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DISASTER MITIGATION BASED ON REVIEW ARTICLES IN SUSTAINABLE DEVELOPMENT MODELS IN INDONESIA

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ABSTRACT: Natural disasters are one of the main challenges facing Indonesia which can threaten the sustainability of development and community welfare. This research aims examines the role of Geographic Information Systems (GIS) in the literature review applied to disaster mitigation as part of a sustainable development model in Indonesia. The methodology used includes spatial analysis and secondary data collection regarding disasters that occurred in various regions. The research results show that the use of GIS in articles read can increase efficiency in disaster risk mapping, spatial planning and data-based decision making. In addition, the integration of GIS in disaster mitigation strategies can strengthen the resilience of society and the environment in Indonesia. This research recommends capacity building and collaboration between government, communities and stakeholders to maximize the potential of GIS in disaster mitigation and achieve sustainable development goals with One of the important goals in the SDGs is Goal 11: Sustainable Cities and Communities**,** which encourages disaster-resilient development, as well as Goal 13: Climate Action, which emphasizes the importance of adaptation and mitigation measures to climate change.

Keywords: Sustainable Development, GIS, Literature Review, and Disaster Mitigation

1. INTRODUCTION

Sustainable Development (SDGs) be a universal agreement to end poverty, protect everything that makes this planet habitable, and ensure that all people enjoy peace and prosperity, both now and in the future. These goals were formally adopted by all UN member states in 2015, for the period 2016-2030, to address the urgent empirical and scientific evidence that the world needs a more sustainable approach that gives us the best chance of ensuring the collaboration and alignment needed when we apply a global approach to guarantee the future, especially for Indonesia [1].

Based on sustainable development indicators, there are 17 indicators that will strive for sustainability. On the other hand, Indonesia is committed to implementing sustainable development in accordance with the Sustainable Development Goals (SDGs). One of the important goals in the SDGs is Goal 11: Sustainable Cities and Communities**,** which encourages disaster-resilient development, as well as Goal 13: Climate Action, which emphasizes the importance of adaptation and mitigation measures to climate change. With increasing urbanization and infrastructure development in various regions in Indonesia, the challenge of integrating disaster mitigation with sustainable development is increasingly pressing. The use of GIS in disaster mitigation can be a solution that is in line with the principles of sustainable development, where economic growth and community welfare do not sacrifice the environment and safety [2-5].

Indonesia is one of the largest archipelagic countries in the world. According to data from the Geospatial Information Agency (BIG) in 2013, the islands in Indonesia were formed due to the meeting of three world tectonic plates: the Australian plate, the Pacific plate and the Eurasian plate [6]. This condition makes Indonesia have a high potential for disasters such as earthquakes, tsunamis, volcanic eruptions and land movements (landslides). With a population of almost 300 million people, Indonesia has been named one of the countries with a very high level of disaster risk. Data shows that, if measured over a period of a decade, the incidence of disasters continues to increase significantly and in particular Indonesia has experienced 11,274 disasters. ("The Impact of Natural Disasters on House Prices," 2023) From these records, it is estimated that disasters in Indonesia have caused as many as 193,240 people to die and resulted in state losses reaching IDR 420 trillion. This figure is certainly very large and on the other hand, the large number of fatalities due to disasters shows how dangerous the disasters are. Indonesia's location on the equator and in the form of an archipelago creates great potential for various types of hydrometeorological disasters, namely floods, flash floods, drought, extreme weather (tornadoes), abrasion, extreme waves, and forest and land fires. The climate change phenomenon contributes to an increase in hydrometeorological disasters [7]. This makes Indonesia vulnerable to potential threats from hydrometeorological and geological disasters [8].

From this graphic illustration, it can be concluded that disasters in Indonesia often occur due to the supporting factors that exist in Indonesia, so mitigating these disasters is needed as a step for sustainable development in Indonesia. Hydrometeorological disasters are the most frequently occurring disasters, reaching 96.8%. namely disasters that are influenced by weather. Such as landslides, droughts, tornadoes, forest and land fires, extreme weather. From this incident, the number of victims who died reached 335 people, 969 people were injured, and 3.22 million people were displaced and suffered.

