatial planning, ensuring safer and more resilient communities across the nation.

In developed nations such as Australia, New Zealand Ministry of Civil Defence & Emergency Management [5] and the United States [6], there exists a wealth of in-depth studies focused on preparedness and response to earthquakes and tsunamis [7] , exemplified by resources like the Tsunami Evacuation Signs document. These materials are comparable to those released by BNPB and regional governments in areas vulnerable to seismic events. By examining and contrasting the publications from our government with those from other countries, we can identify best practices and enhance our own emergency preparedness strategies, ultimately saving lives and protecting communities.

Effective traffic management and clear transportation routes are essential during an evacuation to prevent chaos and congestion. Countries worldwide have implemented vital transportation management standards, such as the Emergency Management Signing and Sign Policy and Guidelines, to ensure public safety and facilitate smooth evacuations in the face of disasters (National Committee on Uniform Traffic Laws and Ordinances [8] . Adopting and adhering to these policies can significantly enhance response efforts and save lives [9].

Researchers are set to develop detailed thematic maps that will significantly enhance our understanding of critical factors, including evacuation routes, land elevation and slope [10] , village locations, population density, hotspots [11], [12] , proximity of residents to the coast, and the primary transportation route south of the Indonesian Capital City (IKN) on the island of Kalimantan. This innovative effort will leverage Quantum GIS [13] , a powerful and comprehensive open-source spatial and geographic information system software widely recognized for its effectiveness in disaster planning. By utilizing this cost-effective tool, we can ensure that our research remains within budget while also providing valuable insights for safe and efficient community planning in Indonesia's future capital.

In this study, the researcher strategically employed C. R. Kothari's research methodology framework to ensure a robust and effective analysis [14].

III. METHODOLOGY

According to C. R. Kothari [14], the detailed steps in the research process provide useful procedural guidance as follows:

A. Formulating the Research Problem:

At this stage, researchers will re-examine the significance of the research problem regarding the Geographic Information System (GIS) for disaster mitigation in the new Capital City of the Nusantara (IKN) located on the Island of Kalimantan, which will serve as Indonesia's future capital. This study will consider various disaster mitigation activities that have already been implemented, such as evacuation direction signs and early warning systems for 13 potential disasters that frequently occur in East Kalimantan. These disasters include floods, flash floods, forest fires, and landslides, which are more likely to happen during heavy rainfall. Consequently, researchers will observe the current state of disaster preparedness and the effectiveness of mitigation tools in the field.

B. Researchers conducted a comprehensive literature:

Survey that revealed significant differences in disaster preparedness between developed and developing countries. In developed nations, evacuation routes, tsunami signs, and early warning systems are more advanced, supported by extensive research studies. Additionally, studies conducted by agencies such as the Government, the National Disaster Management Agency, and the Earthquake and Tsunami Assessment Agency were analyzed. To evaluate this research, the researchers employed spatial methods, particularly geoprocessing using Geographic Information System (GIS) tools. They also reviewed relevant spatial literature pertaining to disaster studies and aimed to align their findings with existing disaster indicators in the field.

C. The development of working hypotheses:

Crucial for researchers studying the Geographic Information System (GIS) for disaster mitigation in the future capital city of Indonesia, located on the Island of Kalimantan. This area is at risk of

experiencing 13 potential disasters, including floods, flash floods, forest fires, and landslides, particularly during heavy rainfall.

D. *Preparing the Research Design:*

The research design outlines the methodology for the study. The researcher will begin by formulating the research problem, which focuses on disaster preparedness and mitigation. The case study will be conducted in the Capital City of the Nusantara (IKN) on the Island of Kalimantan, the future capital city of Indonesia; Next, the researcher will develop an initial hypothesis regarding the problem and will seek relevant secondary data associated with this research. Following that, a primary data survey will be conducted. The collected data will then undergo analysis through geo-processing, and visualization outputs will be created using geographic information systems (GIS); The results will be analyzed and interpreted to assess whether the disaster mitigation evacuation routes in the Capital City of the Nusantara (IKN) are adequate and appropriate. Finally, the researcher will prepare a report summarizing the research activities and findings.

E. *To determine the sample design:*

Researchers will develop an initial research plan utilizing existing data. This includes the need for topographic and spatial information related to the future capital city of Indonesia (IKN) on the island of Kalimantan. Data can be obtained from the Geospatial Information Agency (BIG) and will cover various aspects such as population density, locations of densely populated settlements, tourist attractions, altitude, and land slope in the Indonesian Capital City (IKN).

F. *Researchers will collect data:*

Through satellite observations in Indonesia's future capital city (IKN) on the island of Kalimantan. They will examine evacuation route signs on all main roads and conduct observations in densely populated areas as well as tourist locations.

G. *The researcher will perform geo-processing:*

On primary and secondary data, creating visualizations using geographic information systems.

