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HYDROMETEOROLOGICAL DISASTER: CHALLENGES AND MITIGATION IN INDONESIA

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ABSTRACT

Climate change, which includes increasing global temperatures, irregular rainfall patterns, and extreme changes in weather, has resulted in detrimental consequences for society and the economy, especially concerning an increase in hydrometeorological disasters. Indonesia is prone to natural disasters, primarily related to hydrometeorological events such as floods, landslides, and droughts. Hydrometeorological disasters can cause enormous economic and social losses; therefore, it is vital to holistically address climate change's social and economic impacts. This study aims to analyze trends in hydrometeorological disasters, especially in disaster-prone areas, so that the affected areas know comprehensive mitigation efforts to overcome them. The research methodology uses qualitative methods with descriptive analysis of hydrometeorological disasters in West Java and DKI Jakarta. The study results show that the trend of hydrometeorological disasters in West Java and DKI Jakarta Provinces tends to increase yearly. Several factors, including climate change, uncontrolled development, increasing population, topography and geographical location, and land subsidence, cause the latest disasters. The Indonesian government is actively trying to mitigate the risk of hydrometeorological disasters but is still experiencing some challenges, including topography and geographic location, climate change, limited resources, and low public awareness. Pentahelix collaboration and comprehensive public education are ways of overcoming these disasters. The Pentahelix collaboration allows for synergy between government, industry, and academia in identifying risks, formulating policies, and implementing mitigation programs.

Introduction

Climate change, which includes increasing global temperatures, irregular rainfall patterns, and extreme changes in weather, has resulted in detrimental consequences for society and the economy, significantly increasing hydrometeorological disasters (Yuwono et al., 2024). As a country prone to natural disasters, Indonesia is not immune from this hydro-meteorological disaster due to Indonesia's geographical position at the meeting point of several tectonic plates, its location in a coastal area with many islands, and the tropical climate, which triggers extreme weather (Sutejo, 2020).

The social impacts of climate change can be seen in Indonesia's increasing frequency and intensity of hydrometeorological disasters, such as floods, landslides, and droughts (Pratama, 2023). These disasters can cause loss of human life, displacement, and destruction of settlements and community infrastructure. In addition, hydrometeorological disasters can also disrupt access to health services, clean water, and

sanitation, increase the risk of spreading disease, and affect the mental well-being of the affected community (Dharmawan, 2021).

Statistics show that extreme weather is increasingly impacting the country's economy. Reports from the Intergovernmental Panel on Climate Change (IPCC) show that in the Caucus and Central Asia, for example, the main economic sectors of many countries are directly affected by meteorology, hydrology, and climate-related hazards such as heat waves, forest fires, droughts, floods, and others. Hydrometeorological disasters can cause considerable economic losses, including agricultural, industrial, trade, and infrastructure losses. Floods and landslides can damage agricultural land, destroy crops, and disrupt food supply chains. In addition, the disaster can also cause losses to the tourism sector, an essential income source for many countries, including Indonesia.

In addition to direct losses, the social and economic impacts of climate change can exacerbate social and economic inequalities. Communities already socially and economically vulnerable are more vulnerable to the effects of hydrometeorological disasters. They may need more resources to cope with and recover from disasters and often need help gaining access to assistance and recovery. As a result, social and economic inequality can be exacerbated by climate change and hydrometeorological disasters (Perez et al., 2020).

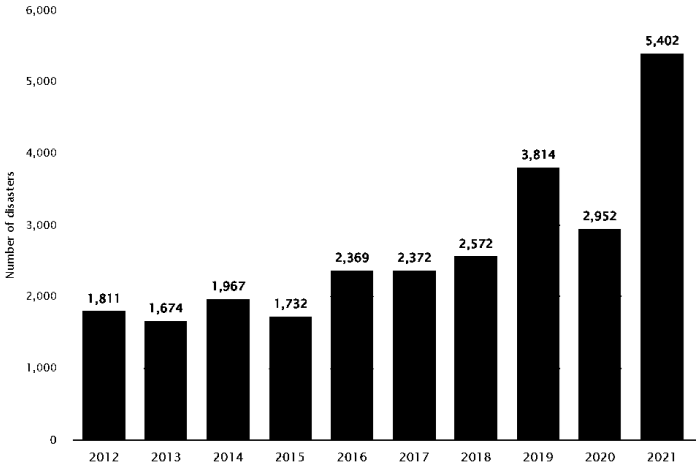

Figure 1 Number of natural disasters in Indonesia per year from 2012 – 2021 (BNPB, 2022)

