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Utilization Of Remote Sensing Technology In Flood Risk Mapping: A Quantitative Approach For National Stability

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Abstract – This study evaluates the role of flood early warning systems in supporting national stability and enhancing national defense through the use of weather radar and Geographic Information Systems (GIS) technology. The study focuses on the DKI Jakarta area which has a high risk of flooding. Rainfall data, weather radar, and spatial analysis are used to identify potential flooding and support rapid and accurate decision making. The results of the study indicate that the implementation of technology-based early warning systems significantly increases the effectiveness of disaster mitigation and minimizes its impact on communities and national vital infrastructure. This study emphasizes the importance of integrating advanced technology into disaster risk management strategies to strengthen national resilience.

Keywords – Flood Early Warning, Weather Radar, Geographic Information System, National Defense.

1. Introduction

Climate change is predicted to increase the frequency and intensity of flooding in the future, which must be considered in the planning of flood embankments, infrastructure, and housing development (Kay et al., 2021). Floods often occur in areas with rapid development, fast flow characteristics, and high debris content (Buslima et al., 2018). The impact of flooding not only directly harms the community, but also has the potential to threaten national stability if not managed properly.

Flood management has been globally recognized as an effective effort to reduce its adverse impacts. Various studies have encouraged a more resilient and sustainable approach to flood management (Wang et al., 2022). Analysis of flood potential, hazard, vulnerability, and risk is carried out at various administrative levels, including at the city and catchment levels (Vojtek et al., 2022). In Indonesia, research related to floods is still limited compared to developed countries, even though its impact is very significant for economic stability, security, and social welfare.

Jakarta, as the center of government and economy, faces complex flood risks due to climate change and urbanization. This area has national vital objects such as the State Palace, the DPR/MPR Building, Tanjung Priok Port, and Soekarno-Hatta International Airport, making it a strategic area with high priority in disaster risk management. The geographical conditions of Jakarta, which are mostly lowlands with inadequate drainage systems, further increase its vulnerability to flooding (Alawiyah & Harintaka, 2021).

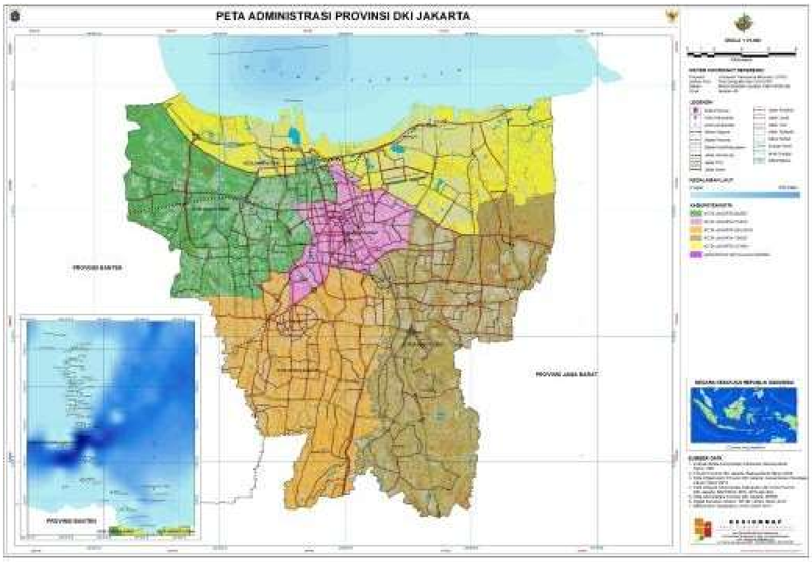

Figure 1. Administrative Map of DKI Jakarta Province

(Source: Thematic Map of Indonesia, 2015)

The major floods that occurred in early 2020 demonstrated the serious impacts of the combination of high rainfall, poor drainage management, and land-use changes. These events resulted in significant economic losses, social disruption, and reduced public confidence in the government's ability to manage disaster risks. Therefore, a technology- based scientific approach, such as weather radar and Geographic Information Systems (GIS), is very relevant in supporting flood mitigation efforts and increasing national resilience.

Figure 2. Jakarta Flood Event in 2020

(Source: Kompas, 2020)

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This study aims to evaluate the role of weather radar technology and GIS in flood risk management, especially in strategic areas such as DKI Jakarta. By utilizing spatial analysis, GIS can help identify flood-prone areas and formulate more effective mitigation strategies. This study is expected to provide significant contributions in strengthening national resilience through better disaster management.

Integration of modern technologies such as weather radar and GIS is not only relevant in the context of flood risk mitigation, but also in maintaining national stability. Technology-based early warning systems enable rapid and targeted responses, minimizing impacts on communities and vital infrastructure. Thus, this study supports the development of more adaptive and data-driven flood risk management policies and strategies to address future challenges.

This study uses a descriptive quantitative method with a spatial analysis approach. This approach integrates Geographic Information System (GIS) technology and weather radar to develop a flood early warning system in the DKI Jakarta area.

The first step of this research is the collection of geographic data, including information on rainfall and topographic maps. Rainfall data was obtained through observations using AWS/ARG from 2021 to 2023, as well as weather radar in 2023. Weather radar data was processed using Rainbow DART software, while rainfall data was processed using ArcGIS software to overlay geographic data. The results of the analysis are in the form of maps depicting the level of flood risk in various areas of DKI Jakarta.

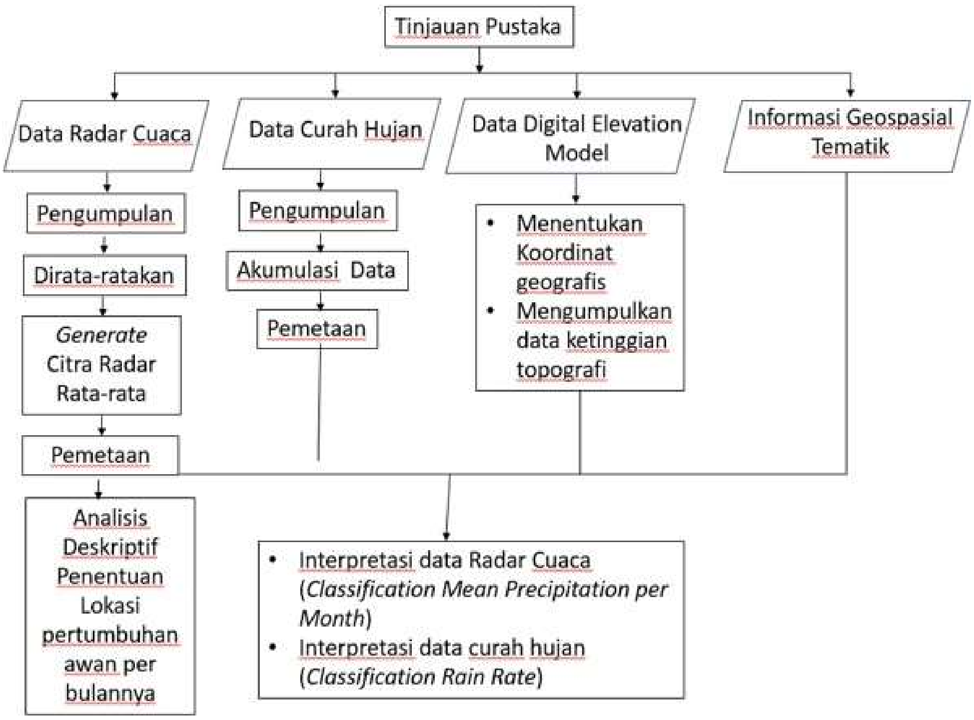

Figure 3. Research Design

The research design consists of three main stages, namely:

a. **Data collection**: Includes weather radar data, rainfall, administrative areas, and flood events.

b. **Data processing**: Radar data was processed using Rainbow DART, while rainfall data was processed using ArcGIS to produce spatial maps.

c. **Data analysis**: Statistical and geospatial analysis was conducted to map flood-prone areas.