H. *Researchers will analyze and synthesize data from:*

Geo-processing and geographic information systems to determine whether the disaster evacuation routes in the Indonesian Capital City (IKN) on the island of Kalimantan, the future capital of Indonesia, are safe and adequate.

I. *Researchers will analyze data to determine:*

If the evacuation route signs along the main route in the Indonesian Capital City (IKN) on the island of Kalimantan are safe and adequate.

J. *The researcher will conduct generalizations and interpretations of this study:*

Providing evaluations and recommendations related to the research, particularly regarding the signage for disaster evacuation routes in the Indonesian Capital City (IKN) on the island of Kalimantan, which will be the future capital of Indonesia.

K. *The researcher will prepare the final report for this study:*

Which aims to highlight the significance of disaster evacuation route signage in the Capital City of the Nusantara (IKN) on the Island of Kalimantan, the future capital of Indonesia. This report is intended to contribute to improved disaster preparedness and mitigation efforts.

IV. RESULTS AND DISCUSSION

The Indonesia Geographic Information System for Disaster Mitigation in the Indonesian Capital City (IKN) on the Island of Kalimantan.

This research highlights the significant potential for disasters facing the Indonesian Capital City (IKN) on the Island of Kalimantan, which will soon become the nation's future capital. East Kalimantan is prone to 13 types of disasters that frequently threaten the area, including floods, flash floods, forest fires, and landslides—especially during heavy rainfall. In light of this, it is imperative to precisely remap evacuation routes for effective disaster mitigation using a robust geographic information system.

To create safe and accessible evacuation strategies, we must conduct thorough measurements of height, slope, and width within the IKN area, alongside evaluating current evacuation routes. This proactive approach will empower the community by ensuring they have efficient and secure pathways to safety during emergencies.

Moreover, an analysis of earthquake potential from 1900 to 2024 indicates that the risk in the Indonesian Capital City area is notably low. Additionally, a review of forest fire incidents from 2012 to 2021 reveals that the likelihood of forest fires is minimal in this region and can be effectively monitored. By addressing these concerns now, we can build a safer future for the IKN community.

The Capital of the Nusantara is strategically located at the heart of the region

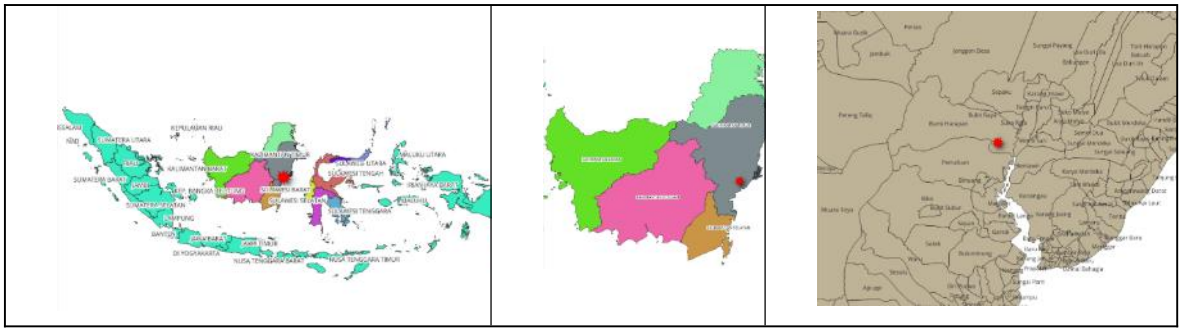

Figure 1. Discover the strategic location of Indonesia's new capital city (IKN), a place designed for growth and innovation

In Figure 1, the territory of the Unitary State of the Republic of Indonesia is depicted. Indonesia is known for having an impressive total of 17,380 officially recorded islands (Geospatial Information Agency (BIG), 2024), which makes it one of the most iconic Nusantaras in the world. The country has an extensive coastline that stretches for 99,093 kilometers, highlighting the stunning beauty of its natural landscapes.

In Figure 1, in the middle and right, is the island of Kalimantan where the capital of Nusantara is located, specifically in the Province of East Kalimantan.

Indonesia covers approximately 2.012 million square kilometers of land and is rich in terrestrial resources. However, it also boasts a vast maritime area of around 5.8 million square kilometers, which accounts for 75.7% of its total area. Within this maritime region, an incredible 2.7 million square kilometers are designated as an Exclusive Economic Zone (EEZ). This indicates that Indonesia's sea area is 2.5 times larger than its land area. This unique geographical advantage offers significant opportunities for economic growth and sustainable development (The House of Representatives of the Republic of Indonesia Documents, n.d.).

