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Mitigation Strategy of Disaster Based on Information Technology in Semarang City

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Abstract - Semarang is a city located on the northern coast of the Java Sea which makes it becomes one of the cities threatened by tidal flooding. Besides tidal flood inundation, several other disasters occuring in Semarang include fires, fallen trees, floods, landslides, hurricanes, and collapsed houses. This study identified the disasters occurred in Semarang City from 2012 through 2021, as well as the strategies to cope with them in general, and specifically using information technology, namely Geographic Information System (GIS) maps. The data in this study were obtained from Regional Development Planning Board, Public Works Office, Central Bureau of Statistics (BPS), Semarang City Social Service, and several related stakeholders. Those data were, then, visualized on a GIS map. The findings indicated that one method of mitigation is the use of GIS maps of floods and landslides, as well as disaster mitigation through Semarang economy and government policies.

Keywords: Semarang, GIS, tidal, flooding, disaster, mitigation

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Introduction

Background

Indonesia is a disaster-prone country. According to BNPB (National Disaster Management Agency), 1,205 disaster incidents occurred from January 1st to April 30th, 2021. The disasters were dominated by hydrometeorological incidents; for example floods, hurricanes, and erosions. Floods are the most common type of natural disaster (501 incidents) followed by tornadoes (339), landslides (233), forest and land fires (97), earthquakes (18), tidal waves and abrasions (16), and drought (16). The number of natural disasters increased by 1% from the previous year (Ichsan, 2022).

Semarang is located on the northernmost part of Java Island. The population of Semarang in 2021 was 1,656,564 people (Central Bureau of Statistics of Semarang, 2022).

Tidal floods often occur because Semarang is a coastal area. In 2022, a tidal flooding occurred in Semarang because of the rupture of embankment. As a result, the water level overflowed from 1.25 m to 1.5 m. Tidal flooding is a frequent problem in coastal areas of Indonesia, because the coasts have complex dynamics and processes that make coastal areas vulnerable to disasters. Semarang has tidal flood pressures lasting for a long time caused by the rising of sea level, global warming, and land subsidence (especially in the north of Semarang). The areas in Semarang that experienced the highest land subsidence were Tanjung Mas, Terboyo Kulon, Purwodinatan, and Central Semarang with as much as 12 - 15 cm/year. Several previous studies had discussed tidal flooding. Researches on prediction analysis of the largest tidal flood inundation were carried out in the centre of Semarang, which is flanked by Banjir Kanal Barat and Banjir Kanal Timur Rivers. The area is dominated by settlements, trade areas, industries, and strategic objects for the government and economy of Semarang (Nugroho, 2013). Some coastal areas of Semarang have a medium to low adaptive capacity to tidal flooding, totaling fifty-eight villages which is 62% of the total coastal subdistricts in Semarang (Suhelmi, 2013).

The occurrence of bacterial contamination is due to poor water quality affected by tidal flooding. Both provider and distribution have a very high-risk levels of contamination, while the customers has a high risk level (Budiyono *et al.*, 2015).

This tidal flood causing chronic stress, leads to the structure of the city to weaken (Egaputra *et al.*, 2022). In addition to tidal flooding, several disaster incidents occurred in Semarang, namely: flood, landslide, tornado, collapsed house, fire, and fallen tree (Central Bureau of Statistics of Semarang, 2022). This study described several disaster incidents that took place in Semarang and their mitigation based on community empowerment.

Geological Information of Semarang

In the Geomorphological Map of Indonesia (modified from Verstappen, 2000), Semarang area is generally occupied by alluvial plains with several embankments and swamps. Deposits that are stuffed in inter-mountain basins and hilly fold complexes are found in the southern and the eastern parts of Semarang. The other area is a complex morphology of volcanic deposits to the east of Semarang, cutting through the Quaternary sediments of Merbabu and Merapi Volcanoes to the bottom of Java Sea in the north of Semarang. Stratigraphically, Semarang area is mostly overlain by Pleistocene Damar Formation, while along the north coast by alluvium deposits. According to Van Bemmelen (1970a), the Damar Formation is composed of tuffaceous sandstone, conglomerate, and volcanic breccia. Sandstone comprises feldspar and quartz, as well as vertebrate remains. Faults in the south of Semarang as a result of the collapse of Mount Ungaran in Late Pleistocene were recognized (Poedjoprajitno, 2008).