Trends in recent years have shown an increased risk of hydrometeorological disasters in Indonesia. Rising global temperatures and changing weather patterns due to climate change have contributed to more frequent and intense disaster events in many regions. Floods, landslides, and drought continue to pose severe threats to Indonesia. Data from BNPB shows the growth trend in the number of natural disasters has increased to 82% due to an anomaly in the increase in global and country-by-country average temperatures, which has led to the rise in the frequency of natural disasters, especially hydro-meteorological disasters as shown in Figure 1 (BNPB, 2022).

Since 2000, Indonesia has lost at least $16.8 billion per year from disasters, and from 1990−2021, losses amounted to around $3.5 trillion. Between 2014 and 2018, the central government spent between $90 million and $500 million annually on emergency response and disaster recovery, while local governments spent an additional $250 million. The Global Facility for Disaster Reduction and Recovery estimates that the annual impact of disasters on the economy is 0.3% of gross domestic product (GDP), and significant disasters can consume up to 3% of GDP. Losses caused by hydrometeorological disasters from 2018 – 2022 have caused losses and damage estimated at IDR 31.5 trillion (BNPB, 2023).

In the long run, economic losses caused by hydrometeorological disasters can hamper economic growth, reduce investment, and disrupt the country's financial resilience. Therefore, it is crucial to address the climate change's social and economic impacts of climate change with a holistic approach. This study aims to analyze trends in hydrometeorological disasters, especially in disaster-prone areas, so that the affected areas know comprehensive mitigation efforts.

Research Methods

The research methodology is qualitative with descriptive analysis, an approach to understanding and explaining phenomena in depth and detail. Data collection is done through observation and document analysis. After data collection, analysis is carried out by organizing, exploring meaning, and summarising the findings from the data. Researchers use an inductive approach to identify patterns, themes, and relationships between the data found. The descriptive analysis describes the results in detail without making statistical generalizations. Next, the researcher interprets these findings by relating them to relevant theories or conceptual frameworks.

Results and Discussion

Hydrometeorological Disaster Factor Data of West Java Province

West Java Province is vulnerable to hydrometeorological disasters. The influencing factors are topographical diversity and high rainfall in West Java province.

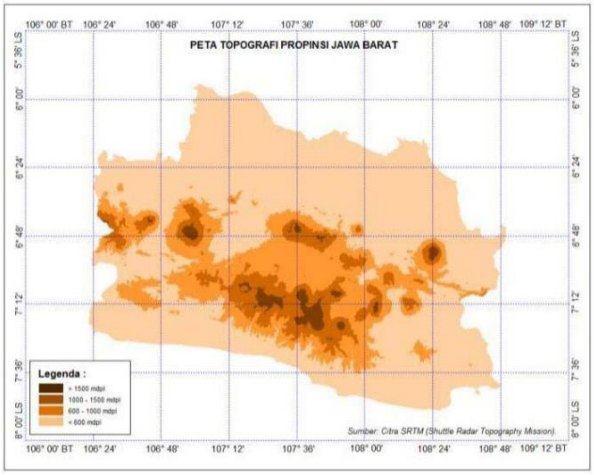

Figure 2
Topographical map of West Java Province (Setiawan & Rohmat, 2011)