SRTM Map - Contour of the Capital of the Nusantara

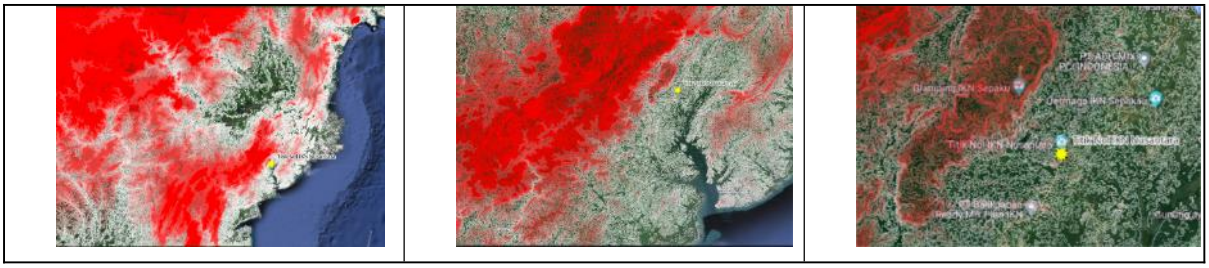

Figure 2. SRTM Map - Contour of the Capital of the Nusantara (IKN)

Figure 2 depicts a Digital Elevation Model (DEM) of the area surrounding the Indonesian Capital City (IKN), which was downloaded from the NASA server using SRTM Tiles. The contours to the west of IKN reveal a series of hills and natural mountains, resembling a natural fortress protecting the Indonesian Capital City.

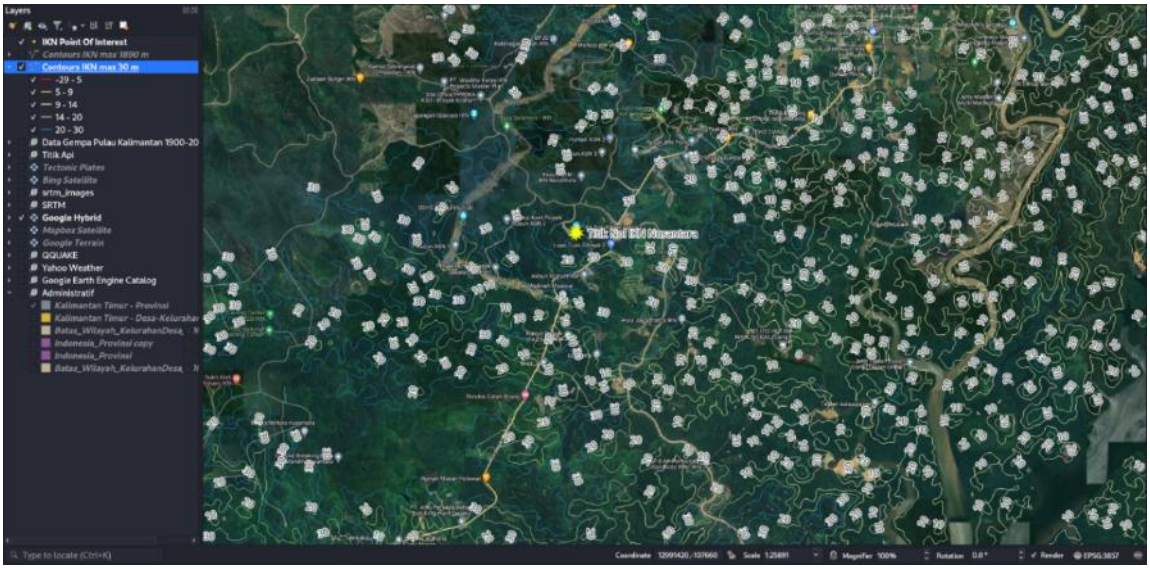

Figure 3. The average elevation of IKN above sea level is crucial for understanding its environmental dynamics and development potential.

In Figure 3, we see that the average elevation surrounding the Indonesian capital city is predominantly between 20 and 30 meters above sea level.

With the highest point at 30 meters, this region boasts a generally favorable terrain, while the lowest elevation ranges from -29 to 5 meters above sea level, highlighting the unique topography that shapes this vibrant area.