The geological conditions around Semarang are in the form of marine sedimentary rocks, namely Kerek and Kalibeng Formations, which are of Early Miocene-Pliocene age. Old Ungaran clastic volcanics were deposited, namely Kaligetas and Damar Formations. Then the last volcanic activity was marked by Young Ungaran deposits, namely Kaligesik, Gadjah Mungkur, Jongkang, as well as Kemalon and Sengkuh Formations (Fahrudin and Winarno, 2012).

Geologically, younger to older (Figure 1) Semarang City is occupied by Alluvium (Qa) comprising beach, river and lake alluvial deposits; Then Gajah Mungkur Volcanics (Qhg), consisting of andesitic lava, blackish grey in colour, fine-grained, holocrystalline, composed of feldspar, hornblende, and augite, hard and compact. Kali Gesik Volcanics (Qpk): basaltic lava, blackish grey in colour, smooth, consists of feldspar, olivine and augite, very hard; and Jongkong Formation (Qpj), augite hornblende andesitic breccia and lava flows, formerly known as Old Ungaran volcanic rocks. This andesitic breccia is blackish brown, components are 1 - 50 cm in size, angular - slightly rounded with tuffaceous groundmass, medium porosity, compact and hard.

Then, Damar Formation (QTd), consisting of tuffaceous sandstone, conglomerate, and volcanic breccia. The tuffaceous sandstone is brownish yellow in colour with fine-coarse grain, consisting of mafic minerals, feldspar, and quartz with a tuffaceous groundmass, moderately hard porosity. Moreover Kali Getas Formation (Qpkg) is made up of breccia and lahars with intercalation of lava and fine-to coarse-grained tuff, locally at the bottom were found claystone