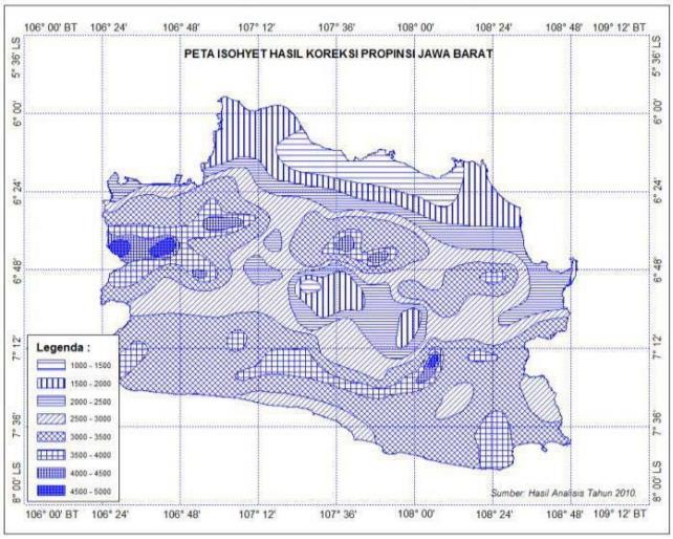

Figure 3
West Java Province rainfall map (Setiawan & Rohmat, 2011)

In addition, West Java Province has a high population density, especially in urban areas such as Bandung and its surroundings. West Java Province is also experiencing uncontrolled development and increased urbanization in several regions.

Figure 4
Map of population growth in West Java Province 1961-2020
(West Java Open Data, 2021)

West Java Province also experienced many natural disasters in 2020, as shown in Figure 4, where most natural disasters were hydrometeorological, as shown in Figure 5.

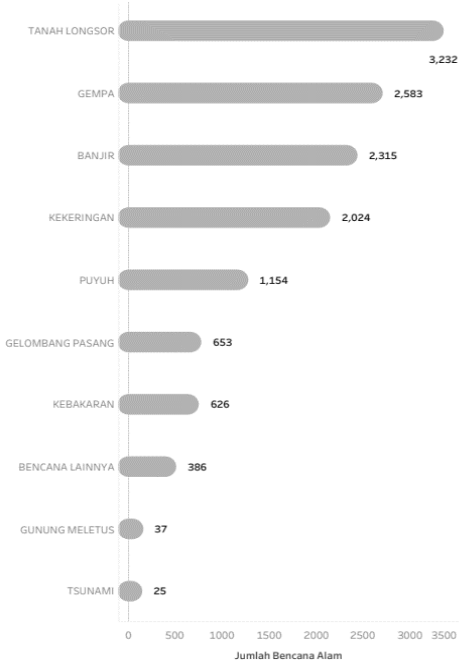

Figure 5
West Java Province Disaster Map in 2020 (West et al., 2020)

Figure 6
Number of Disasters in West Java Province by Type in 2020
(West Java Open Data, 2020)

Data on Hydrometeorological Disaster Factors for DKI Jakarta Province

DKI Jakarta Province has also experienced an increase in population from year to year, which has caused DKI Jakarta Province to become the most populous province in Indonesia.

Figure 7
Map of the location of DKI Jakarta Province and flood vulnerability status (Dahlia et al., 2018)

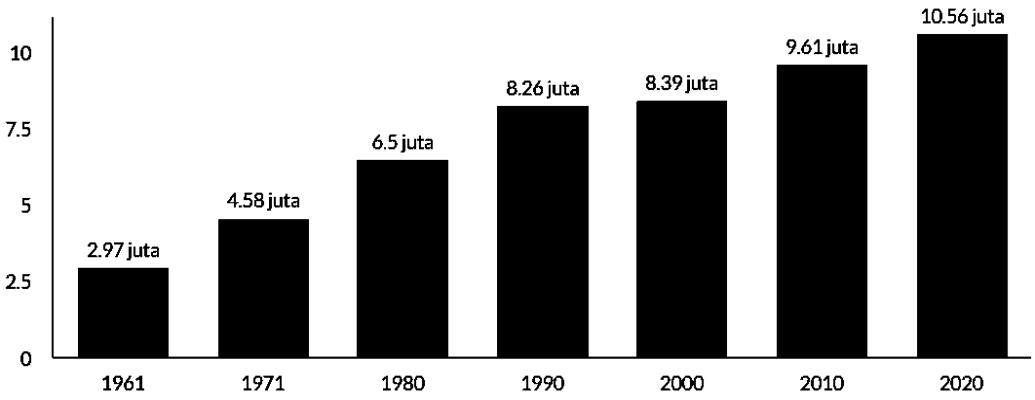

Figure 8
Total population of DKI Jakarta 1961 – 2020
(Central Bureau of Statistics DKI Jakarta, 2021)

DKI Jakarta Province experiences hydrometeorological disasters, especially floods, every year.