The research was conducted in the DKI Jakarta area, which includes five administrative cities and one administrative district, namely Central, North, West, South, East Jakarta, and the Thousand Islands. The focus of the research was locations with high rainfall intensity and significant flood vulnerability levels. The results of the research are in the form of a flood risk map integrated into the flood early warning system for DKI Jakarta.

2. Data collection technique

In this study, data collection techniques for the research being studied include:

a. Observation

Rainfall observations using AWS in DKI Jakarta for the period 2021-2023 and weather radar for 2023. Weather radar data comes from Tangerang radar with a coverage radius of 250 km, covering the DKI Jakarta area.

b. Documentation

The documentation includes news of flood events from 2019-2023, collected from official sources such as BPBD DKI Jakarta.

2.1 Data Processing Techniques

a. Weather Radar Data Processing

Radar data processing using Rainbow DART to produce SRI (Rainfall Intensity) radar products. The data is visualized in the form of a map with a color scale of rain intensity.

b. Rainfall Data Processing

Rainfall data from AWS is processed using ArcGIS with the IDW interpolation method to produce a spatial distribution map of rainfall. This process includes:

- Convert daily rainfall data to annual format
- Input XY data into ArcGIS
- Data interpolation and classification process

2.2 Data Analysis Techniques

Rainfall data analysis was conducted using a descriptive approach using interpolated maps to understand the spatial distribution of rainfall. This process helps determine areas with high flood risk.

While radar data analysis is done based on radar reflectivity (dBZ). Rain intensity is categorized in the following scale:

Tabel 1. Rain Intensity Category (Source: BMKG)

Rain Intensity Category	dBZ Value	mm/hour
Light rain	25 to 35	1 to 5
Moderate rain	35 to 45	5 to 10
heavy rain	45 to 55	10 to 20
Very heavy rain (very heavy rain)	>55	>20

3. Rainfall Data Collection Analysis Results

From the rainfall distribution map collected from January to December 2021- 2023, several general patterns related to rainfall distribution in the Jakarta area can be observed. Rainfall in Jakarta varies greatly, both between regions and between months. This can be seen from the difference in color intensity that indicates the level of rainfall at each measurement point. There is a clear seasonal pattern, where rainfall is generally higher in certain months.

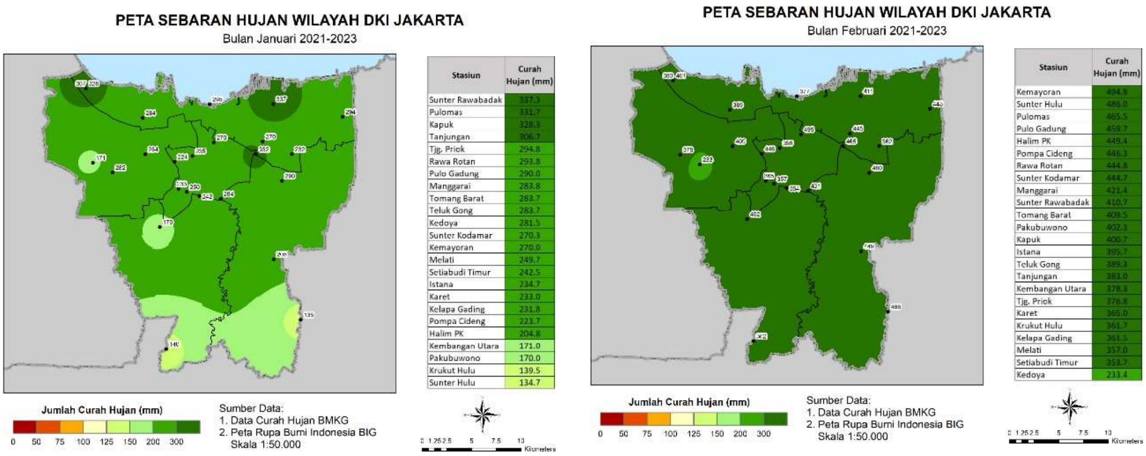

Figure 4. Map of Average Rainfall Distribution in 2021 – 2023 for DKI Jakarta in January (left)

and February (right)

In January (Figure 4 left) and February (Figure 4 bottom), rainfall in Jakarta generally showed an even distribution pattern in most areas of the city. February, which is the peak of the rainy season, recorded higher rainfall intensity compared to previous months, which tend to have rainfall intensity with increasing frequency and volume. This condition caused almost all areas in Jakarta to experience significant rainfall intensity. The high rainfall intensity during February did not only occur at several points, but spread widely to cover strategic areas in Jakarta. This usually has an impact on increasing surface water flow and the risk of inundation in areascertain areas, especially in areas prone to flooding.

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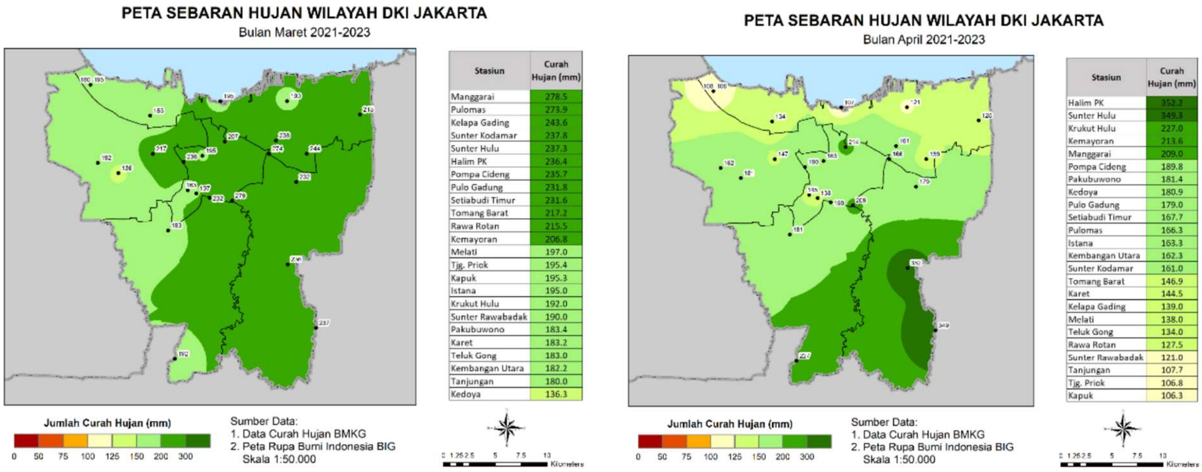

Figure 5. Map of Average Rainfall Distribution in 2021 – 2023 for DKI Jakarta in March (left) and April (right)

In March (Fig. 5 left) and April (Fig. 5 right), rainfall in Jakarta began to show a gradual decrease, marking the transition from the rainy season to the dry season.

