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Geographic Information System-Based Analysis of Flood-Affected Infrastructure in Kembangan Sub-District

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A B S T R A C T

Flood is one of the hydrometeorological disasters that have occurred in Indonesia in recent years. Jakarta is one of the cities that is prone to flood. This research was conducted to analyse the infrastructure affected by floods in Kembangan Sub-district, West Jakarta based on Geographic Information System. Data processing was processed using QGIS 3.16, and then analysed using Excel. The results show that Kembangan Sub-district has low physical vulnerability. However, physical vulnerability can increase if more infrastructure is affected if flooding is not taken seriously by the community and government.

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INTRODUCTION

The current climate change is identified as one of the primary contributing factors to the rising prevalence of hydrometeorological disasters in Indonesia. An increase in global temperatures and alterations to rainfall patterns have resulted in the occurrence of extreme weather events, including floods, landslides and droughts. According to data from the National Disaster Management Authority (BNPB) for the period between January and May 2023, flooding represents the most prevalent type of hydrometeorological disaster, with a total of 423 events. The occurrence of floods can be attributed to a number of factors, including the presence of high rainfall, the alteration of rainwater catchment areas, and the degradation of environmental quality resulting from human activities that lead to the overexploitation of natural resources. Flooding can be defined as the overflow of river water into the surrounding land due to the volume of water exceeding the capacity of the river in question. This is a persistent issue that has been observed in numerous regions, particularly in the northern coastal areas of Java, including Jakarta, Semarang and Surabaya. These areas are traversed by large rivers that drain into the Java Sea, which has resulted in the formation of geomorphological features in the northern part of Java. These features are the result of fluvial, fluviomarine and coastal activities, which have collectively contributed to the vulnerability of cities in this region to flooding due to the overflow of river water (Rakuasa et al. 2023).

Other factors that contribute to the occurrence of flooding include high rainfall, uncontrolled land use in the watershed area, topographical features that are relatively flat or sloping, inadequate drainage systems, and community behaviour that results in the accumulation of litter (Rakuasa et al., 2023). The Kembangan Sub-district is situated within the West Jakarta area, which is susceptible to flooding. This is attributed to a reduction in river capacity resulting from the construction of settlements on riverbanks (Suprajaka et al., 2019). Subsequently, the damage to the connecting channels and drainage functions that facilitate the overflow of river water during periods of high rainfall intensity cannot be controlled. This disrupts the optimisation of water control and results in the formation of large puddles during the rainy season. As indicated by the data provided by BPBD DKI Jakarta (2023), the height of the floods that inundated Kembangan Sub-district from 2022 to 2023 reached 40-120 cm for a period of more than three days. This information suggests that the height and duration of flooding may result in losses in terms of infrastructure, including private assets (homes or businesses) and public assets or assets used by the community in general, such as health, education, government, and worship buildings.

Kembangan sub-district is astronomically located between 5^{o}19′12″ - 6^{o}23′54″ S dan 106^{o}22′42″ - 106^{o}58′18″ E It is incorporated within the West Jakarta Administrative City. The total area of Kembangan subdistrict is 24.16 km^2, divided into six urban villages (BPS, 2021). The subdistrict's boundaries are as follows:

North : Rawa Buaya urban village, Cengkareng sub-district
East : Kedoya urban village, Kebon Jeruk sub-district