The IKN Position in Relation to World Tectonic Plates

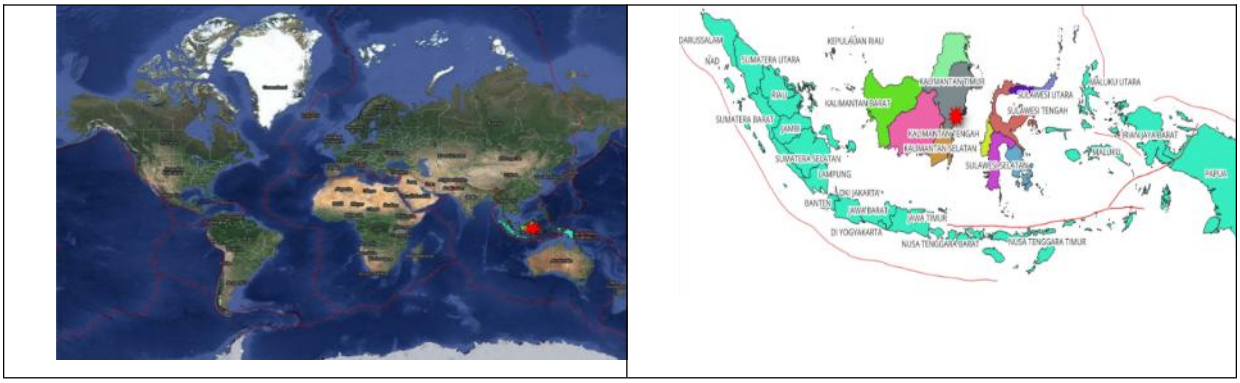

Figure 4. Understanding the IKN Position and Its Significance within World Tectonic Plates

The position of the Indonesian capital (IKN) in relation to global tectonic plates is depicted in Figure 4. IKN is strategically located away from the megathrust tectonic plate zones to the south and east, which is a significant advantage. The term "megathrust" describes immense earthquakes triggered by tectonic plates shifting dramatically, often leading to devastating tsunamis (Potensi Megathrust di Selat Sunda dan Mentawai (ITB), n.d.). Specifically, the Sunda Megathrust, situated south of Sumatra and Java, is notorious for generating earthquakes with magnitudes surpassing eight, posing a serious tsunami threat. Understanding this geography is crucial for ensuring the safety and resilience of IKN (Sumber Gempa Bumi Zona Penunjam (Megathrust), ESDM, n.d.).

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Analyzing the Pattern of Earthquake Activity on the Islands of Kalimantan and Sulawesi (1900-2024)

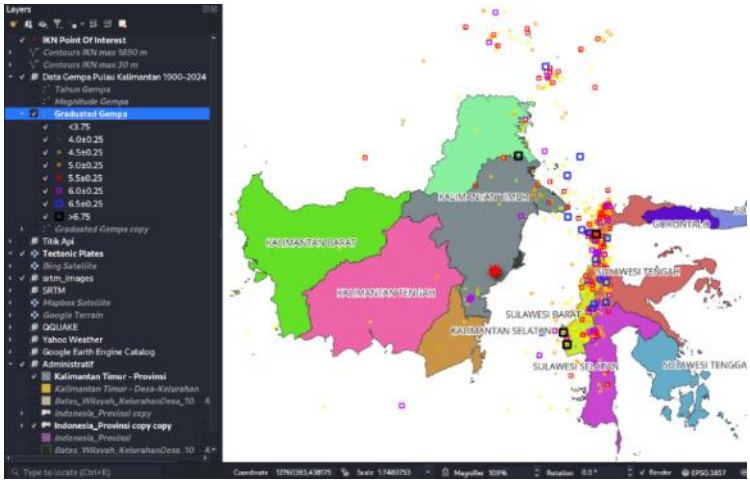

Figure 5. Distribution of Earthquakes on the Islands of Kalimantan and Sulawesi (1900-2024)

Distribution of Earthquakes in East Kalimantan and Surrounding Areas, analysis of Earthquake Distribution in East Kalimantan and Neighboring Regions (1900-2024): A Critical Examination of Seismic Patterns and Their Implications.

The investigation of earthquake data from 848 seismic points, spanning from 1900 to 2024 and sourced from the USGS Earthquake Explorer, reveals critical insights displayed in Figure 5. Notably, the IKN region has experienced several noteworthy earthquakes:

In the south, a magnitude 4.8 earthquake struck in 1998, located approximately 81 km from the nearest land, highlighting the geological activity in this area.

To the west, a magnitude 4.2 earthquake was recorded in 2019, situated about 103 km from land, further illustrating the seismic risks encountered.

To the east, an earthquake in 2003 registered a magnitude of 4.9, occurring around 144.9 km offshore, emphasizing the potential for coastal impacts.

Finally, to the north, the area was shaken by a significant 6.2 magnitude earthquake in 1924, located about 205 km from land, underscoring the historical seismic threats in the region.

This data reinforces the importance of continual monitoring and preparedness in response to earthquake activity surrounding the IKN area.