Meanwhile, the damage caused was 31,746 housing units damaged, 347,813 units submerged, thousands of health, education and worship facilities damaged due to the flood disaster [3, 6, 13, 14, 15]. Considering the large impact of natural disasters on people's lives, it is important to immediately realize community preparedness so that they can anticipate the impacts they cause. Disaster management stages are regulated in Article 33 and are divided into three stages, namely pre-disaster, emergency response and post- disaster. In disaster management efforts, the central government also collaborates with regional governments, business institutions, the private sector and the community. The use of technology and innovation such as big data, artificial intelligence (AI), and Geographic Information Systems (GIS) is also very important to predict extreme weather patterns and floods, as well as to formulate faster and more accurate responses. In the context of disaster mitigation,

Geographic Information Systems (GIS) is one of the key technologies that enables spatial mapping and disaster risk analysis. GIS provides tools capable of visualizing disaster data, identifying vulnerable areas, and integrating information from various sources to support decision making. By utilizing GIS, the government and stakeholders can plan mitigation strategies that are more targeted, both in terms of prevention, preparedness and emergency response. Utilizing this technology not only makes planning easier, but also allows better coordination between various parties in reducing disaster risk. In addition, the development of disaster insurance schemes and community-based financing can help communities recover more quickly after disasters. Inter-agency coordination and a strong regulatory framework are needed to regulate mitigation. The aim of this research is to analyze the level of disaster vulnerability in Indonesia and design sustainable development mitigation for disasters that occur in Indonesia [9-12, 16, 17, 18].

2. METHODS

This research uses an approach qualitative descriptive with the aim of identifying, analyzing and describing the role of Geographic Information Systems (GIS) in disaster mitigation and how this technology is applied in the context of sustainable development in Indonesia and collecting secondary data regarding disasters that occurred in various regions. This approach will explore the relationship between the use of GIS, disaster mitigation efforts, and sustainable development models with specific case studies in the Indonesian region.

This research will focus on regions in Indonesia that have a high level of vulnerability to disasters, especially floods, where flood problems in Indonesia are similar to those of various countries abroad. This location was selected based on the level of disaster risk and mitigation efforts that have been implemented using GIS. Secondary data includes relevant documents such as BNPB reports, spatial data from government agencies and research institutions, scientific journals, and other publications related to GIS, disaster mitigation, and sustainable development. This data will also involve disaster risk maps, geospatial data, and development policy analysis using Sustainable Development Goals (SDGs) indicators related to mitigation.

3. RESULTS AND DISCUSSION

Indonesia is geographically located between two continents (Asia and Australia) and two oceans (the Indian Ocean and the Pacific Ocean), making it an archipelagic country with thousands of large and small islands. Its location in the tropics and along the equator means that Indonesia receives high rainfall throughout the year, especially during the rainy season. This combination makes Indonesia vulnerable to various types of natural disasters, one of which is floods. Geographic Location and Flood Risk Factors [11].

Indonesia's location in the tropical zone causes high rainfall intensity in many areas, especially during the rainy season. rainy season, which runs from November to March. This high rainfall increases the risk of flooding, especially in low-lying areas near large rivers. Apart from that, coastal areas located along the coast are also often affected by tidal floods caused by rising sea levels due to high tides or climate change [12].

River Flow Factors and Topography Indonesia has a very extensive river network, such as the Kapuas River in Kalimantan, the Musi River in Sumatra, and the Citarum River in Java. These rivers flow through various areas, from mountains to lowlands, and often cause flooding during high rainfall. Lowlands located downstream of rivers such as in Jakarta, Semarang and other big cities are very vulnerable to flooding because these rivers often overflow when they are unable to accommodate large amounts of rainwater [13]. Impact of Urbanization and Environmental Management Rapid urbanization in Indonesia's big cities exacerbates the risk of flooding. The rapid development process is often not balanced with good spatial planning, especially in terms of water and drainage management. Deforestation, conversion of green land into residential or industrial areas, and poor drainage systems exacerbate the risk of flooding, especially in urban areas such as Jakarta. The inability of land to absorb rainwater due to land conversion causes water to flow to the surface and inundate residential areas [14-15].

Several cases related to disasters that occurred in Indonesia, problems in city development such as Padang Pariaman, considering that the land in city development and the Padang Pariaman area is an area that is only suitable as a cultivation area, looking at the criteria index for the level of landslide vulnerability, Padang Pariaman is in type A, so it is prone to landslides. which is high but has been processed into a capital and residential area, with this statement being an example that current development has not seen adequate regional characteristics that are suitable for development.

Besides that, According to the Malang City Regional Disaster Management Agency (BPBD), floods have occurred frequently for 20 years, since 2003 to be precise, and have increased significantly in the last five years. The city of Malang has experienced a total of more than 700 floods in all sub-districts since 2019. Approximately 211 flood disasters have been recorded during 2022. There are still many areas that should be water catchment areas where land has been converted into designated areas, such as housing, shops and educational institutions. Even the river border area, which was supposed to be a catchment area, is now being built with various types of new buildings, ranging from apartments, hotels and other buildings [16].