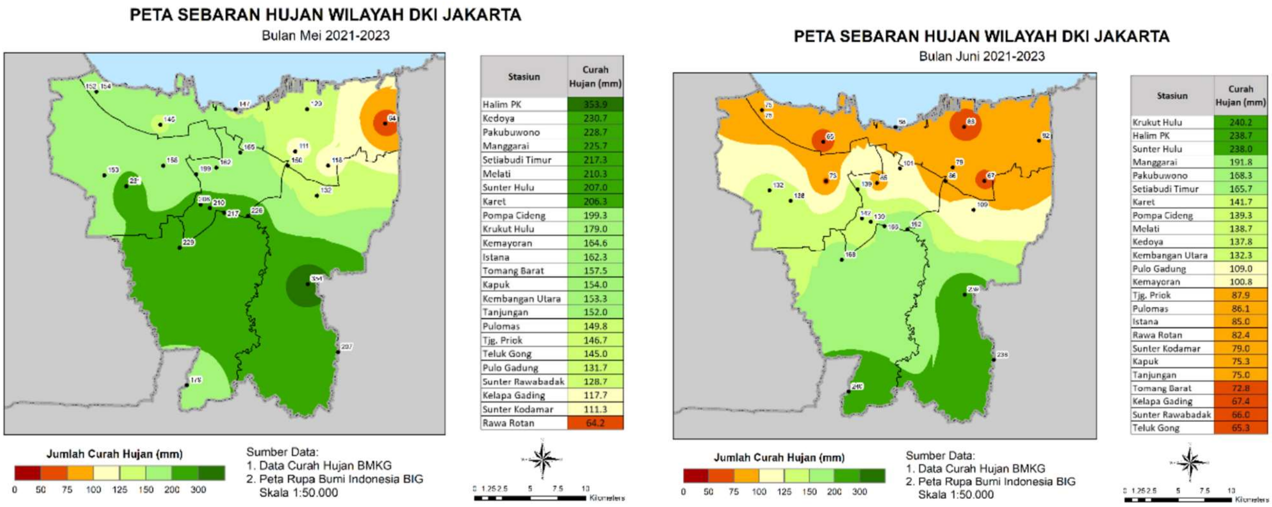

Figure 6. Map of Average Rainfall Distribution in 2021 – 2023 for DKI Jakarta in May (left) and June (right)

Entering May (Figure 6 left) and June (Figure 6 right), the decrease in rainfall is increasingly significant until most areas enter the dry season. Several areas such as North Jakarta, East Jakarta, and West Jakarta experienced a fairly sharp decrease in rainfall during the period from May to June. This decrease has an impact on changes in environmental conditions, with less rainfall falling, average daily temperatures increasing, and air humidity starting to decrease.

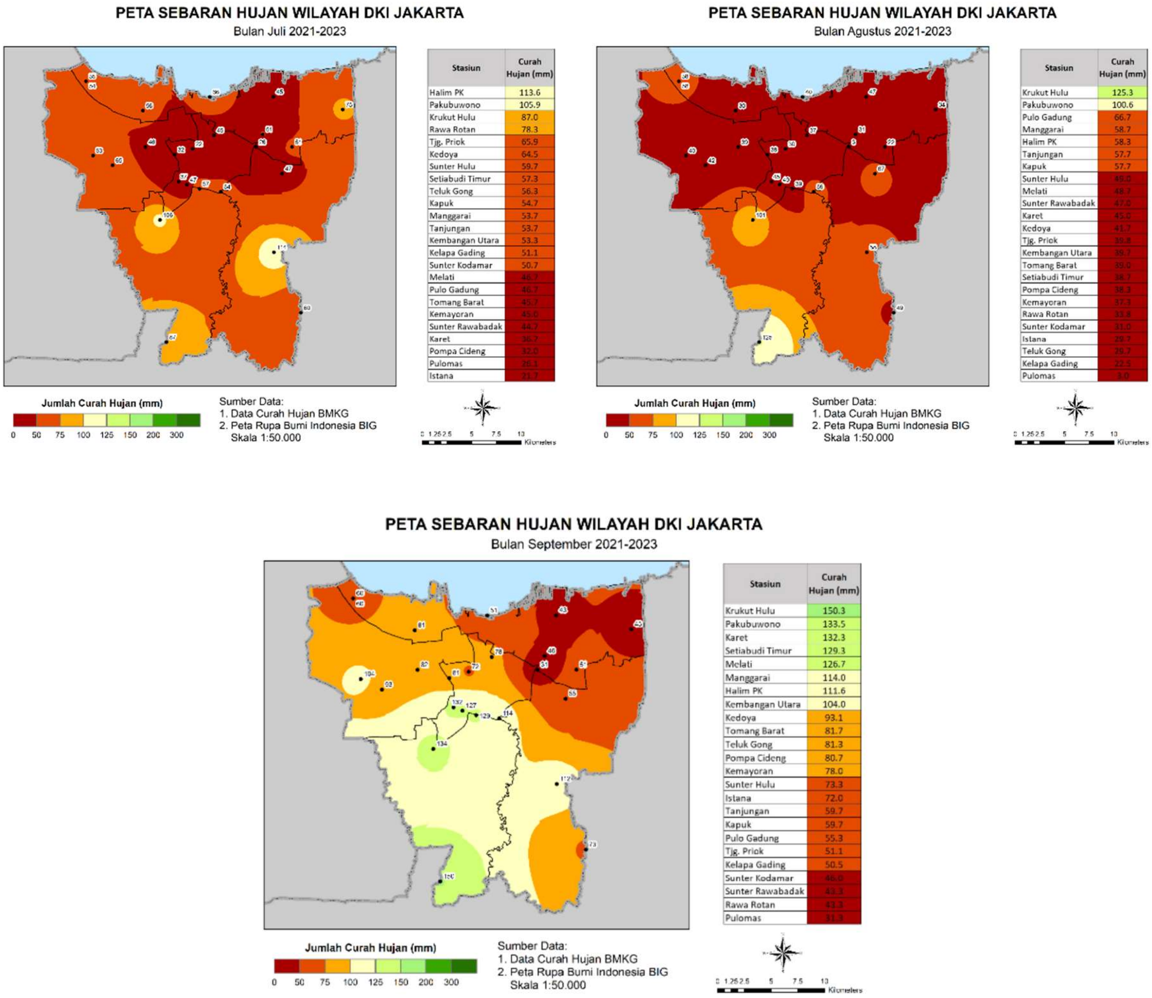

Figure 7. Map of Average Rainfall Distribution in 2021 – 2023 for DKI Jakarta in July (top left), August (top right), and September (bottom)

In the period of July (Figure 16 top left), August (Figure 16 top right), and September (Figure 16 bottom), Jakarta enters the dry season, where the overall rainfall intensity tends to be low. Only a few areas, such as South Jakarta, still experience light to moderate rain at certain times. During the dry season, areas with low rainfall need to consider water resource management carefully and efficiently. Information on rainfall distribution during this period is very important in planning the management of reservoirs, rivers, and groundwater sources so that water availability remains sufficient for the needs of the community and the environment. Regulation of water flow from reservoirs and efforts to conserve groundwater sources are alsobecomes an important aspect to maintain water supply during this dry season.

