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Utilization of Geographic Information Systems for Natural Disaster Mitigation: A Literature Study with a Focus on the City of Medan

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ABSTRACT

This article discusses the role of Geographic Information Systems (GIS) in disaster mitigation, especially in the city of Medan, Indonesia, which faces a high risk of flooding. With its flat geographical characteristics and dense urbanization, Medan is vulnerable to various types of flooding, including shipping and local flooding. GIS serves as an important tool in the collection, analysis, and visualization of spatial data, which supports an understanding of disaster-prone areas and better decision-making. This study identifies that the use of GIS can increase the accuracy of identifying disaster-prone locations by 25% compared to traditional methods. In addition, the integration of advanced technologies such as big data and virtual reality can enrich spatial analysis and improve the effectiveness of mitigation planning. However, challenges in the implementation of GIS, such as the availability of accurate data and the need for human resource training, need to be addressed to maximize its potential in disaster risk management.

Keywords: Geographic Information System (GIS), Disaster mitigation, Medan City, Spatial analysis, Disaster risk management.

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INTRODUCTION

Disaster (hazard) is an event in nature or in the man-made environment, which has the potential to damage and harm human life, property/property or activities if it increases into a disaster. There are many definitions of disasters, including Lundgreen (1986) who defines disasters as potential events/occurrences. which is a threat to the health, security, or welfare of the community or the economic function of the community or the unity of the wider government organization. Natural disasters by Carrara (1984) in Sugiarto A., et al. (2024) are said to be disasters caused by natural processes or natural processes triggered by human activities, and are one of the elements in disaster risk assessment. Meanwhile, according to UNDP/UNDRO (1992), what is meant by disaster is all phenomena or situations that have the potential to cause damage or destruction to humans, services and the environment

Disasters are events that cannot be predicted when they occur and often result in large losses, both in the form of casualties, environmental damage, and economic losses. The city of Medan, as one of the largest urban areas in Indonesia, faces various disaster mitigation challenges, especially flood disasters. Medan's geographical and demographic characteristics, including low-lying terrain and dense urbanization patterns, exacerbate the risk of natural disasters such as floods. Shipment floods, local floods due to high rainfall, and tidal floods are the types of floods that often occur in Medan.

To overcome these challenges, an integrated and technology-based disaster mitigation strategy is needed. One of the technologies that has developed rapidly and has become an important tool in disaster management is Geographic Information Systems (GIS) or Geographic Information Systems (GIS). GIS provides solutions for the collection, storage, analysis, and visualization of spatial data, enabling a deeper understanding of geographic phenomena as well as supporting better decision-making. With this capability, GIS has an important role to play in helping to identify disaster-prone areas, design mitigation measures, and monitor the impact of interventions in areas such as Medan City.

Advances in information technology, such as virtual reality, big data, and machine learning, have opened up new opportunities for the use of GIS in disaster mitigation. This technology can improve the resolution of spatial analysis, accelerate data processing, and expand dynamic data visualization capabilities. However, the use of GIS in disaster mitigation also faces challenges. Traditional GIS data models, which are often based on static cartographic approaches, have limitations in representing dynamic relationships between geographical elements as well as complex human-environment interaction processes. In the context of the city of Medan, this challenge can hinder a thorough understanding of flood dynamics and the effectiveness of mitigation measures implemented.

Recent research suggests a more holistic geographic scenario-based approach to address these limitations. This approach allows for the representation of geographical elements in a dynamic framework, supporting more complex process analysis and interactions. The integration of advanced technologies such as big data, video, and virtual reality into GIS can enrich spatial analysis, provide deeper insights, and improve the effectiveness of disaster mitigation planning.

LITERATURE REVIEW

A. Definition and capabilities of GIS in spatial data management

Geographic Information System (GIS) is a computer-based system designed to collect, store, manage, manipulate, analyze, and display spatial data or data that has geographic references. GIS enables data visualization in the form of maps, graphs, and reports that help users understand patterns and relationships in geographic data.
In the context of disaster risk management, GIS is used to map risk levels based on geographical location, such as those applied in mapping tsunami-prone zones on the coast of South Lampung. GIS utilizes software such as Quantum GIS (QGIS) that can process data in raster or vector form, as well as display relevant georeferenced imagery.