South : South Jakarta City
West : Banten Province

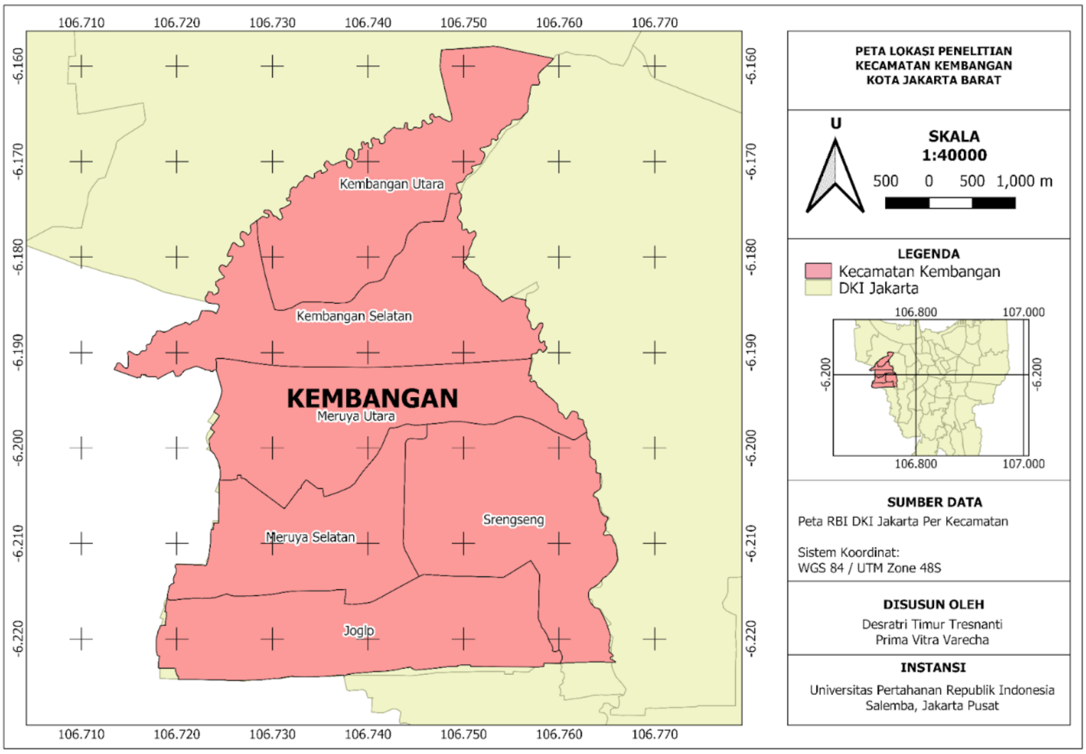

Figure 1. Map of Kembangan Subdistrict

The Kembangan subdistrict is located at an altitude of 7 metres above sea level. The sub-district is traversed by a number of rivers and streams, including the Kali Angke, Kali Pesanggrahan, and Kali Cantiga. The low-lying topography of the Kembangan subdistrict, coupled with the intensity of precipitation, can result in the overflow of rivers, leading to the occurrence of flooding. On 3 February 2023, flooding occurred in one RT in Kembangan Utara Urban Village due to precipitation and the overflowing of the Kali Angke, forcing 20 families to evacuate to the mosque (Prihatini & Sari, 2023). Community activities were also disrupted due to flooded road access on Jalan Raya Joglo, caused by the overflowing of Kali Gebyuran, which was unable to accommodate the additional water volume following the precipitation (Shubhy, 2023).

This research project aims to identify critical infrastructural facilities within the Kembangan subdistrict of South Jakarta that have been adversely impacted by flooding. The analysis will employ the utilisation of spatial data, encompassing the location, typology, and condition of the aforementioned infrastructure, facilitated by the QGIS platform.

THEORETICAL REVIEW

Floods

A flood is defined as an event where normally dry land becomes inundated with water due to a combination of factors, including high rainfall, low topographic conditions or depressions, and the low ability of the soil to absorb water. Floods are among the most prevalent natural disasters, both in terms of their intensity and the number of locations affected annually. In Indonesia, floods are typically precipitated by elevated precipitation levels, which overwhelm the capacity of water drainage systems, including rivers, natural creeks, and artificial channels, to accommodate the accumulated rainwater, resulting in overflow. The causes of flooding can be divided into two categories: natural factors, including erosion, sedimentation, and river physiography/geophysical conditions, and human factors, such as inadequate river or drainage capacity and inappropriate land use changes in riverbank areas. As a result of flooding, significant losses can occur, including damage to infrastructure, economic losses, and even loss of human life (Anggraini et al., 2021; Muin & Rakuasa, 2023).

The development of adaptive strategies represents a crucial subsequent stage in the process of flood disaster mitigation based on mapping. The objective of these strategies is to reduce vulnerability to disaster risk, with a particular focus on efforts to make communities and social and economic systems more resilient to disasters. In the context of flood disasters, adaptive strategies can be implemented by increasing water absorption capacity, reducing infrastructure vulnerability through the reinforcement of building structures, and raising public awareness about the importance of protecting themselves and their assets from flooding. Flood mapping using GIS can provide crucial information to support the implementation of adaptive strategies, particularly when determining the location, type, and scale of adaptive interventions required based on map data.