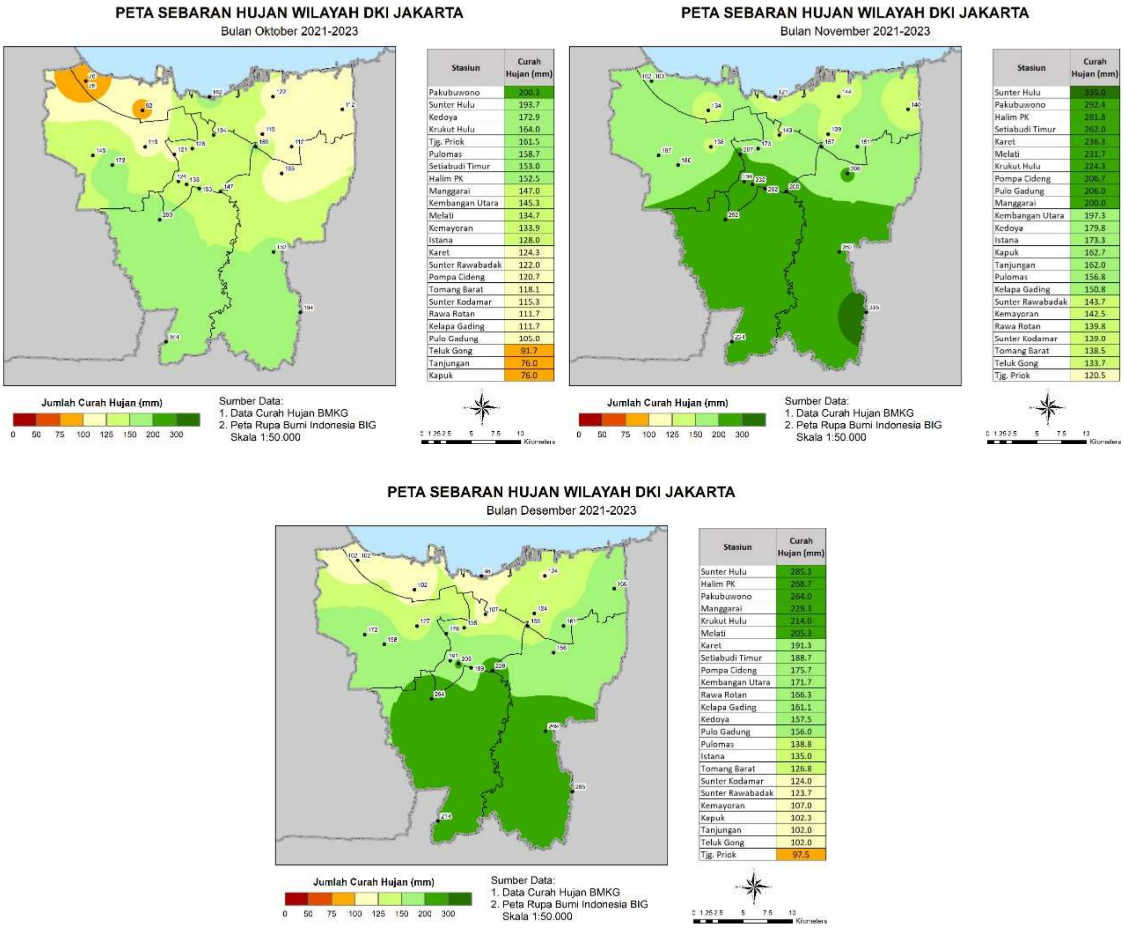

Figure 8. Map of Average Rainfall Distribution in 2021 - 2023 for the DKI Jakarta area in October (top left), November (top right), and December (bottom)

In October (Figure 8 top left), November (Figure 8 top right), and December (Figure 8 bottom), Jakarta began to enter the beginning of the rainy season, where rainfall showed a significant increase in various regions. This increase marks the transition from the dry season to the rainy season, marked by increasingly intense rainfall over time. The South Jakarta area in particular often experiences heavy rain and long duration. This condition also affects river flows and increases the risk of waterlogging in several areas, especially in areas with limited drainage or in lowlands. The increase in rainfall in these months is a concern in infrastructure management and preparation for potential flooding.

Based on the analysis of the rainfall distribution map above, it can be concluded that rainfall in Jakarta is greatly influenced by seasonal factors. This information is very important for various purposes, such as spatial planning, disaster mitigation, and water resource management. Areas with high rainfall need to be equipped with adequate drainage systems to prevent temporary flooding or flash floods. This data is used to create flood risk maps and develop early warning systems.

3.1 Weather Radar Data Collection Analysis Results

Weather radar imagery data collected from January to December 2023 can observe several general patterns related to rainfall

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distribution in the Jakarta area. Rainfall in Jakarta varies greatly, both between regions and between months. This can be seen from the difference in color intensity that indicates the level of rainfall at each measurement point.

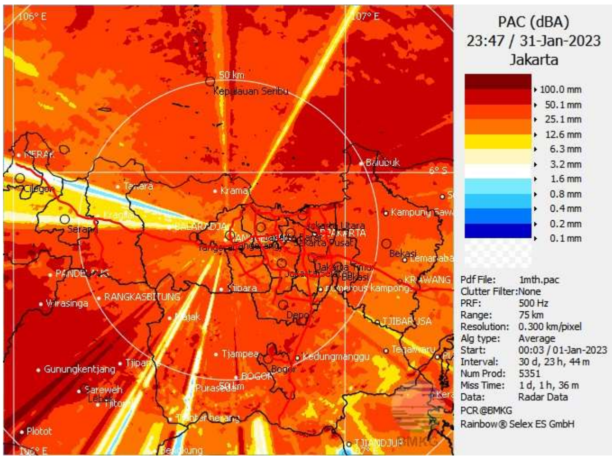

Figure 9. PAC Radar Image Products January 2023 DKI Jakarta area

In January (Figure 9), radar imagery shows high rainfall intensity dominating the Jakarta area. High rainfall detected in several areas such as Central Jakarta and West Jakarta indicates the potential for inundation or flooding in lowland areas and near rivers. This radar imagery data is very relevant in supporting the implementation of a flood early warning system during January, which is the peak of the rainy season in Jakarta. This system can utilize real-time rainfall monitoring to provide warnings to communities in affected areas, especially in flood-prone areas.

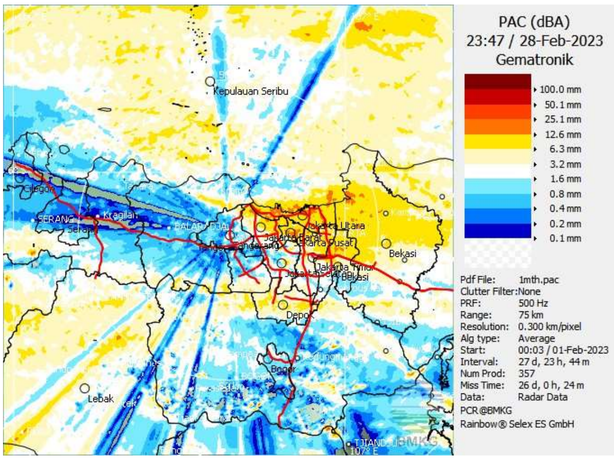

Figure 10. PAC Radar Image Products for February 2023 DKI Jakarta area

Figure 10 shows the distribution of average rainfall in February with red indicating very high rainfall (>100 mm), yellow for moderate to high rainfall (12.5 – 50 mm), and blue for low rainfall (0.1 – 6 mm). From this map, it can be seen that the areas of Central Jakarta, East Jakarta, and part of South Jakarta are dominated by yellow, indicating significant rainfall, while other areas such as West Jakarta have lower rainfall intensity (blue). This information allows for real-time monitoring of rainfall and identification of flood-risk areas.

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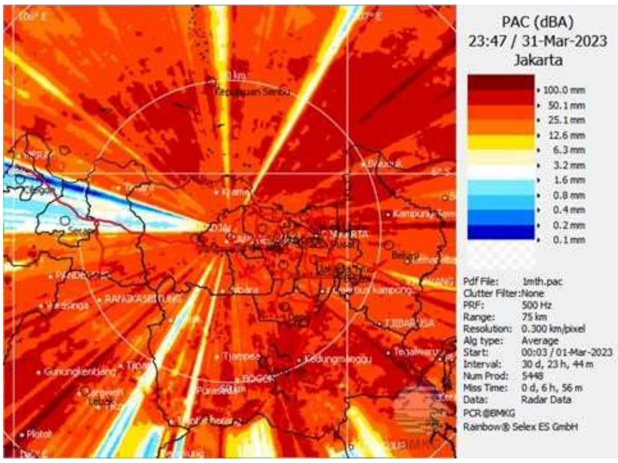

Figure 11. PAC Radar Image Products March 2023 DKI Jakarta area

Figure 20 shows the distribution of average rainfall in March with red dominating the areas of Central Jakarta, East Jakarta, and South Jakarta. This red color indicates very high rainfall reaching an intensity of up to 100 mm or more. Extreme rainfall like this can increase the risk of flooding in densely populated areas. Mitigation steps that can be prepared are activating water pumps, notifying evacuation for people in vulnerable areas, and optimizing drainage to reduce puddles.