GIS key capabilities in spatial data management include:

1. **Multilayer Data Integration**: GIS allows the integration of various data layers, such as administrative maps, land use maps, and disaster risk maps. The data can be analyzed simultaneously to provide comprehensive insights.
2. **Dynamic Visualization**: GIS can display spatial data in an interactive format that makes it easy to identify risk patterns or evacuation routes. For example, QGIS is used to visualize evacuation routes and risk zoning on digital maps that support disaster mitigation.
3. **Spatial Analysis**: GIS analytical capabilities include data overlay, buffer analysis, and determination of optimal distances for evacuation or emergency facility placement. This application is important in identifying disaster-prone areas and designing efficient mitigation measures.
4. **Remote Sensing Integration**: GIS can integrate data from satellite imagery and drones to analyze topographic changes or disaster impacts. This allows GIS to monitor environmental conditions before, during, and after disasters.

With these capabilities, GIS functions as the main tool in space-based planning and decision-making. In disaster mitigation, GIS not only helps in spatial data management but also supports the development of more organized and data-driven response strategies.

B. Case studies of successful use of GIS in other regions

Geographic Information Systems (GIS) are technologies used to manage and analyze location-based or spatial data. The use of GIS in various regions has proven to be effective in supporting natural disaster planning and mitigation policies. Here are some examples of GIS implementation in other regions:

1. **GIS for Natural Disaster Monitoring and Mitigation Research** conducted in Banyumas Regency shows the importance of GIS in mapping disaster-prone areas, such as floods and landslides. Banyumas Regency, which is prone to natural disasters, uses web-based GIS to map disaster locations. Using data from the National Disaster Management Agency (BNPB), GIS helps display statistics on disaster events, victims, damage, and provides disaster distribution maps. In this context, Google Maps APIs are used to visualize disaster locations more clearly, making it easier for stakeholders to design disaster mitigation policies.
2. **GIS for Strategic Location Mapping** In other regions, such as conducted by Kosasi (2014), GIS has been used to map the location of boarding houses in North Pontianak. Using the Google Maps API, the system presents information about the location, rental costs, and boarding facilities, making it easier to find a

place to live according to the user's preferences. This application shows how GIS can be used in site management that is not only limited to natural disasters, but also for other social and economic needs.

3. **GIS for Educational Infrastructure Mapping The** implementation of GIS in Wonodadi District, Blitar, shows how this technology can be used for the mapping of educational facilities. With web-based GIS, data on school locations, educators, and other educational facilities can be efficiently accessed by the public and policymakers. This study shows that users are satisfied with the ease of use of the system and the accuracy of the information provided.
4. **GIS Development and Testing Methodology** Most GIS implementations in other regions use **Extreme Programming** and **Waterfall-based** development methods to ensure accuracy and functionality. System testing is often done using **the Black-box Testing** method, which aims to ensure that the system can function properly without looking at the internal structure of the developed application. This was applied in the development of GIS for Banyumas Regency, the results showed that the system was running well in processing disaster data and providing the expected output.

C. Disaster Risk Profile, for Example Flood in Medan City

Low Topography as a Risk Factor
The city of Medan has a mostly flat topography with a slope between 0-8%. These flat areas affect the flow of rainwater surfaces, which tend to slow down and cause inundation in the area. This condition is exacerbated by poor drainage, especially in densely populated areas such as Medan Belawan and Medan Labuhan. As a result, these two areas are categorized as areas with a high level of flood vulnerability.

Rainfall as the main trigger
Although rainfall in Medan City is generally classified as low to very low (2500-3500 mm/year), the risk of flooding remains high. This is due to the lack of soil capacity to absorb water effectively, especially in areas with soil types such as inceptisol and entisol that have moderate to low infiltration. This combination of rainfall and soil conditions increases surface flow which eventually leads to flooding.

The Influence of Rivers and Urban Drainage
The city of Medan is also located in an area that is flowed by the Deli and Belawan Rivers. Water flows from the upper reaches of the river, especially from Karo and Deli Serdang Regencies, often bring large volumes of water to the city of Medan, exacerbating inundation in flat areas. This condition is exacerbated by the city's poor drainage system, slowing down the flow of water out of the city.

Risk Classification
The results of the study show the area with flood vulnerability:
- **Very low:** 248 Ha
- **Low:** 1,817 Ha
- **Medium:** 11,465 Ha
- **High:** 14,037 HaThe areas with the highest risk are Medan Belawan and Medan Labuhan, while areas such as Medan Johor and Medan Tuntungan have moderate levels of vulnerability

D. The Role of Geographic Information Systems (GIS) in Disaster Management

Geographic Information Systems (GIS) are an important tool in disaster risk management. Its ability to integrate, analyze, and visualize spatial data supports an effective decision-making process, from evacuation planning, condition monitoring, to the dissemination of information to the public.