Distribution of Earthquakes around the Capital City of the Nusantara to the South

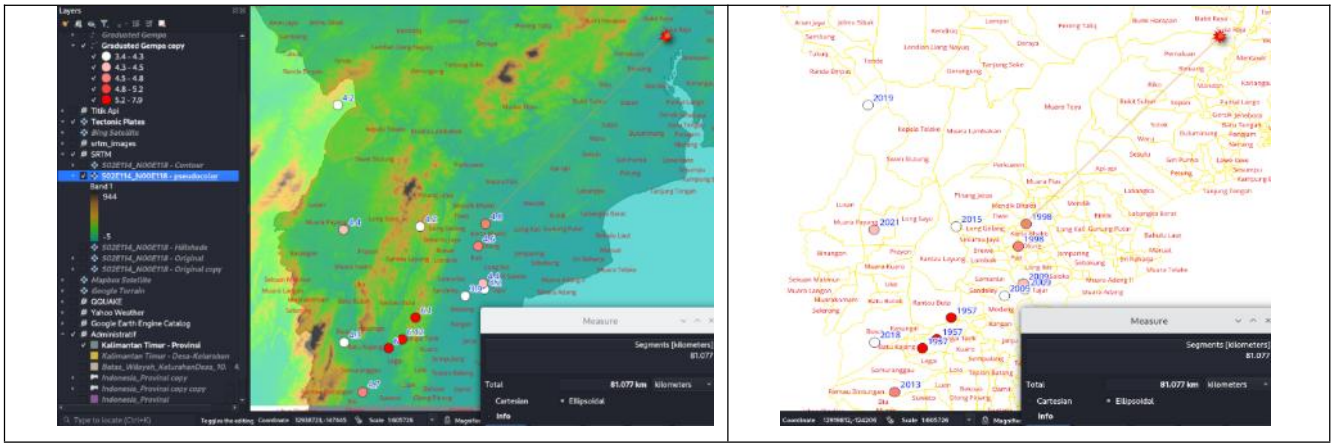

Figure 6. Understanding the Distribution of Earthquakes Around the Capital City of the Nusantara from the South is crucial for effective disaster preparedness and response

Distribution of Earthquakes Around the Capital City of the Nusantara from the West

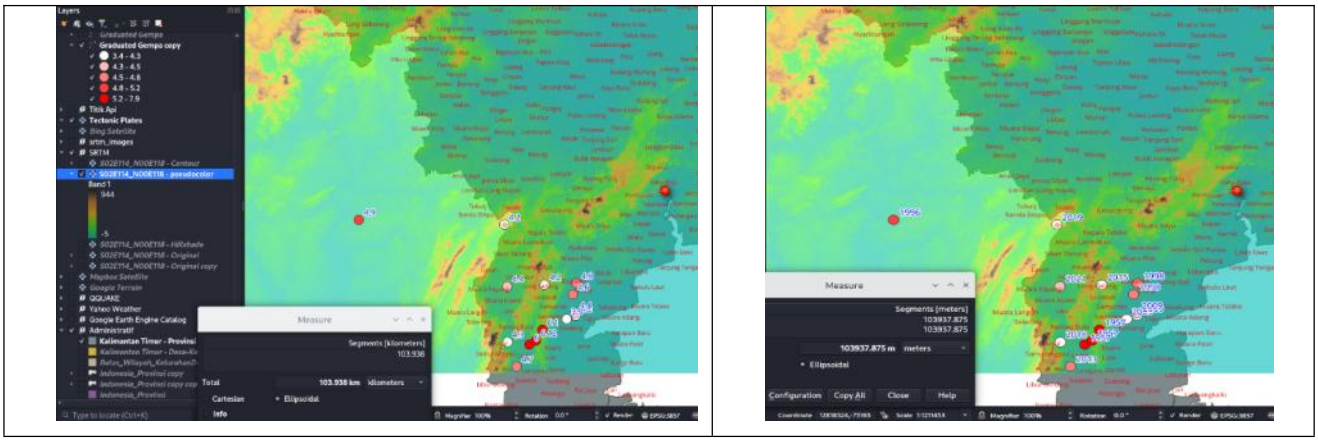

Figure 7. Understanding the Distribution of Earthquakes to the West of the Capital City of the Nusantara is crucial for effective disaster preparedness and safety planning

Distribution of Earthquakes around the Nusantara's Capital City from the East (Sea)