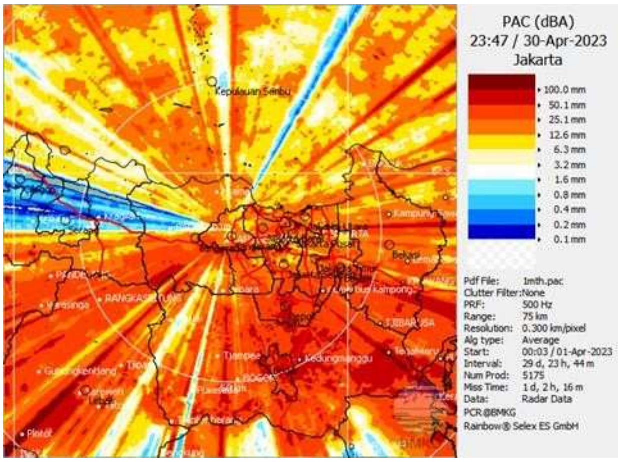

Figure 12. PAC Radar Image Products April 2023 DKI Jakarta area

Figure 12 shows the distribution of average rainfall in April dominated by orange to red colors, indicating high to very high rainfall (between 50 mm and more than 100 mm). The areas of Central Jakarta, East Jakarta, South Jakarta show high rainfall intensity, while West Jakarta shows lower rainfall intensity as seen from the blue and yellow hues. With the dominance of high rainfall in various regions, the risk of flooding increases, especially in low-lying and densely populated areas. Mitigation steps that can be taken are adjusting river flows and drainage so that the impact of flooding can be optimized.

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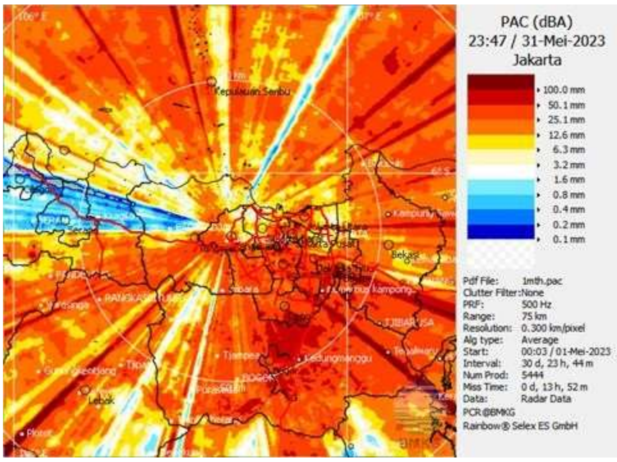

Figure 13. Radar Image PAC Products May 2023 DKI Jakarta area

Figure 13 shows the distribution of average rainfall in May which is dominated by dark red to brown for Central Jakarta and parts of East Jakarta. This color gradation reflects the level of rainfall, very high (>50 mm). Steps that can be taken to minimize the impact of flooding include monitoring river flows, maximizing drainage systems and reservoirs.

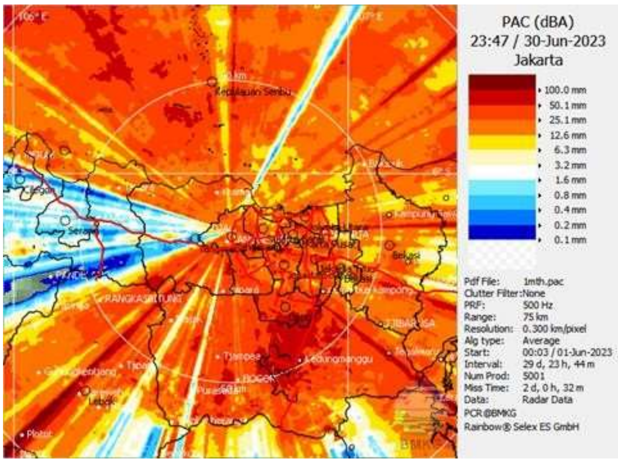

Figure 14. Radar Image PAC Products June 2023 DKI Jakarta area

Figure 14 shows the distribution of average rainfall in June dominated by dark red for Central Jakarta, West Jakarta, and parts of South Jakarta, identifying very high rainfall intensity (>50 mm). This data can be used for flood early warning systems with high-risk areas in Jakarta already identified and to provide information to the public and related parties for anticipatory measures, such as evacuation or regulation of river flow and drainage.

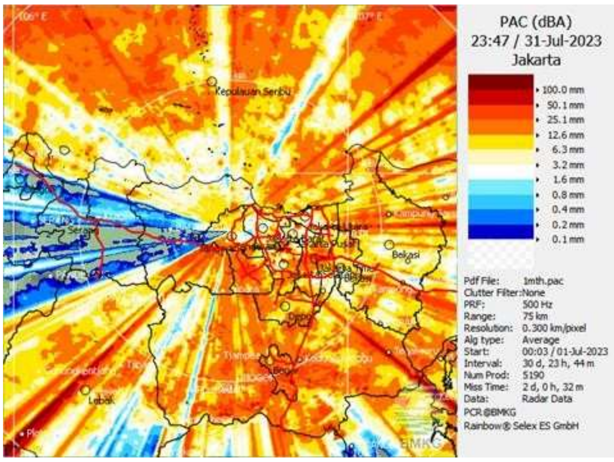

Figure 15. PAC Radar Image Products July 2023 DKI Jakarta area

Figure 15 shows the distribution of average rainfall in July which is dominated by dark red in Central Jakarta and parts of East Jakarta, indicating very high intensity rain (>50 mm) and potential flood risk in the area. By conveying information about high rainfall to the public through various social media platforms to increase alertness, one of which is by increasing public awareness of emergency measures, such as preparing important items and evacuation routes. Then ensure that drainage, water pumps, and water gates function optimally to reduce the potential for flooding.

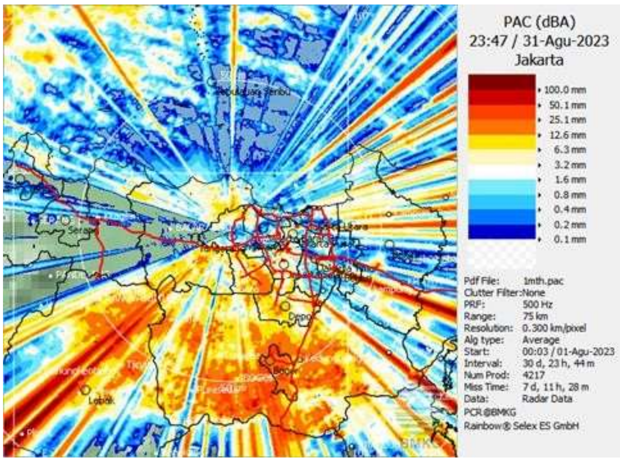

Figure 16. PAC Radar Image Products August 2023 DKI Jakarta area

Figure 16 shows the distribution of average rainfall in August dominated by blue to white in the Jakarta area indicating light rainfall, but the potential for water flow from upstream areas (Bogor) still needs to be watched out for. The implementation of a flood early warning system is very important from this radar data, especially to predict water flow from high areas to Jakarta. Mitigation steps that can be taken include increasing drainage capacity, optimizing reservoirs, and early warnings to communities in vulnerable areas. Public education about evacuation and prevention can also reduce the impact of disasters.