Geographic Information System (GIS)

Geographic Information System (GIS) is a computer-based system utilised for the capture, storage, analysis and visualisation of geographic data that has a spatial reference or location on the Earth's surface (Rahmanto et al., 2020). A Geographic Information System (GIS) is formed of three principal components: the system, the information and the geography. A Geographic Information System (GIS) is a computer-based information system that is capable of collecting, managing, storing, manipulating, and analysing data that is related to locations or regions on the Earth's surface. The incorporation of geographic elements renders GIS an invaluable instrument for the administration and comprehension of data pertaining to locations on Earth, whether in two-dimensional or three-dimensional formats.

GIS functions by employing both spatial and non-spatial data. Spatial data is defined as information that can be measured or identified based on a specific location on the Earth's surface. Examples of this type of data include maps, aerial photographs, and satellite images. This data can be represented in the form of points, lines, or polygons, organised in the manner of map layers. In contrast, non-spatial data is supporting data that complements spatial information. Examples of this type of data include statistical, numerical, or descriptive data, which can be displayed in the form of tables, diagrams, or text.

In its application, GIS can be used for a variety of purposes, including mapping, spatial analysis, modelling, and the visualization of patterns on the Earth's surface (Ryka, et al., 2020). QGIS is a free, open-source GIS software that is compatible with a range of operating systems. It is capable of being used to create mapping, to analyse spatial data and to perform other functions associated with GIS. QGIS is compatible with a range of GIS data formats, including vector data, raster data, and attribute data. Furthermore, QGIS has a straightforward and intuitive interface (Fitri & Ferdiansyah, 2017). The utilisation of geographic information systems (GIS) for mapping can assist in the analysis of factors that contribute to flooding, including topography, hydrology, and land use. Additionally, it can facilitate the identification of optimal and effective evacuation routes by initially assessing road conditions, the accessibility of evacuation centres, and the distance between residences and evacuation centres. The assessment of critical infrastructure for flood damage can also be conducted.

METHODOLOGY

This research employs secondary survey methods and qualitative methods of literature study. The data used in this research is secondary data obtained from the website of an institution or agency that provides geospatial data. Indonesian landform data (RBI) per sub-district is obtained from the website tanahair.indonesia.go.id in the form of vector data. The RBI data contains data on sub-district areas throughout Indonesia, road network data, and building area data. Flood data in the form of vector data is obtained from the inasafe.org website.

The data were processed using QGIS 3.16. The data sets included flood-affected building data, road data, and flood data. The data processing process commenced with the delineation of the data according to the research location, namely Kembangan Sub-district. This was achieved through the use of the Clip vector tool, as the data were vector data. Following this, an overlay was performed to facilitate the visualisation and analysis of the areas affected by flooding. In addition to the processing of data in the form of maps, data extraction was also conducted and exported to an Excel worksheet. The extracted data comprised information on the area of buildings and the length of roads affected by flooding. This data was then analysed using the Pivot Table tool to facilitate the examination of the type, number and area of buildings, as well as the type and length of roads affected by flooding.

The output of data processing using QGIS 3.16 is a map layout of infrastructure that has been affected by the flooding event. In addition, data on the area covered by buildings, the building types present, the types of roads affected by the flooding and the lengths of these roads were also extracted from the data processing. These results informed a data analysis, which used descriptive analysis techniques in order to explain the extent of the flooding's impact on the infrastructure.