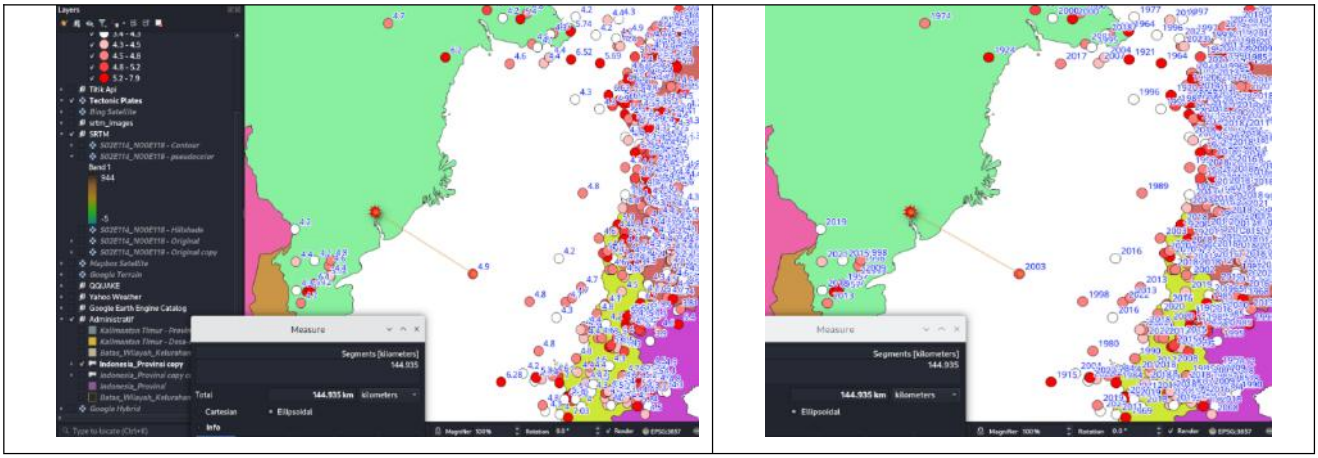

Figure 8. The distribution of earthquakes around the capital city of the Nusantara, particularly from the east (sea), demands our urgent attention and proactive measures.

Distribution of Earthquakes Around the Capital City of the Nusantara from the North

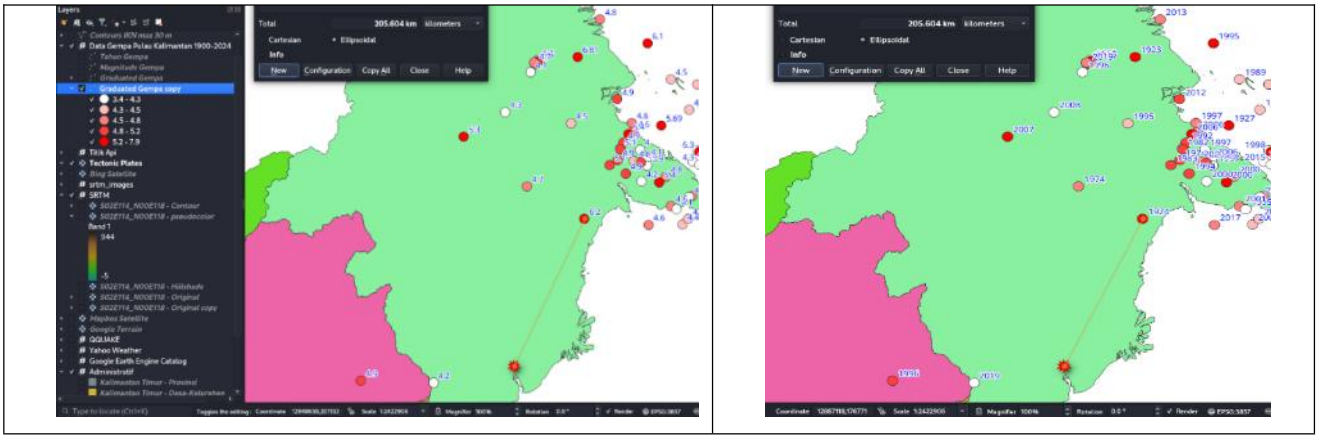

Figure 9. Understanding the Distribution of Earthquakes North of the Capital City in the Nusantara. This knowledge is crucial for ensuring safety and preparedness in our communities

Analyzing the Distribution of Hotspots in East Kalimantan Province (2012-2021) is crucial for understanding environmental changes and addressing challenges

Figure 10. Visualize the Trends: Distribution of Hotspots in East Kalimantan Province (2012-2021)

One of the most pressing challenges for disaster mitigation in Indonesia's new capital, Nusantara (IKN), is the threat posed by forest fires and hotspots. As illustrated in Figure 10, data from NASA satellites—the Visible Infrared Imaging Radiometer Suite (VIIRS) and the Moderate Resolution Imaging Spectroradiometer (MODIS)—highlights the distribution of hotspots from 2012 to 2021.

The observations for 2021 reveal a significant improvement, showing that the area around IKN is relatively safer from hotspots compared to previous years. Notably, in 2020, hotspots were alarmingly close, particularly in the northern regions. Between 2016 and 2019, hotspots continued to exist predominantly to the north of IKN but remained distant from the capital itself. However, from 2012 to 2015, IKN and its surroundings faced notable challenges with multiple hotspots.

Given the 13 potential disasters that frequently occur in East Kalimantan, including floods, flash floods, forest and land fires, and landslides—especially during heavy rainfall—there is an urgent need to prioritize the mitigation of forest and land fires. This calls for meticulous planning and the establishment of an independent task force dedicated to this cause. It is essential to monitor forest use permits (IPH) and Industrial Timber Forest Product Management Permits (IUPHHK-HTI) with strict oversight, ensuring that all stakeholders are educated about the risks associated with forest and land fires.