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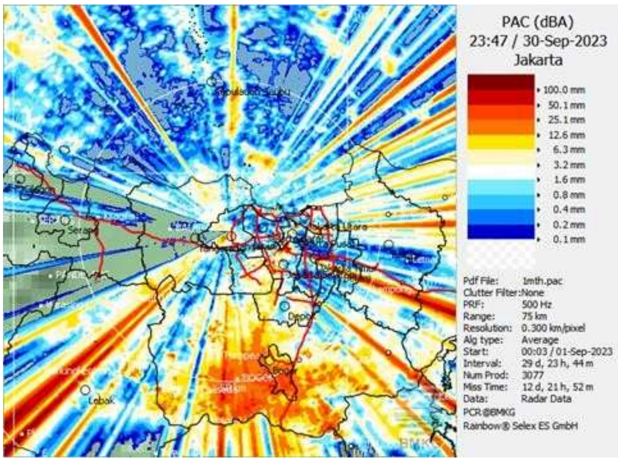


Figure 17. Radar Image PAC Products September 2023 DKI Jakarta area

Figure 17 shows the distribution of average rainfall in October which is dominated by yellow to blue colors indicating light to moderate rainfall intensity. Rainfall is still high for the upstream area (Bogor) so that the river discharge flowing into the Jakarta area is still anticipated. Mitigation can be done by optimizing reservoirs and water gates, accelerating the cleaning of drainage channels, and providing early warning information to the community for preparedness, especially those living around the river flow.

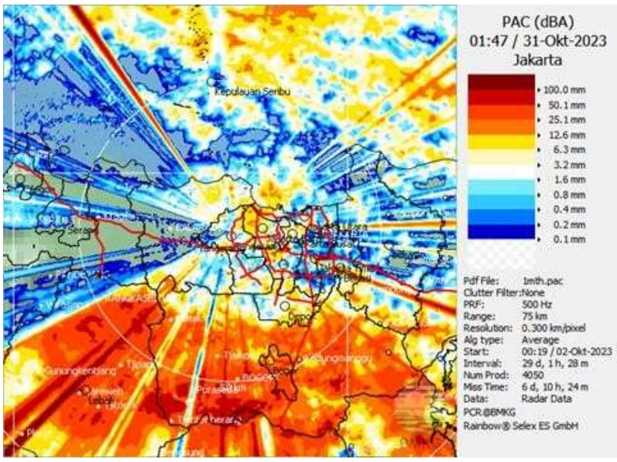


Figure 18. PAC Radar Image Products October 2023 DKI Jakarta area

Figure 18 shows the distribution of average rainfall in October which is dominated by yellow to blue colors indicating light to moderate rainfall intensity. Mitigation can be done by optimizing reservoirs and water gates, accelerating the cleaning of drainage channels, and providing early warning information to the community for preparedness, especially those living around rivers.

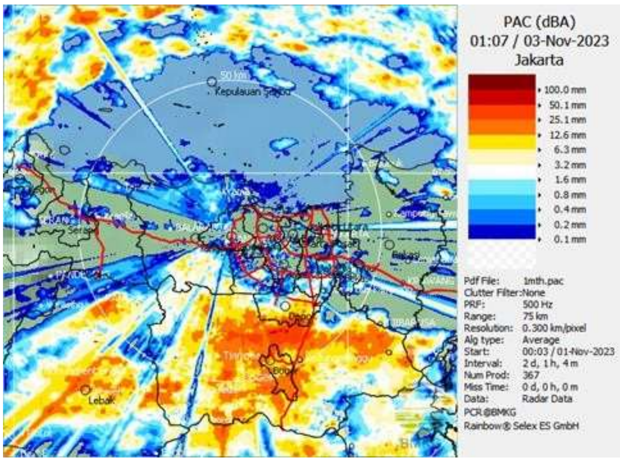


Figure 19. Radar Image PAC Products November 2023 DKI Jakarta area

Figure 19 shows the distribution of average rainfall in November which is dominated by blue to white colors indicating light rain intensity. However, in the southern part of Jakarta, it is dominated by red indicating high intensity rain (>100 mm) so that it has the potential to flow water to the downstream area (North Jakarta) through major rivers such as Ciliwung. Flood anticipation can be done by providing early warnings to communities in river basins, activating water pumps in flood areas, and coordinating with related parties to ensure evacuation routes and emergency posts are ready for use. In addition, the drainage system in urban areas is functioning optimally to reduce possible puddles.

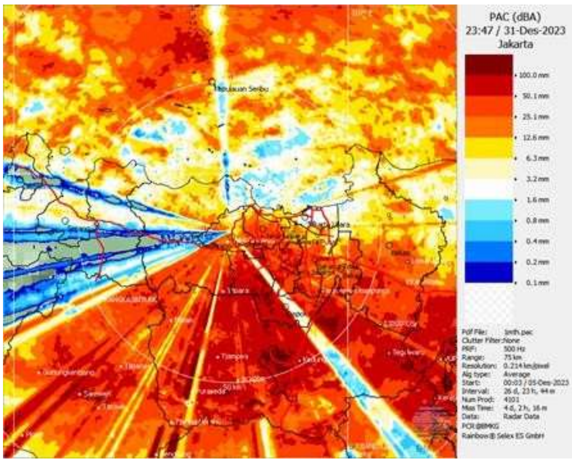
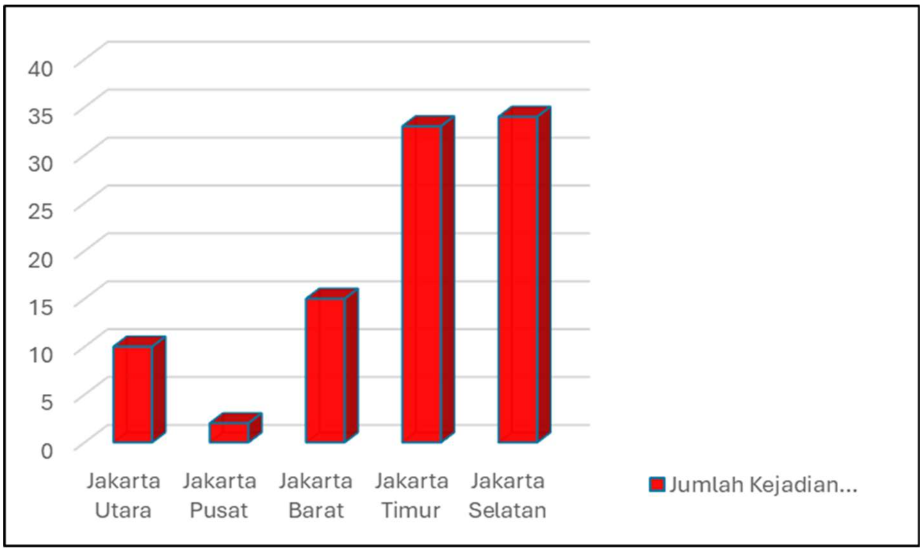


Figure 20. Radar Image PAC Products December 2023 DKI Jakarta area

Figure 20 shows the distribution of average rainfall in December which is dominated by yellow, red, and orange colors indicating very high intensity rain (>100 mm) in almost all areas of Jakarta. With this distribution, mitigation measures such as monitoring at main water gates, readiness of evacuation posts, and flow control in upstream areas are very important to minimize the impact of flooding, especially in South Jakarta, East Jakarta, and West Jakarta which are indicated to have higher rainfall intensity.