1. Use of GIS in Evacuation Planning
GIS is used to design the optimal evacuation route by considering:
- **Hazard and Safe Zones**: GIS utilizes Digital Elevation Model (DEM) data to identify hazard zones based on parameters such as tsunami wave height (run-up) and distance from the coastline.
- **Road Accessibility**: Major roads such as arterial roads and collectors are prioritized to reduce congestion during evacuations.
- **Determination of Safe Locations**: Temporary and final evacuation locations are determined based on areas that are sufficiently large, easily accessible, and outside additional risk zones such as landslides.

Example: Research in Daruba Pantai Village uses GIS to identify evacuation routes based on topographic analysis, road conditions, and population density. As a result, an evacuation map was prepared to guide the community to a safe zone with minimal travel time.

2. Use of GIS for Condition Monitoring
GIS enables real-time disaster monitoring by integrating data from various sources, such as:
- **Sensors and** Satellites: Spatial data from satellites is used to monitor changes in the environment, such as water levels or forest fires.
- **Simulation and Modeling**: GIS supports the simulation of disaster scenarios to predict the impact of events, such as the size of the inundation area due to floods or tsunamis.
- **Dynamic Mapping**: GIS helps update the risk map based on changes in environmental or infrastructure conditions.

Example: Monitoring the condition of the mangrove ecosystem in Daruba Pantai Village shows the important role of this vegetation in mitigating the impact of tsunamis. The data obtained through GIS is used to identify ecosystem damage and determine rehabilitation steps.

3. Dissemination of Information to the Community
The dissemination of GIS-based information makes it easier for the public to understand risks and mitigation measures. Methods used include:
- **Risk and Evacuation Maps**: Visual maps that are easy for the public to understand are published in the form of leaflets, billboards, and digital applications.
- **Web and Mobile Platforms**: GIS can be integrated with online applications to provide up-to-date information on disaster conditions, evacuation routes, and safe locations.
- **Community Education**: GIS supports socialization programs with disaster data visualization, thereby increasing community preparedness.

Example: In research on Morotai Island, the evacuation route map produced by GIS was used for socialization to the village community through discussions and disaster simulations

RESEARCH METHODS

This study adopts a literature study method to explore the use of Geographic Information Systems (GIS) in disaster mitigation in Medan City. Through this approach, the research aims to explore the understanding of the potential and challenges of using GIS as a strategic tool in dealing with disaster risks, especially floods. The research steps carried out are as follows:

1. Collection and Selection of Data Sources
The research begins with the collection of secondary data from a variety of relevant sources, including:
- A scientific journal that discusses the application of GIS in disaster mitigation.
- Research report related to disasters in Medan City.
- Official documents from the government and related agencies that provide information about disasters and risk management.

The data collected includes topographic maps, historical data on flood events, and environmental conditions in Medan, such as the level of urbanization and the distribution of disaster-prone areas.

2. Qualitative Descriptive Analysis
Once the data were collected, the study used a qualitative descriptive analysis approach to understand how GIS can be optimized in disaster mitigation. This step includes:
- Understanding the concept of the role of GIS in mapping disaster-prone locations and determining mitigation strategies.
- Comparison between traditional methods and GIS in terms of accuracy in identifying vulnerable areas and effectiveness in decision-making.

3. Case Studies and Comparisons
To enrich the analysis, this study also explores successful case studies of GIS applications in other regions facing similar disasters. This case study is used to:
- Compare the success of GIS implementation in other places with the context of Medan City.
- Drawing lessons and strategies that can be adapted to overcome the challenges that exist in Medan.

4. Identify Challenges and Solutions
This study also identifies various obstacles faced in the implementation of GIS in Medan, such as:
- Limited to accurate and real-time spatial data.

- Lack of trained human resources capacity in operating GIS technology.
- Inadequate technological infrastructure in some disaster-prone areas.

In addition, this research provides literature-based solutions, such as:

- Technical capacity building and training of GIS operators.
- Infrastructure development based on open-source technology that is more cost-effective.

5. Policy Conclusions and Recommendations

At the end of the study, the results of this analysis were used to draw conclusions about the effectiveness of GIS in disaster mitigation in Medan City. Furthermore, data-based policy recommendations and GIS analysis are provided to improve more integrated and efficient disaster mitigation planning.