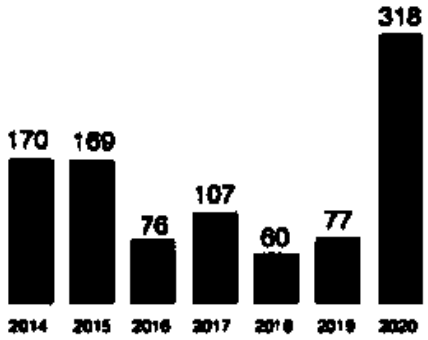

Figure 9
Number of urban villages in DKI Jakarta affected by floods from 2014 to 2020 (BPBD DKI Jakarta, 2021)

Hydrometeorological Hazard Trends in West Java Province and DKI Jakarta Province

The trend of hydrometeorological disasters in West Java Province and DKI Jakarta Province tends to increase yearly, as shown in Figure 5 and Figure 8. Hydrometeorological disasters in West Java Province and DKI Jakarta Province are rising due to several factors.

West Java and DKI Jakarta provinces have high yearly rainfall, especially during the rainy season. Heavy rain increases the risk of flooding and landslides, especially on steep slopes. In recent years, irregular rain patterns and high rainfall intensity have caused severe flooding and landslides in several regions of West Java (Tejakusuma, Sittadewi, and Fitriani, 2023). In addition, the geographical location of DKI Jakarta located in coastal areas and lowlands at the mouth of the Ciliwung River and the Jakarta River causes an increase in hydrometeorological disasters every year (Priyamdolo et al., 2022).

West Java Province has a high population density, as shown in Figure 3, especially in urban areas such as Bandung and its surroundings. Dense settlements and a lack of adequate drainage infrastructure make it difficult for rainwater to flow appropriately, increasing the risk of flooding. Population density causes uncontrolled development and increased urbanization in several areas of West Java, which has changed natural land use. Deforestation for settlements, infrastructure, and business developments that do not pay attention to environmental aspects causes an imbalance in the natural hydrological cycle.

DKI Jakarta Province has a high population density, even the densest in Indonesia, as shown in Figure 7. High population density causes rapid urban development in Jakarta, which changes natural land use. Reducing green open land, cutting forests, and replacing agricultural land with settlements and infrastructure has reduced the innate capacity to absorb rainwater. Doing this causes a faster water flow to the surface and increases the risk of flooding in the affected areas (Noveri, Najib, & Yusuf, 2020).

In addition, the Jakarta area is experiencing significant land subsidence due to continued land subsidence. Land subsidence causes a relative subsidence of Jakarta's coastal areas; as a result, it increases the risk of tidal flooding and seawater intrusion during high tides. Due to climate change, a rise in sea level on the coast of Jakarta has increased the risk of hydrometeorological disasters such as tidal flooding (Firman, Surbakti, Idroes, & Simarmata, 2011).

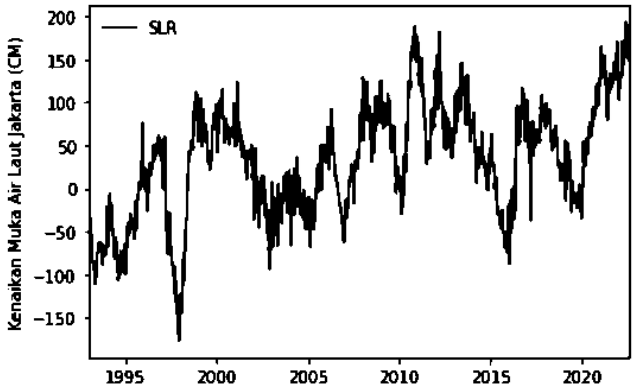

Figure 10
Distribution Distribution of Sea Level Rise in Jakarta 1992 – 2021 (Rais et al., 2022)