3.2 Flood Incident Data Collection Analysis Results

Several significant trends support the importance of implementing a flood early warning system. The most frequently affected areas indicate the need for more intensive mitigation measures. The detected flood frequency patterns provide insight into the right time to undertake more intensive and accurate preparedness measures.



Grafik 1. DKI Jakarta Flood Events 2019 – 2023

Source: DiBI Data

The data collected shows that flooding in Jakarta during the period 2019 to 2023 occurred with varying frequencies in each region. Based on the graph, the areas that most often experience flooding are South Jakarta, East Jakarta, West Jakarta, and North Jakarta, while Central Jakarta has the lowest flood frequency among the five regions. This distribution provides an overview of areas with a higher level of vulnerability to flooding, as well as being the basis for formulating more targeted mitigation measures in each region. The relationship between the high incidence of flooding and the potential impact on national stability is an important foundation because frequent disruptive flooding can affect the smooth running of economic, social, and security activities in the capital. The implementation of a flood early warning system will play an important role in ensuring that the government and community are optimally prepared to deal with flooding, so that national stability is maintained.

4. Conclusion and Suggestions

Based on the results of the data analysis that has been carried out regarding the Implementation of the Flood Early Warning System for National Stability to Improve National Defense are as follows:

1. The use of weather radar and GIS in flood early warning systems in

2. DKI Jakarta is effective in mapping vulnerable areas and providing real-time rainfall intensity data. This data integration allows for more accurate analysis and rapid response in dealing with flood threats. Rainfall data from 2021 to 2023 and weather radar data from 2023 support spatial analysis and early warning with

flood potential levels especially in November 48%, December 42%, January 64%, February 101%, March 53%, and May 44%.

3. The implementation of a technology-based early warning system contributes to increasing the country's defense preparedness and resilience by reducing the social, economic, and security impacts of flooding. Synergy between the TNI, BNPB, local governments, and the community is essential to strengthening an effective disaster management system.

5. Suggestion

Based on the results and discussion, this study still needs improvement. Suggestions for further research that may expand the scope of the study are as follows:

1. Improving GIS and weather radar technology as well as human resource training to support flood mitigation.

2. Conduct flood risk education to the community regarding the flood early warning system routinely in each region.

3. Strengthening synergy between the government, TNI, BNPB, BMKG, academics, and the private sector.

4. Using the integration of rainfall data, weather radar imagery, and AI technology for flood risk analysis.

5. This study did not consider the topography and watersheds of the DKI Jakarta area, therefore it is necessary to add topography and watersheds in further research.

REFERENCE

[1]. Alawiyah, AM, & Harintaka, H. (2021). Identification of Flood Inundation in DKI Jakarta Area Using Sentinel-1 Satellite Imagery. JGISE: Journal of Geospatial Information Science and Engineering, 4(2), 95. https://doi.org/10.22146/jgise.68353

[2]. Anafi, NFM, Noor, NM, & Widyasamratri, H. (2023). A Systematic Review of Real-time Urban Flood Forecasting Model in Malaysia and Indonesia - Current Modelling and Challenge. Jurnal Planologi, 20(2), 150. https://doi.org/10.30659/jpsa.v20i2.30765

[3]. Arcgis, D. (2011). Processing SRTM DEM Data. May.

[4]. Azis, IS, Sugandi, D., & Setiawan, I. (2021). Learning of disaster mitigation through problem based learning method in senior high school. IOP Conference Series: Earth and Environmental Science, 683(1). https://doi.org/10.1088/1755-1315/683/1/012053

[5]. Belhajjame, K., Zhao, J., Garijo, D., Gamble, M., Hettne, K., Palma, R., Mina, E., Corcho, O., Gómez-Pérez, J.M., Bechhofer, S., Klyne, G., & Goble, C. (2015). Using a suite of ontologies for preserving workflow-centric research objects. Journal of Web Semantics, 32, 16–42. https://doi.org/10.1016/j.websem.2015.01.003

[6]. Buslima, FS, Omar, RC, Jamaluddin, TA, & Taha, H. (2018). Flood and flash flood geo-hazards in Malaysia. International Journal of Engineering and Technology(UAE), 7(4). https://doi.org/10.14419/ijet.v7i4.35.23103

[7]. Cai, Y., Li, L., Elahi, E., & Qiu, Y. (2018). Selection of policies on typhoon and rainstorm disasters in China: A content analysis perspective. Sustainability (Switzerland),10(2),1–13. https://doi.org/10.3390/su10020387

[8]. Cea, L., & Costabile, P. (2022). Flood Risk in Urban Areas: Modelling, Management and Adaptation to Climate Change: A Review. In Hydrology (Vol. 9, Issue 3). https://doi.org/10.3390/hydrology9030050

[9]. Chan, SW, Abid, SK, Sulaiman, N., Nazir, U., & Azam, K. (2022). A systematic review of the flood vulnerability using geographic information system. Heliyon, 8(3). https://doi.org/10.1016/j.heliyon.2022.e09075

[10]. De Almeida, LG, De Souza, AD, Kuehne, BT, & Gomes, OSM (2020). Data analysis techniques in vehicle communication networks: Systematic

[11]. mapping of literature. IEEE Access, 8, 199503–199512. https://doi.org/10.1109/ACCESS.2020.3034588

[12]. Ding, L., Ma, L., Li, L., Liu, C., Li, N., Yang, Z., Yao, Y., & Lu, H. (2021). A

[13]. survey of remote sensing and geographic information system applications for flash floods. Remote Sensing, 13(9), 1–20. https://doi.org/10.3390/rs13091818

[14]. Djuyandi, Y., Casnoto, H., & Hidayat, W. (2019). Military operations other than war (Mootw): Synergy of Indonesian national armed forces (TNI) and national disaster management agency (BNPB) in disaster management. Humanities and Social Sciences Reviews, 7(4), 111–121. https://doi.org/10.18510/hssr.2019.7416

[15]. Eko Nuryanto, D. (2013). 20th CENTURY RAINFALL CHARACTERISTIC IN JAKARTA BASED ON

GLOBAL CLIMATE EVENTS. Manuscript Submitted: May 31, 11.

[16]. Feng, B., Zhang, Y., & Bourke, R. (2021). Urbanization impacts on flood risks based on urban growth data and coupled flood models. Natural Hazards, 106(1). https://doi.org/10.1007/s11069-020-04480-0

[17]. Firdaus, D., Andriani, I., & Sidik, RP (2023). Visualization of Disaster-Prone Location Data in West Java Using Google Data Studio. Intech Scientific Journal: Information Technology Journal of UMUS, 5(1), 69–77. https://doi.org/10.46772/intech.v5i1.994

[18]. Goodchild, M. F. (2009). Geographic information systems and science: Today and tomorrow. Annals of GIS, 15(1), 3–9. https://doi.org/10.1080/19475680903250715

[19]. Hall, J. W., Dawson, R. J., Sayers, P. B., Rosu, C., Chatterton, J. B., & Deakin, R. (2003). A methodology for national-scale flood risk assessment. Proceedings of the Institution of Civil Engineers: Water and Maritime Engineering, 156(3), 235–247. https://doi.org/10.1680/wame.2003.156.3.235

[20]. Hammami, S., Zouhri, L., Souissi, D., Souei, A., Zghibi, A., Marzougui, A., & Dlala, M. (2019). Application of the GIS based multi-criteria decision analysis and analytical hierarchy process (AHP) in the flood susceptibility mapping (Tunisia). Arabian Journal of Geosciences, 12(21). https://doi.org/10.1007/s12517-019-4754-9

[21]. Hang, HT, Hoa, PD, Tru, VN, & Phuong, NV (2021). Application of Shannon'S Entropy Model and Gis in Flash Flood Forecasting Along National Highway-6, Hoa Binh Province, Vietnam. International Journal of GEOMATE, 21(87), 50–57. https://doi.org/10.21660/2021.87.j2316 Jamroni.pdf. (nd).