Moreover we should consider the implementation of a specialized air squadron for combating large-scale forest fires, akin to the capabilities seen in developed countries. With the advent of the Nusantara Capital (IKN), we have a unique opportunity to implement comprehensive forest and land fire mitigation strategies on Kalimantan Island, ensuring a safer and more resilient future.

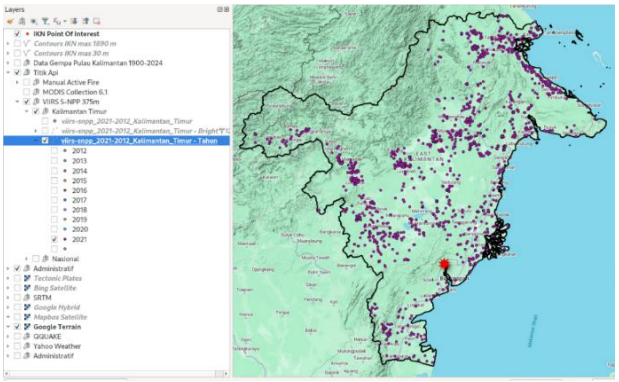

Figure 11. Hotspot Distribution in East Kalimantan Province in 2021: A critical examination

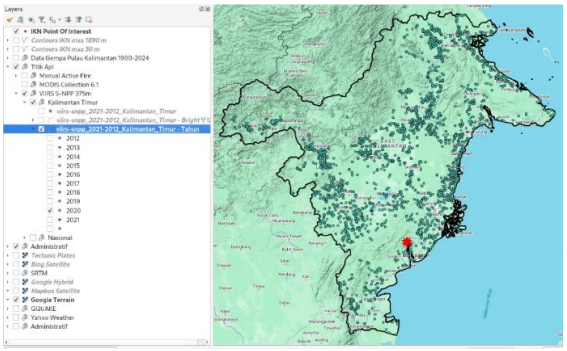

Figure 12. Distribution of Hotspots in East Kalimantan Province in 2020

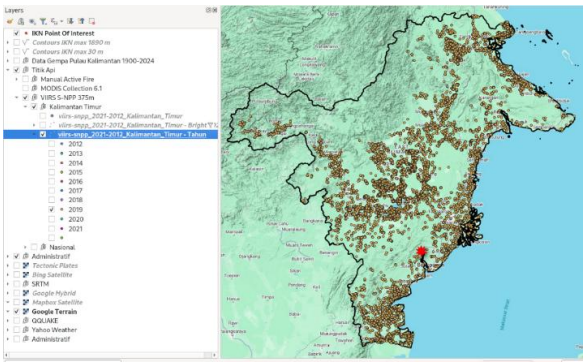

Figure 13. Distribution of Hotspots in East Kalimantan Province in 2019

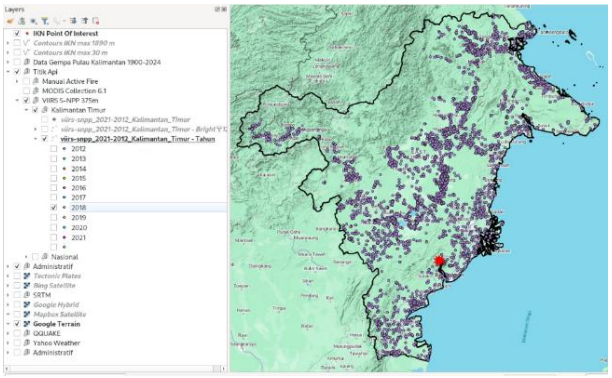

Figure 14. Distribution of Hotspots in East Kalimantan Province in 2018

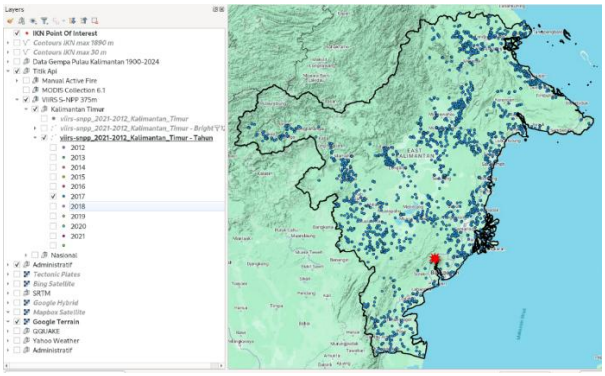

Figure 15. Distribution of Hotspots in East Kalimantan Province in 2017

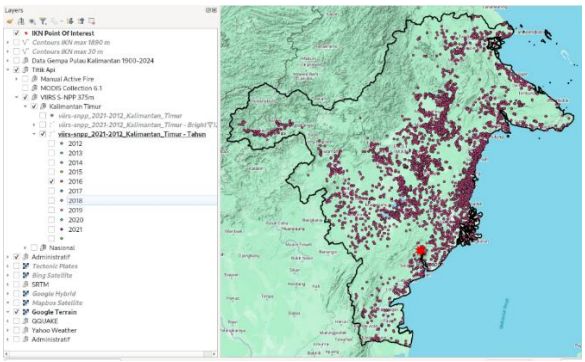

Figure 16. Distribution of Hotspots in East Kalimantan Province in 2016

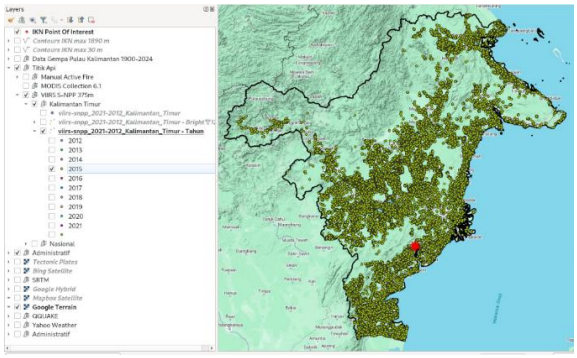

Figure 17. Distribution of Hotspots in East Kalimantan Province in 2015

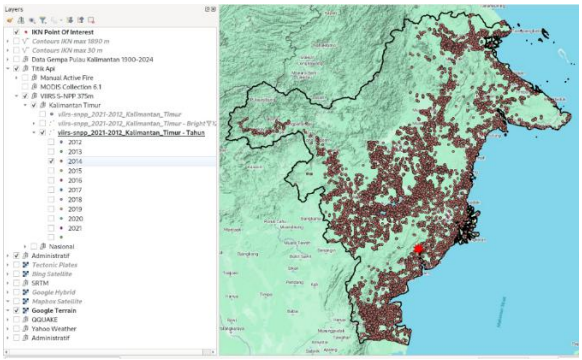

Figure 18. Distribution of Hotspots in East Kalimantan Province in 2014

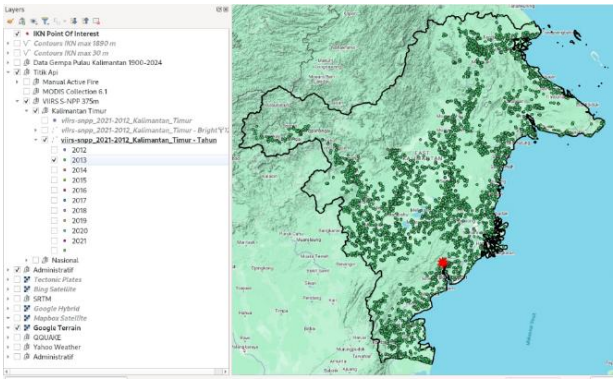

Figure 19. Distribution of Hotspots in East Kalimantan Province in 2013