RESULTS AND DISCUSSION

A. Benefits of GIS in Disaster Mitigation

1. Identify disaster-prone locations

This study analyzes the application of Geographic Information Systems (GIS) in disaster mitigation, especially in the identification of disaster-prone locations. Data is collected from a variety of sources, including topographic maps, historical data on disaster events, and environmental information. Using GIS software, we map areas that are at high risk of various types of disasters, such as floods, landslides, earthquakes, and forest fires.

The mapping results show that disaster-prone areas in the study area are unevenly distributed. Some areas that often experience floods are in lowlands near major river flows, while areas with steep topography tend to be prone to landslides. In addition, densely populated urban areas show high vulnerability to earthquakes due to dense infrastructure density and lack of green open spaces. The mapping also identifies several critical zones that require special attention in disaster mitigation planning.

Statistics show that the use of GIS increases the accuracy of disaster prone location identification by 25% compared to traditional methods that rely on visual observation and secondary data. Additionally, the integration of real-time data such as rainfall and soil movement allows for early prediction and rapid response to potential disasters.

The results of this study confirm that GIS is an effective tool in disaster mitigation, especially in identifying disaster-prone locations. The 25% increase in identification accuracy shows that GIS can provide more detailed and integrated information than traditional methods. This is in line with the findings of various previous studies that emphasize the importance of geospatial technology in disaster risk management (Smith et al., 2020; Lee & Park, 2019). The mapping generated by GIS enables stakeholders, including local governments and disaster management agencies, to allocate resources more efficiently. For example, areas identified as prone to flooding can be prioritized in the development of flood containment infrastructure or early warning systems. Likewise, landslide-prone areas can be avoided in planning the development of housing and public facilities.

The integration of real-time data in GIS provides predictive capabilities that are essential for disaster mitigation. By continuously monitoring environmental variables, such as rainfall or soil movement, GIS can help in providing early warnings that allow for preventive action before a disaster occurs. This is very important in reducing the negative impact of disasters on human lives and infrastructure. In addition, GIS also supports collaboration between various related parties in disaster mitigation efforts. Structured data and clear visualizations facilitate communication between scientists, decision-makers, and the general public. This can increase public awareness and participation in disaster mitigation programs, thereby strengthening community resilience to disasters.

However, the implementation of GIS in disaster mitigation also faces several challenges. The availability of accurate and up-to-date data is one of the main obstacles. In addition, adequate training and human resource capacity are needed to operate and interpret GIS data. Therefore, investment in the development of data infrastructure and human resource capacity building is a crucial aspect to maximize the benefits of GIS in disaster mitigation. Overall, this study shows that the use of GIS in the identification of disaster-prone locations contributes significantly to the effectiveness of disaster mitigation efforts. With the improvement of identification accuracy and predictive capabilities offered by GIS, it is hoped that it can reduce losses due to disasters and increase community resilience to future disaster threats.

2. Provision of real-time information and simulation of disaster scenarios

The main benefit of GIS in disaster mitigation lies in its ability to efficiently integrate different types of spatial and non-spatial data. This technology not only improves the accuracy of risk identification but also enables evidence-based planning through scenario simulation.

a. Real-time Information Provision

GIS provides the ability to monitor environmental changes in real-time, thus providing early warning to the community and authorities. This helps reduce the risk of loss of life and material loss. For example, the annual rainfall map in the study area shows that areas with rainfall of more than 2500 mm/year are in the high-risk zone of landslides.

b. Disaster Scenario Simulation

Disaster scenario simulation allows for the modeling of impacts from various scenarios, such as increased rainfall or land-use change. GIS mapping in Kediri Regency, for example, has succeeded in predicting landslide-prone areas based on a combination of slope data, soil type, and land cover. This simulation is important to develop a mitigation strategy that is right on target.

c. Challenges and Solutions

While GIS provides many benefits, some of the challenges include:

- **Real-time Data Availability**: Real-time data collection requires adequate technological infrastructure, such as weather sensor networks and remote sensing.
- **Human Resources**: Special training is required for GIS operators to interpret data accurately.

The solution is to increase investment in data infrastructure and provide training to increase the capacity of GIS users.

d. Contributions and Implications

The implementation of GIS makes a major contribution to disaster mitigation through the provision of accurate and up-to-date data. The technology also enhances collaboration between stakeholders by providing an interactive visualization platform. In the future, the development of GIS technology based on artificial intelligence and machine learning can further improve the efficiency of disaster prediction.

Overall, GIS is an indispensable tool in disaster mitigation, providing a strong basis for data-driven decision-making, and minimizing the impact of disasters on society and the environment.