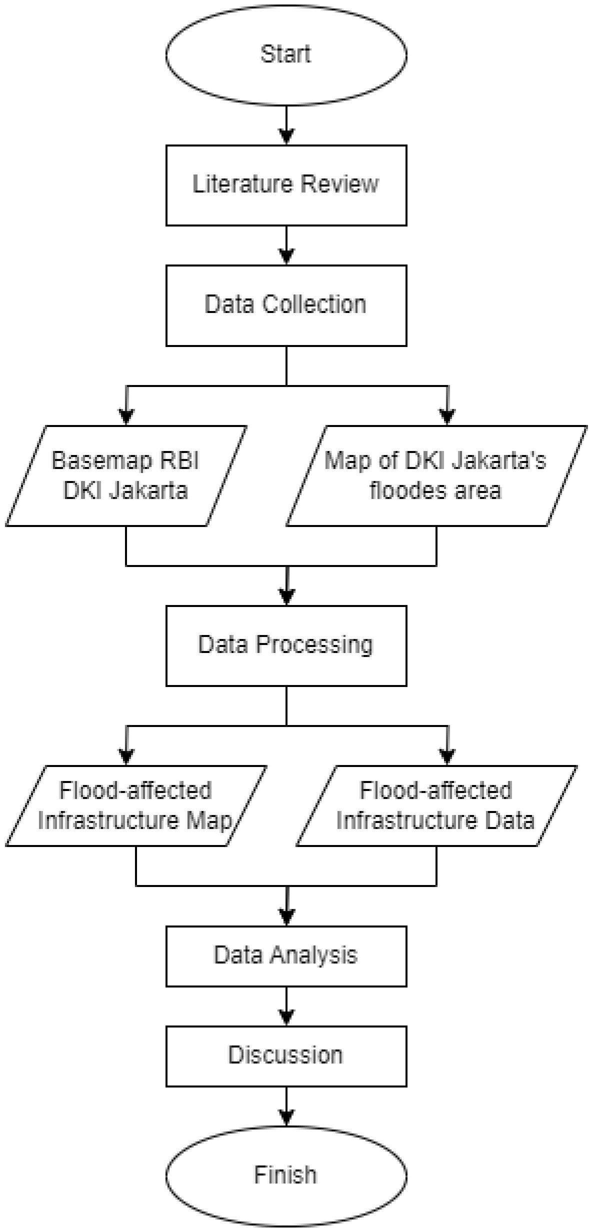

Figure 2. Flowchart

RESULT AND DISCUSSION

During the monsoon season, high rainfall results in the overflow of water that should be collected through artificial drainage and flood storage channels as well as naturally by the Kali Angke, Kali Mookervart, Cengkareng Drain, Kali Pesanggrahan, and other tributaries. However, due to a reduction in water absorption capacity, changes in water flow capacity resulting from sedimentation, and the loss of green space caused by dense settlements and other forms of built-up land, flooding in Kembangan Subdistrict is an inevitable consequence. It is evident that these factors are just some of the numerous determinants of whether flooding is caused by natural or human processes. The flow of water originating from residential areas will proceed to the primary drainage system, subsequently flowing into the river and ultimately emptying into Jakarta Bay via the Cengkareng Drain. The map of flood-affected infrastructure in Kembangan Subdistrict, processed with QGIS 3.16, is provided below for reference.