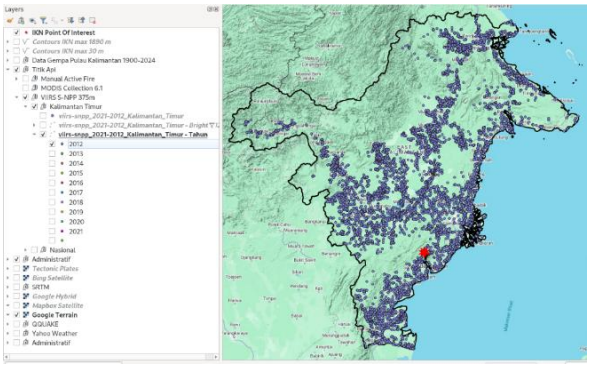

Figure 20. Distribution of Hotspots in East Kalimantan Province in 2012

V. CONCLUSION AND FUTURE WORK

Geographic Information System for Disaster Mitigation in the Indonesian Capital City (IKN) on the Island of Kalimantan.

This research addresses the potential disasters facing the Indonesian Capital City (IKN) on the Island of Kalimantan, which is set to be the future capital of Indonesia. East Kalimantan is susceptible to 13 types of disasters that frequently occur, including floods, flash floods, forest fires, and landslides, particularly during heavy rain. Therefore, it is essential to remap evacuation routes for disaster mitigation using a precise geographic information system.

To ensure effective evacuation, measurements of height, slope, and width in the IKN area are necessary, along with an evaluation of existing evacuation routes. This will enable the local community to have adequate and safe evacuation options.

Additionally, an examination of the potential and distribution of earthquakes from 1900 to 2024 in East Kalimantan reveals that the earthquake risk in the Indonesian Capital City area is very low. Furthermore, an analysis of forest fire occurrences from 2012 to 2021 indicates that the potential for forest fires in the IKN area is minimal and can be monitored effectively.

VI. ACKNOWLEDGMENTS

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