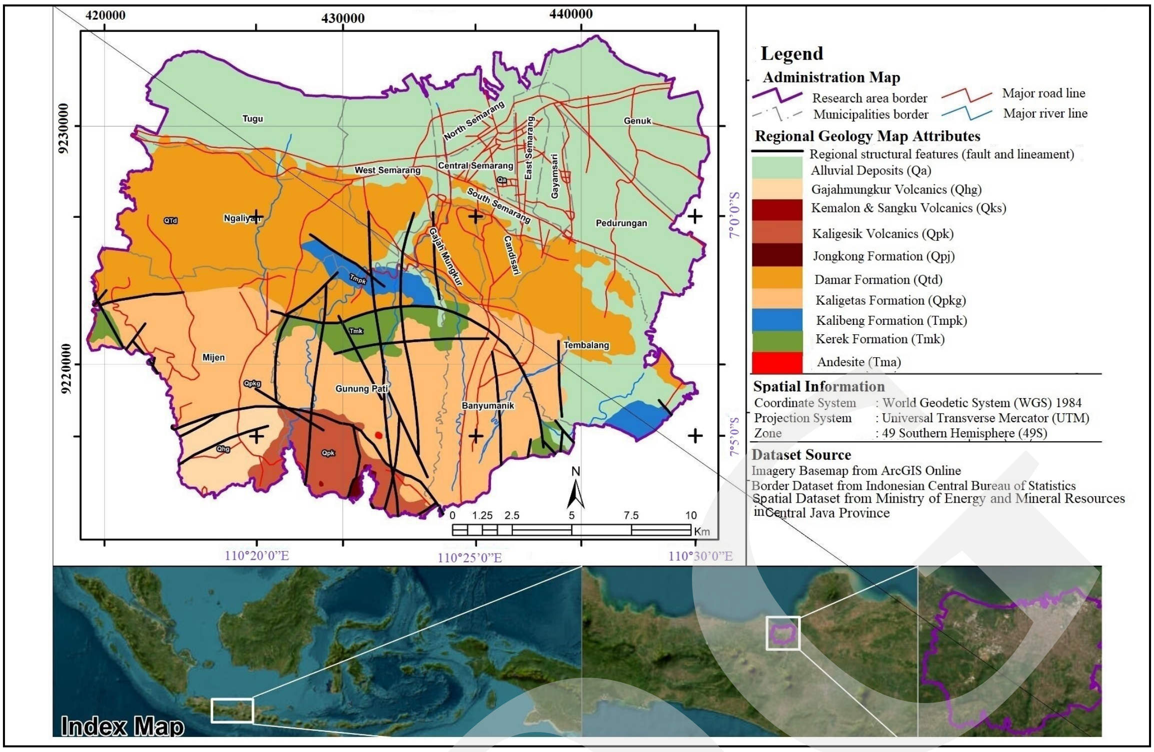

Figure 1. Geological Map of Semarang Area (modified from Thanden *et al.*, 1949).

containing mollusks and tuffaceous sandstone. Then, Kalibeng Formation (Tmpk), consisting of marl, tuffaceous sandstone and limestone. Marl is greenish to blackish grey composed of clay minerals and carbonate cement, low porosity to impermeable, somewhat hard in the dry state and easily crushed in the wet condition. The oldest unit is Kerek Formation (Tmk), alternating claystone, marl, tuffaceous sandstone, conglomerate, volcanic breccia, and limestone. Light-dark grey claystone, calcareous, partly siltstone or sandstone intercalation, containing foram, molluscs, and coral colonies (Soedarsono, 2012).

Methods and Materials

Methods

The research was conducted in Semarang City, Central Java Province, Indonesia. The city of Semarang is located on the northern coastline of Java Island and is directly adjacent to Java Sea. The area around the coast of Java Sea is prone to tidal flooding as well as other coastal disasters. Disaster mitigation measures must be implemented in order to reduce the impact to the community. Several studies used strategic analysis in coastal disasters, especially coastal erosion (Sugianto *et al.*, 2022), contributed ICZM to mitigation coastal erosion (Cantasano *et al.*, 2021), climate change mitigation-based economy (Gouldson *et al.*, 2016), community planning, and public participation (Pearce, 2003), landslide (Puri and Khaerani, 2018), and flood (Budiarti, 2018).

The mitigation described in this study identified mitigation in general, and specifically using information technology visualized on a GIS map. The attributes needed in GIS management are elements of points, lines, and polygons. Point elements are cities, line elements as roads, and polygon elements as residential areas; as well as the number of landslides and floods in Semarang. Processing of GIS attributes using Arc-View software, which has a network analysis extension, can function to determine the service area of a point from a distance determined according to the availability of the road network or accessibility (Purbani *et al.*, 2015). This research used Web GIS which is a system created to work with spatially georeferenced data (Imansyah, 2020). Method in this study was carried out by collecting spatial data, digitizing maps, importing maps in shp format, and giving symbols and styles. When there was still an error occurred then editing was conducted. Reversely, when it was done correctly, the style and corresponding symbol were also done, after that, a combination of spatial and nonspatial data was carried out. The next step was inserting them into digital maps and entering them into Web GIS. For nonspatial data collection, the first step was to group the data, to make data tabulations, to correct the data, and to do them. When errors still appear, editing action was taken. Reversely, when it was correct, the style and corresponding symbols were done, after that, a combination of spatial and nonspatial data was done. Then, the data was inserted into digital maps and entered into Web GIS (Ujianti *et al.,* 2022). The spatial data were the map of Semarang City, while the secondary data were disaster maps. Web GIS planning diagram is presented in Figure 2.