[22]. Jauh, P., & Diponegoro, U. (nd). Rainfall Data Processing Lecture-Drainage- Presentation.

[23]. Jiang, W., Ji, X., Li, Y., Luo, X., Yang, L., Ming, W., Liu, C., Yan, S., Yang, C., & Sun, C. (2023). Modified flood potential index (MFPI) for flood monitoring in terrestrial water storage depletion basins using GRACE estimates. Journal of Hydrology, 616(October 2022), 128765. https://doi.org/10.1016/j.jhydrol.2022.128765

[24]. Kay, A.L., Rudd, A.C., Fry, M., Nash, G., & Allen, S. (2021). Climate change impacts on peak river flows: Combining national-scale hydrological modeling and probabilistic projections. Climate Risk Management, 31(September 2020), 1–15. https://doi.org/10.1016/j.crm.2020.100263 Ministry of Health of the Republic of Indonesia. (2011). No.主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析 Title. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 16(2), 39–55.

[25]. Kurowksa, K., Marks-Bielska, R., Bielski, S., Aleknavičius, A., & Kowalczyk, C. (2021). Geographic information systems and the sustainable development of rural areas. Land, 10(1), 1–18. https://doi.org/10.3390/land10010006

[26]. Lü, G., Batty, M., Strobl, J., Lin, H., Zhu, A.X., & Chen, M. (2019). Reflections and speculations on the progress in Geographic Information Systems (GIS): a geographic perspective. International Journal of Geographical Information Science, 33(2), 346–367. https://doi.org/10.1080/13658816.2018.1533136 Mazurek, M. (2023). Social Sciences. The Interwar World, 386–402. https://doi.org/10.4324/9781003105992-27

[27]. Menéndez, P., Losada, I.J., Torres-Ortega, S., Narayan, S., & Beck, M.W. (2020). The Global Flood Protection Benefits of Mangroves. Scientific Reports, 10(1), 1–11. https://doi.org/10.1038/s41598-020-61136-6

[28]. Mohd Yassin, NA, Aizam Adnan, N., & S Md Sadek, ES (2023). PLANNING MALAYSIA: ANALYSIS OF FLASH FLOOD POTENTIAL INDEX (FFPI) AND SCENARIOS ASSESSMENT IN SHAH ALAM USING GIS

[29]. APPROACH Analysis of Flash Flood Potential Index (FFPI) and Scenarios Assessment in Shah Alam Using GIS Approach. Journal of the Malaysian Institute of Planners VOLUME, 21(2), 1–12. https://browser.creodias.eu.

[30]. Munawar, HS, Hammad, AWA, & Waller, ST (2022). Remote Sensing Methods for Flood Prediction: A Review. Censorship, 22(3). https://doi.org/10.3390/s22030960

[31]. Nkwunonwo, U. C., Whitworth, M., & Baily, B. (2020). A review of the current status of flood modeling for urban flood risk management in the developing countries. In Scientific Africa (Vol. 7). https://doi.org/10.1016/j.sciaf.2020.e00269

[32]. Nugro, P. (2014). 7 Causes of Flooding In City Areas Which Are Very Densely Populated. Jay, 7(2), 205.

[33]. Education, J., Dan, L., & Sustainability, P. (2021). Article info ABSTRACT Received: 27. 22, 50–60.

[34]. Permana, DS, Hutapea, TDF, Praja, AS, Fatkhuroyan, & Muzayanah, LF (2016). Multi Weather Radar Format Data Processing Using Python-Based Wradlib. Journal of Meteorology and Geophysics, 17(3), 157–164.

[35]. Popa, M.C., Peptenatu, D., Draghici, C.C., & Diaconu, D.C. (2019). Flood hazard mapping using the flood and Flash-Flood Potential Index in the Buzau River catchment, Romania. Water (Switzerland), 11(10). https://doi.org/10.3390/w11102116

[36]. Practices, G., & Learned, L. (2008). Private Sector Activities in Disaster Risk Reduction. Sampath, 1, 97.

[37]. Prakasa, A., & Utami, FD (2019). Integrated Weather Radar Information System of BMKG BMKG The Integrated Weather Radar Information System of BMKG. Journal of Telecommunication, Electronics, and Control Engineering (Jtece), 01, 86–96.

[38]. Romali, NS, & Yusop, Z. (2021). Flood damage and risk assessment for urban areas in Malaysia. Hydrology Research, 52(1). https://doi.org/10.2166/NH.2020.121

[39]. Taryana, A., El Mahmudi, MR, & Bekti, H. (2022). Analysis of Flood Disaster Preparedness in Jakarta. JANE - Journal of Public Administration, 13(2), 302. https://doi.org/10.24198/jane.v13i2.37997

[40]. Turner, L. W., Udal, M. C., Larson, B. T., & Shearer, S. A. (2000). Monitoring cattle behavior and pasture use with GPS and GIS. Canadian Journal of Animal Science, 80(3), 405–413. https://doi.org/10.4141/A99-093

[41]. Vojtek, M., Janizadeh, S., & Vojteková, J. (2022). Riverine flood potential assessment at municipal level in Slovakia. Journal of Hydrology: Regional Studies, 42(July). https://doi.org/10.1016/j.ejrh.2022.101170

[42]. Vojtek, M., Janizadeh, S., & Vojteková, J. (2023). Riverine flood potential assessment using metaheuristic hybrid machine learning algorithms. Journal of Flood Risk Management, 16(3), 1–17. https://doi.org/10.1111/jfr3.12905

[43]. Wallwey, C., & Kajfez, R.L. (2023). Quantitative research artifacts as qualitative data collection techniques in a mixed methods research study. Methods in Psychology, 8(February), 100115. https://doi.org/10.1016/j.metip.2023.100115

[44]. Wang, L., Cui, S., Li, Y., Huang, H., Manandhar, B., Nitivattananon, V., Fang, X., & Huang, W. (2022). A review of the flood management: from flood control to flood resilience. In Heliyon (Vol. 8, Issue 11). https://doi.org/10.1016/j.heliyon 2022.e11763

[45]. Wei, X., Guo, H., Wang, X., Wang, X., & Qiu, M. (2022). Reliable Data Collection Techniques in Underwater Wireless Sensor Networks: A Survey. IEEE Communications Surveys and Tutorials, 24(1), 404–431. https://doi.org/10.1109/COMST.2021.3134955

[46]. White, M. G. (2020). Why human subjects research protection is important. Ochsner Journal, 20(1), 16–33. https://doi.org/10.31486/toj.20.5012

[47]. Wu, CH, Lee, SY, Chiang, JCH, & Tsai, P.C. (2023). Role of precession on the transition seasons of the Asian monsoon. Npj Climate and Atmospheric Science, 6(1), 1–9. https://doi.org/10.1038/s41612-023-00426-y

[48]. Yin, Q., Ntim-Amo, G., Ran, R., Xu, D., Ansah, S., Hu, J., & Tang, H. (2021). Flood disaster risk perception and urban households' flood disaster preparedness: The case of Accra metropolis in Ghana. Water (Switzerland), 13(17). https://doi.org/10.3390/w13172328

[49]. Yu, Q., Wang, Y., & Li, N. (2022). Extreme Flood Disasters: Comprehensive Impact and Assessment. Water (Switzerland), 14(8), 1–14. https://doi.org/10.3390/w14081211

[50]. Yuan, Z., Ton That, D.H., Kothari, S., Fils, G., & Malik, T. (2018). Utilizing provenance in reusable research objects. Informatics, 5(1), 1–25. https://doi.org/10.3390/informatics5010014