Then North Jakarta, which is located at an altitude of only 0 to 3 meters above sea level, faces a serious risk of tidal flooding when high tide occurs. The height of tidal floods in this area can reach 100 cm. Rising sea levels and land subsidence are the main causes of tidal flooding in North Jakarta, while rainfall is not a significant factor. Sea levels in this area are rising by about 0.5 cm every year, while the land is falling by between 20 and 28 cm per year. This problem is further exacerbated by the reclamation of Jakarta's north coast for residential development, which results in the loss of mangrove forests which function as natural protection from sea tides.

The condition of the land on the coast of Semarang City is very saturated, causing pools of sea water to persist for a long time on land. This type of soil is young alluvial soil, has a fine and soft structure, so it is very susceptible to sinking, making it less suitable for dense residential areas with high levels of groundwater extraction. Rising sea levels and land subsidence are the main causes of tidal floods in East Semarang. Every year, sea levels rise by around 5 mm, while the land in this region drops by 5.58 cm. Unfortunately, this situation is exacerbated by poorly maintained flood control infrastructure in Semarang City, which requires serious attention from the government. Embankments and drainage are damaged, and rivers in East Semarang are getting shallower due to the accumulation of rubbish and materials. This situation requires real steps to protect the area from the increasing threat of flooding. A similar statement to the geomorphology of the coast of Brebes Regency is dominated by alluvial soil, with relatively flat topography. The slope in this area ranges from 0-3%, including the gentle category. The natural physical conditions on the coast of Brebes Regency make this area very vulnerable to land subsidence and tidal floods.

Gorontalo Province is currently actively eveloping sustainable development in all sectors. Between 2000 and 2018, this area experienced 44 flood disasters [11]. One of the worst floods occurred in 2016, which inundated nine sub-districts, including Limboto City as the district capital. The flood caused damage to a number of public infrastructure and forced thousands of people to evacuate. Frequent flooding occurs due to overflowing rivers in the Biyonga, Bulota and Alo sub-watersheds, which are part of the Limboto

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watershed. Approximately 20.95% of one of these sub-watersheds has experienced land degradation due to development that is not in accordance with the regional function directions based on the Decree (SK) of the Minister of Agriculture No. 837/Kpts/Um/11/1980 concerning Criteria and Procedures for Determining Protected Forests.

Application of GIS in Disaster Risk Identification and Mapping

InaRISK, developed by the National Disaster Management Agency (BNPB), is a Geographic Information System (GIS) based platform designed to map and identify disaster risks throughout Indonesia. The process of collecting data until its formation Flood Hazard Map through InaRISK consists of several stages involving various data sources and information processing methods. Basic data collection includes topography, hydrology, rainfall, land use and socio-economic data

Overlay Data: Topographic, hydrological, and rainfall data are superimposed or superimposed to identify areas geographically at risk of flooding. Generalization on Flood Maps is a process of simplifying geographic data with the aim of making the map easier to read and understand. In the context of flood disaster maps, generalization helps reduce excessive detail while retaining important and relevant information. Based on the raster data processing method, generalization and classification, the flood potential output and flood hazard index are produced in the indicator table as follows: Classification: From the sum of the score values, a total score will be obtained which will then be classified into threat levels based on the results of calculating threat class intervals. The result of adding up the score values will produce a total score which is then classified into three classes, namely low, medium and high threat classes based on calculating class intervals using a formula, then mapping information is obtained as below: GIS mapping results show that several areas in Indonesia, such as around coastlines and river flows, have a high level of flood danger, especially on the islands of Sumatra, Java, Kalimantan and Papua. This area has a steep slope and is crossed by large rivers which have the potential to become flood flow routes. InaRISK data is generalized by dividing regions into risk classes (low, medium, high). This technique helps present the level of vulnerability of an area in categories that are easier to understand. Risk assessments show that areas with high population density, especially around river valleys and residential areas around the coast are at greater risk [11-14].

High rainfall intensity, coupled with low soil absorption capacity due to changes in land use, increases the amount of surface runoff that flows into rivers and causes rivers to overflow. Urban areas with a lot of concrete, such as Jakarta, show a significant increase in water runoff because the soil is no longer able to absorb water [17]. Land subsidence increases the risk of tidal floods in coastal areas and worsens the impact of flooding when heavy rain occurs. Interactions between humans and the environment, such as urbanization and land use changes, influence vulnerability and adaptive capacity to flooding. Deforestation, conversion of agricultural land into residential areas, and damming of river flows for infrastructure development have also contributed to increasing the risk of flooding in many regions in Indonesia [18]. Climate change increases the frequency and intensity of rainfall and causes sea levels to rise, thereby exacerbating the risk of flooding in coastal areas. Many coastal areas in Indonesia are experiencing tidal flooding due to rising sea levels, especially along the north coast of Java and several small islands in Indonesia.