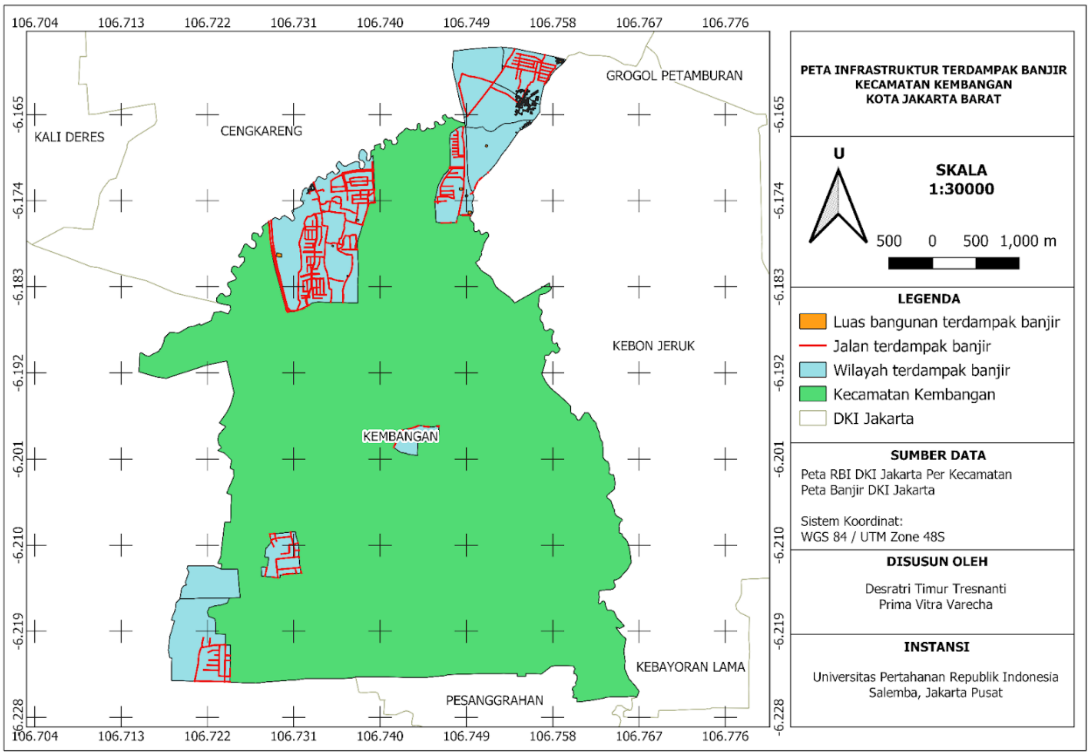

Figure 3. Map of Flood Affected Infrastructure

The impact of flooding has resulted in a range of damages and losses to various public infrastructure in Kembangan, West Jakarta. The geographical location of Kembangan Sub-district, changes in land use, high rainfall intensity, tidal or tidal water coming from rivers, and poorly functioning or blocked drainage channels are the primary causes of floods that impact public infrastructure. The damage to buildings is classified into three categories: light damage, medium damage, and heavy damage. The impact of loss refers to the disruption of access caused by inundation, which hinders activities and impedes the functioning of buildings or road infrastructure. The results of the data management of flood-affected buildings indicate that the impact of flood disasters on public infrastructure is significant, with places of worship and residential areas being the most affected. This demonstrates that floods have a differential impact on the various types of infrastructure present in Kembangan Sub-district.

Table 1. Flood-Affected Buildings

Building Type	Total	Area (m^2)
Health Clinic	1	938,16
Worship Place	4	1.623,13
Housing	345	30.304,41

Total	**350**	**32.865,7**

The data indicates that the impact of flood disasters on public infrastructure buildings is relatively limited. Consequently, authorities such as the local government and BPBD may direct their attention to the number of affected residents' settlements, as 345 houses with an area of 30.304,41 square metres were damaged. The damage observed can be classified as minor, affecting non-structural components such as floor coverings, walls, door and window frames. The analysis results indicate that the majority of areas within Kembangan Subdistrict exhibit a relatively low level of physical vulnerability, as evidenced by the distribution of residential structures. This is attributed to the fact that this subdistrict has a moderate population density of 20 individuals per hectare (BPS, 2017). It can be inferred that as residential areas expand and population density increases, the level of physical vulnerability based on residential structures will also rise.

Table 2. Roads Affected By Flooding

Road Type	Number of Roads	Length (m)
Highway	3	1.068,6
Connecting highway	4	326,62
Main road	3	1.193,86
Residential road	164	29.561,58
Alternative roads	12	2.342,07
Alternative connecting road	1	3,1
Alley	9	3.217,62
Total	**196**	**37.710,35**

A consequence of the elevated intensity and duration of the flooding will be an increased discharge of floodwater. An increase in floodwater discharge will exert greater pressure on road infrastructure, which may result in damage. The type and condition of the road infrastructure in the Kembangan sub-district have an impact on the extent of flood damage. Road infrastructure constructed from less robust materials, such as soil, is more susceptible to damage from flooding. Furthermore, road infrastructure that is already in a compromised state will be particularly susceptible to damage from flooding. The topographic and hydrological conditions of the Kembangan Sub-district area are characterised by a sloping terrain and a rather poor drainage system. It can be observed that the total length of roads that are flooded are residential and alternative roads. These areas are, on average, less supported by a drainage system that meets the standards set out in relevant guidelines, which makes them more vulnerable to flooding. The consequences of flooding in the Kembangan Sub-district include functional damage, such as the rendering of roads slippery and dangerous, thereby impeding access, and economic damage, in the form of material losses sustained by flooded goods and vehicles. Additionally, residents of the sub-district experience a loss of time, which in turn results in a loss of income.

CONCLUSIONS AND RECOMMENDATIONS

In terms of spatial analysis, the overall vulnerability level of Kecamatan Kembangan is relatively low. The distribution of built-up areas with residential land use exhibits a low level of vulnerability. However, the presence of a large number and area of public facilities, particularly those located in residential areas, can potentially elevate the level of physical vulnerability. The use of GIS can facilitate more accurate, efficient, and effective analysis of infrastructure affected by floods.

FURTHER STUDY

In accordance with the findings of the research, which have revealed the existence of flood-affected infrastructure (houses and buildings), it is anticipated that further research will be conducted to examine alternative pathways and the potential for the creation of GIS-based evacuation route maps. Additionally, it is hoped that research will be undertaken to assess the suitability of flood-safe areas as temporary evacuation sites or disaster posts in the event of a larger flood in the Kembangan Sub-district area.

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