Challenges of Hydrometeorological Disaster Mitigation in West Java Province and DKI Jakarta

The provinces of West Java and DKI Jakarta face challenges in mitigating hydrometeorological disasters, including:

1. Topography and Geographical Conditions: West Java has hilly and steep slopes. These conditions increase the risk of disasters such as floods and landslides. Disaster management in areas with challenging topography can become more complex, requiring appropriate mitigation strategies to reduce risks and minimize disaster impacts (Djalante, Garschagen, Thomalla, & Shaw, 2017). Meanwhile, DKI Jakarta is experiencing significant land subsidence, namely the slow subsidence of the land surface. Subsidence causes relative subsidence of coastal areas, increasing the risk of tidal flooding and seawater intrusion during high tides. Therefore, it complicates disaster mitigation efforts and requires ongoing management.
2. Urbanization and Spatial Planning: High population growth and rapid urban development in DKI Jakarta and West Java are increasing pressure on the natural environment and exacerbating the risk of hydrometeorological disasters. Shrinkage of green open land, conversion of agricultural land into settlements and infrastructure, and a lack of available space can hamper disaster mitigation efforts. In addition, an inadequate drainage system is a severe challenge in disaster mitigation in DKI Jakarta and West Java. Poor or lousy drainage makes it difficult for rainwater to flow appropriately, triggering flooding in various areas (Aliyah & Kurniawan, 2022).
3. Climate Change: Global climate change affects weather patterns and increases the risk of hydrometeorological disasters in West Java and DKI Jakarta. Increased intensity of

unstable rainfall, rising sea surface temperatures, and changes in weather patterns can exacerbate the risk of flooding, tidal flooding, and other threats of hydrometeorological disasters. The challenges of disaster mitigation include adaptation to climate change, including increasing the resilience of infrastructure and developing early warning systems that can anticipate and respond to changes in extreme weather (Setiowati et al., 2018)

4. Limited resources: West Java Province needs more resources in disaster mitigation efforts. Limited budget and adequate infrastructure facilities can hinder the government's ability to develop early warning systems, improve disaster-resistant infrastructure, and implement other mitigation programs.
5. Public awareness: Some areas in West Java still need a higher awareness of disaster risk, especially in rural areas. Factors such as lack of access to information, low disaster literacy, and lack of active community participation can affect awareness and preparedness (Amri, Bird, Ronan, Haynes, & Towers, 2017).

Hydrometeorological disaster mitigation efforts

The following are hydrometeorological disaster mitigation efforts that need to be carried out by West Java Province.

1. Wise spatial planning: Spatial planning is needed that pays attention to aspects of disaster mitigation, such as limiting development in disaster-prone areas, maintaining green open land as water absorbers, and protecting water catchment areas. Planned and sustainable development will help reduce the risk of hydrometeorological disasters (Putri, Buchori, & Handayani, 2023).
2. Improvement of drainage infrastructure: Good and adequate drainage infrastructure significantly reduces the risk of flooding. It is necessary to repair, maintain, and develop drainage systems in areas prone to flooding. Construction of drainage canals, excavation of reservoirs, and regulation of river flow can help drain rainwater efficiently and reduce the risk of flooding (Jati & Santoso, 2019).
3. Community capacity building: Increasing community capacity in dealing with hydrometeorological disasters is an important step. Training and socialization on disaster mitigation can be carried out to provide an understanding of risks, preparatory actions, and disaster management. The formation of disaster volunteer groups can also assist in post-disaster response and recovery.
4. Weather monitoring and early warning: An effective early warning system is essential to reduce the impact of hydrometeorological disasters. Developing a sophisticated and adequate weather monitoring system and providing accurate and fast information to the public is necessary. These will allow sufficient time for communities to take mitigation measures before a disaster occurs.
5. Sustainable environmental management: Hydrometeorological disaster mitigation efforts involve sustainable environmental management. Forest conservation, afforestation, and land restoration will help maintain the sustainability of the natural hydrological cycle. Ecosystem protection and rehabilitation also reduce the risk of hydrometeorological disasters (Jati & Santoso, 2019).