Mitigation and Linkage of GIS with Sustainable Development Goals (SDGs)

This research also shows that the use of GIS in disaster mitigation is directly supportive Sustainable Development Goals (SDGs), specifically Goal 11: Sustainable Cities and Communities And Goal 13: Climate Change Action. By using GIS, the government can plan development that is more resilient to disasters and ensure that development does not sacrifice environmental sustainability. GIS helps create a balance between development needs and environmental protection, thereby creating more sustainable and equitable development for future generations. So, based on indicators with flood disaster mapping in Indonesia, there is harmonization of sustainable development that can be carried out as a mitigation effort as follows:

Regional Spatial Planning (RTRW) that is Responsive to Disaster Risk

Disaster risk zoning involves grouping areas based on their level of exposure to natural hazards, such as floods or earthquakes. Risk zoning aims to assist development planning, so that human activities can be regulated based on the level of risk in an area.

Green Belts and Green Open Spaces: Maintaining green areas around rivers or coastlines can help mitigate flooding, erosion and abrasion. This area functions as a buffer that absorbs water and prevents large water flow rates.

Zoning and Development Regulations: Establish rules that prohibit or limit types of development in high-risk zones. Advanced

Planning and Development Requirements: Soil investigation, bearing capacity analysis, mitigation analysis floods, landslides and earthquake vulnerability, according to AMDAL recommendations (not only DED studies on individual buildings). For example, in earthquake-prone areas, tall buildings can be limited, and in flood-prone areas, buildings should have high foundations or rest on piles.

Infrastructure Development and Disaster Resilience

Disaster-resistant infrastructure development is a strategic approach in planning, building and maintaining infrastructure to reduce damage due to natural disasters such as earthquakes, floods, hurricanes and landslides. Disaster-resistant infrastructure not only aims to reduce the impact of physical damage but also maintains the economic, social and operational functions of society after a disaster occurs. One of them is Drainage Management and Flood Mitigation Systems Integrate adequate drainage infrastructure to reduce the risk of urban flooding, such as large canals, water storage tunnels, and small dams that help manage water runoff. Drainage channels in densely populated settlements are a means used to channel water towards final disposal. Drainage itself means draining, channeling, throwing away or diverting water to another place [19-23]. The water in residential areas is water that comes from household waste and rainwater. The construction of drainage channels can be in the form of open channels and closed channels [24-28]. The implementation of the construction of drainage channel embankments in the field is adjusted to the design plan that has been made [29-31]. stated that the factors causing silting in drainage channels include the entry of ground surface scour into the channel, liquid waste and wet solids. waste that decomposes in channels, and sedimentation. Therefore, rehabilitation of drainage channels from the original land using concrete buildings can minimize this.

Area Hydrological System Protection

1) This effort aims to avoid infiltration of rainwater that enters and collects on slopes that are prone to landslides
2) The implementation of protecting the area's hydrological system is carried out through efforts to replant denuded slopes with the right types of plants in upstream areas or catchment areas.
3) Planting appropriate vegetation is very important in controlling the rate of water flowing downstream, or towards the lower slopes

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5. CONCLUSION

Geographic Information System (GIS)-based disaster mitigation in the sustainable development model in Indonesia is an innovative approach that combines mapping and risk management technology with sustainable development principles. In the context of flood mitigation, GIS allows more accurate mapping of flood-prone areas, identification of risk factors such as changes in land use, rainfall patterns and topography, as well as real-time monitoring of environmental conditions. Through this spatial data analysis, GIS supports the government and stakeholders in developing more effective flood mitigation plans, both in regional spatial planning, building disaster-resistant infrastructure, and preparing agile emergency response procedures. From the data obtained, a classification of Indonesia's flood levels was formed based on regions everywhere and with ratios ranging from high, medium and low. (Lubis, t.t.) Areas that have a high ratio, namely at interval 1, are areas that are frequently affected by flooding and influence sustainable development methods number 3 and 11. Through the application of GIS, the government can carry out long-term planning that prevents the negative impact of flooding on infrastructure, agricultural land and residential areas, as well as ensuring that development in these areas can take place in a sustainable manner.

With targeted risk management, GIS technology supports a faster and more precise response to flood events, facilitates collaboration between institutions, and increases public awareness of potential risks in their environment. As technology develops and data becomes available, GIS has the potential to continue to strengthen sustainable development models that are adaptive and responsive to the challenges of flood disasters in Indonesia.

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