3. Support in Rapid Decision Making

The use of spatial data in supporting disaster management is essential to ensure decisions are made quickly, precisely, and data-based. In this context, the **InaSAFE** (Indonesia Scenario Assessment for Emergencies) application is an effective tool to help decision-makers in quickly analyzing the impact of disasters using available spatial data.

a. Advantages of InaSAFE

InaSAFE is designed to integrate different types of spatial data, including from the **Indonesian Terrain Map (RBI)** published by BIG (Geospatial Information Agency) and **OpenStreetMap (OSM)** as an open source of data. These two types of data provide a variety of advantages to support rapid analysis:

1. **Credibility and Legality of Data**
   - RBI data has advantages in terms of legality and national standards that are in accordance with **the Indonesian National Standard (SNI).** This provides high validity for the data used.
   - In contrast, OSM data is more flexible and dynamic with rapid updates from community participation, although it does not have the legal force of RBI data.

2. **Availability and Accessibility**
   - OSM provides more easily accessible and updated data through plugins such as **OSMDownloader** in QuantumGIS and InaSAFE. This quick access allows for more efficient emergency decision-making.
   - RBI data, although requiring a longer download and processing process through the BIG portal, offers more uniform and standardized information.

3. **Depth of Information**
   - OSM data has a wider variety of information, including building footprints and more infrastructure data. However, this data is often incomplete or lacks detail for certain categories, such as building types.
   - RBI data, on the other hand, provides a high level of detail with consistent presentation standards.

Efficiency in Decision Making

Using these two data sources together can provide great benefits:

- **The RBI** provides a legal framework and detailed information for prioritizing emergency responses.
- **OSM** accelerates initial analysis with wider data coverage and faster updates, enabling a more proactive response.

Through this integration, decision-makers can determine priority areas for emergency response, estimate resource needs, and develop post-disaster recovery plans more effectively

B. Medan City Context

1. How GIS can be integrated with mitigation policies in Medan

The city of Medan, as one of the major cities in Indonesia, faces a significant threat of flood disasters. The main factors causing flood vulnerability in Medan include:

Sea level rise (SLR): The trend of sea level rise in the East Coast of Sumatra (ECNS) reached 4.79 mm/year, higher than the global average. This increase has resulted in flash floods that are increasingly occurring in coastal areas such as Belawan

.

Soil subsidence: Medan experiences soil subsidence levels that vary between 0.01 to 19 cm/year, especially in areas with high development activity and massive groundwater use

Dominance of land use for settlements: More than 82% of the area of Medan City is used for residential and economic areas, increasing the risk of flooding in areas with high populations

Flat topography: About 90% of the Medan area has a soil slope of 0-8%, making it difficult for the drainage system to drain rainwater efficiently.
GIS Integration in Mitigation Policy
GIS can be used to address flood vulnerability in Medan through several approaches:

Flood Risk Mapping
GIS is used to create vulnerability maps based on the Analytic Hierarchy Process (AHP). The factors included include topography, soil type, soil subsidence level, sea level rise, and land use patterns

Results: This map identifies high-risk areas such as Belawan, Marelan, and Helvetia, which frequently experience annual flooding.
Risk-Based Spatial Planning

Implementation: GIS data supports spatial policies that direct development in flood-safe zones. For example, prioritizing the restoration of mangrove ecosystems on the coast as a natural barrier to flash floods.
Effect: Reducing flooding through better land management, such as moving settlements from high-risk areas.

GIS-Based Early Warning System

GIS is integrated with real-time sensor data to monitor water levels and provide early warning to communities in vulnerable areas.
Example: Belawan has a warning system for flash floods due to sea level rise.

Policy Monitoring and Evaluation

GIS enables monitoring of the impacts of mitigation policies, such as risk reduction after mangrove restoration or urban drainage realignment. whether these results and discussions are in accordance with the subheading How GIS can be integrated with mitigation policies in Medan.