6. Policy integration and coordination: It is crucial to have an integrated policy framework for hydrometeorological disaster mitigation. Coordination between local government, related institutions, and the community is crucial in effectively implementing mitigation measures. Preparing a comprehensive disaster mitigation plan and consistent implementation is the key to reducing the risk of hydrometeorological disasters.

DKI Jakarta Province

To overcome the hydrometeorological disaster in DKI Jakarta, several mitigation steps are needed, including:

1. Drainage system improvement: Adequate drainage infrastructure is critical in reducing the risk of flooding in DKI Jakarta. It is necessary to repair, maintain, and develop an effective drainage system to drain rainwater properly. Construction of drainage canals, excavation of reservoirs, increase of water pump capacity, and maintenance of rivers and canals are essential steps in flood mitigation (Mishra et al., 2018).
2. Wise spatial planning: Spatial planning that addresses disaster mitigation is vital in DKI Jakarta. Limiting development in flood-prone and coastal areas and maintaining green open land as water catchment and flood control spaces will help reduce the risk of hydrometeorological disasters (Kristiadi, Sari, Herdiansyah, Hasibuan, & Lim, 2022).
3. Increasing community capacity: Increasing community awareness and capacity regarding the risks of hydrometeorological disasters is an important step. Training, socialization, and disaster simulation can provide an understanding of disaster preparation and management actions. The community must actively participate in the early warning system, evacuation, and post-disaster management.
4. Improvement of disaster-resistant infrastructure: Developing disaster-resistant infrastructure is essential to mitigating hydrometeorological disasters. The selection of waterproof building materials, the increase in the carrying capacity of building structures, and the selection of locations that are safe from disaster hazards are steps that must be considered in infrastructure development in DKI Jakarta.
5. Handling of soil subsidence: Addressing soil subsidence is a challenge in mitigating hydrometeorological disasters in DKI Jakarta. Monitoring and controlling subsidence through wise spatial arrangements, limiting groundwater extraction, and using appropriate technology to address land subsidence is necessary.
6. inter-agency coordination and cooperation: Good coordination between local government, related agencies, and communities is essential for implementing effective mitigation measures. Collaboration between related agencies, such as the Regional Disaster Management Agency (BPBD), the Water Resources Office, the Spatial Planning Office, and other related institutions, is needed to implement integrated hydrometeorological disaster mitigation.

Conclusion

Indonesia is prone to natural disasters, especially those related to hydrometeorological events such as floods, landslides, and droughts. Some factors that make Indonesia vulnerable to this disaster are its geographical position, which is located at the meeting point of several tectonic plates, its location in a coastal area with many islands, and the tropical climate that triggers extreme weather. DKI Jakarta and West Java provinces have experienced an increasing trend of hydrometeorological disasters in recent years caused by climate change, uncontrolled development, increasing population, topography and geographical location, and land subsidence.

The Indonesian government is actively trying to mitigate the risk of hydrometeorological disasters but is still experiencing several challenges related to topography and geographic location, climate change, limited resources, and low public awareness. Pentahelix collaboration and comprehensive public education are needed to overcome these challenges. The Pentahelix collaboration allows for synergy between government, industry, and academia in identifying risks, formulating policies, and implementing mitigation programs. As a policyholder, the government can cooperate with industry in developing disaster-resistant technology and infrastructure. Academics have a role in providing up-to-date knowledge and research to support evidence-based decision-making. Meanwhile, civil society can provide input, participate, and monitor the implementation of mitigation programs. The media is essential in disseminating accurate information and advocating to raise public awareness. Community education is a crucial step in dealing with hydrometeorological disasters. Through education, people can understand disaster risks, preparatory actions, and mitigation steps that need to be taken. Increasing public awareness about climate change, extreme weather patterns, and the importance of adaptation is vital in reducing disaster risk. Various channels, such as public campaigns, training, seminars, socialisation in schools, and using social media to disseminate accurate and easy-to-understand information are ways of educating the community.

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