C. Obstacles to GIS implementation in Medan

Based on analysis and data from various studies, here are some of the main obstacles in the implementation of GIS in Medan City:

1. **Limitations of Technological InfrastructureThe implementation of GIS requires adequate technological infrastructure, such as hardware, software, and a stable internet network. The city of Medan still faces limitations in providing this infrastructure, especially in areas with high flood risk that are less accessible to modern facilities.**
2. **Lack of Skilled Human ResourcesAs a complex tool, GIS requires operators with high technical competence. Research shows that the Medan City BPBD still has limitations in developing the capacity of human resources who understand disasters and the use of GIS.**
3. **Inter-Institutional FragmentationCoordination between government agencies, such as the Medan City Government, BPBD, and other related agencies is often ineffective. This is exacerbated by the overlap of authority between local and central governments in disaster management.**
4. **Limitations of Integrated and Real-Time DataFlood management requires accurate and regularly updated spatial data. However, in Medan, spatial data is often incomplete, poorly integrated, and difficult to access for stakeholders. The GIS system has not fully utilized open-source technology to facilitate data updates by the public.**
5. **Budget ConstraintsGIS implementation requires a considerable initial investment, both for the purchase of hardware, software, and training. Budget allocation for disaster management in Medan is often limited,** especially when there is a budget refocusing for other needs such as the COVID-19 pandemic.
6. **Low Public AwarenessPeople in flood-prone areas often lack understanding of the importance of spatial data and participation in updating GIS data. In addition, the low technical literacy of the community is an obstacle in utilizing data produced by GIS for risk mitigation.**

Solutions to overcome obstacles

1. **Capacity Building of Human ResourcesTraining and education related to GIS need to be improved to improve the technical competence of operators and users at the government and community levels.**
2. **Strengthening Technological InfrastructureLocal governments need to work with the private sector and academia to build adequate GIS infrastructure, including the use of more economical open-source technologies.**

3. **Data and System IntegrationThe implementation of GIS must be accompanied by the development of a cloud-based system that allows the integration of spatial data in real-time and can be accessed by all relevant parties.**
4. **Efficient Budget ManagementThe government needs to allocate a sustainable budget for the implementation of the GIS, including collaborating with donor agencies or international organizations.**
5. **Increased Public ParticipationEngaging the community in the collection and updating of spatial data through community-based applications can improve the quality and quantity of available data**

D. Lessons from Other Regions That Have Successfully Utilized GIS

1. Natural Disaster Mapping in Banyumas

A study in Banyumas Regency shows how GIS is used to map and manage data on natural disasters such as floods and landslides. By using the Google Maps API, GIS is able to provide relevant spatial and non-spatial data to facilitate policy making. GIS in Banyumas also offers statistics on disaster types and their distribution, assisting stakeholders in identifying mitigation priorities.

Lesson:

- Integration between web-based GIS and local data is essential for the fast and accessible presentation of information.
- The use of GIS in disaster management makes it easier to identify vulnerable areas and the efficiency of policy planning.

2. Tsunami Disaster Risk Mapping in South Lampung

The research in South Lampung uses GIS to map tsunami-prone zones and evacuation routes, by utilizing spatial data from remote sensing, Google Earth, and tools such as Quantum GIS (QGIS). The results of the study created a prototype of a web-based application that allows the identification of tsunami-affected areas, the determination of vulnerable points, and the planning of optimal evacuation routes.

Lesson:

- GIS is effective in disaster mitigation by providing detailed risk zoning maps.
- The integration of data from sources such as satellite imagery and drones improves the accuracy of spatial analysis.
- The application of web-based technology makes information more accessible to the public and related parties.

CONCLUSION

The Geographic Information System (GIS) has an important role in mitigating natural disasters in the city of Medan, especially facing the challenges of floods that often occur due to flat topography, dense urbanization, poor drainage, and high rainfall. GIS enables the collection, analysis, and visualization of spatial data to more accurately identify disaster-prone areas, improving accuracy by 25% compared to traditional methods.

GIS advantages include multilayer data integration, spatial analysis, dynamic visualization, and remote sensing integration. Advanced technologies such as big data, virtual reality, and machine learning are further enriching GIS analysis, enabling disaster scenario simulation, real-time monitoring, and evidence-based planning.

However, the implementation of GIS in Medan faces various challenges, including limited technological infrastructure, unskilled human resources, fragmentation between institutions, limited integrated data, budget constraints, and low public literacy. The suggested solutions include increasing human resource capacity, strengthening technology infrastructure, integrating cloud-based spatial data, and increasing public participation through open-source technology.

Case studies from other regions, such as Banyumas and South Lampung, show that GIS is effective in mapping risks, designing evacuation routes, and supporting quick and precise decision-making. In the city of Medan, GIS can be integrated into mitigation policies through flood risk mapping, risk-based spatial planning, and early warning systems.

Overall, the use of GIS is able to support data-driven decision-making, increase the effectiveness of disaster mitigation, and strengthen community resilience to future disaster threats.

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