Materials

Data collection in this study used a literature review, interviews, field observations, and documentation (Hidajat *et al.*, 2021). This research is a

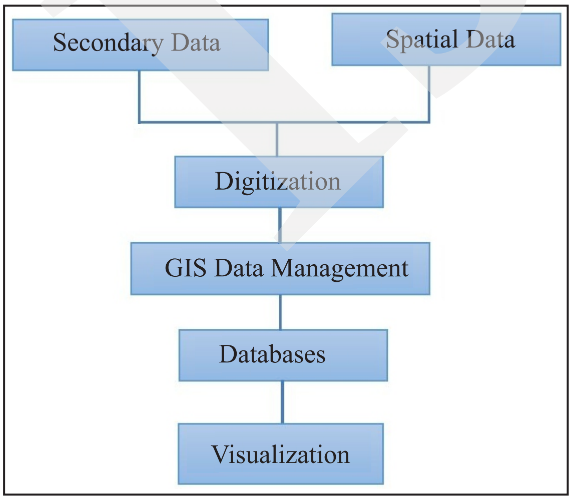

Figure 2. GIS Planning Diagram (Herlambang and Setyawati, 2016).

cross sectional study (Setyawati and Herlambang, 2020) using secondary data obtained from the report compiled by The Regional Development Planning Agency, The Regional Planning Agency, The Public Works Agency, and The Semarang City Social Service which were published through the official website of BPS of Semarang Municipality within the years of 2016 - 2022. Those data were used to support the results of this study obtained from the data which was then presented on a Web GIS map.

Result and Analysis

Population and Social Vulnerability

The population by age level in Semarang City revealed that female is higher than male; namely 819,785 male residents and 836,779 female residents, with a sex ratio of 98.01%. The total population in 2021 was 1,656,564 people (BPS Semarang, 2022).

The availability of arable land can be threatened by population growth and urbanization process, hence the possibility of this food disaster must be a concern (Diack *et al.*, 2017). The graph of the population by age group and sex in Semarang is presented in Figure 3.

Map area of population by age group and sex in Semarang City was visualized on the GIS Web “SIG Ketahanan Pangan” and is presented in Figure 4.

The high population density affects the social vulnerability of the community in potentially disaster-prone areas. Areas with a dense population represent a higher chance of loss of life and loss of property. The elderly population (60 years and over) is 184,798 people; the population of children aged 0 - 14 years is 363,757 people. The elderly population and the age of children (0 - 14 years) are two variables of social vulnerability. When a disaster process occurs, the elderly population and children have a low capacity, therefore, they depend on the productive age. The productive age population (15 - 60 years) is 1,108,0009 people. The female population aged

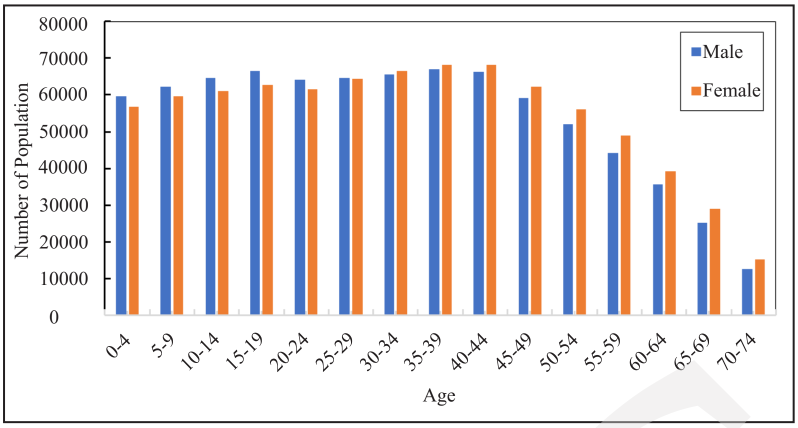

Figure 3. Population by age group and sex in Semarang City.

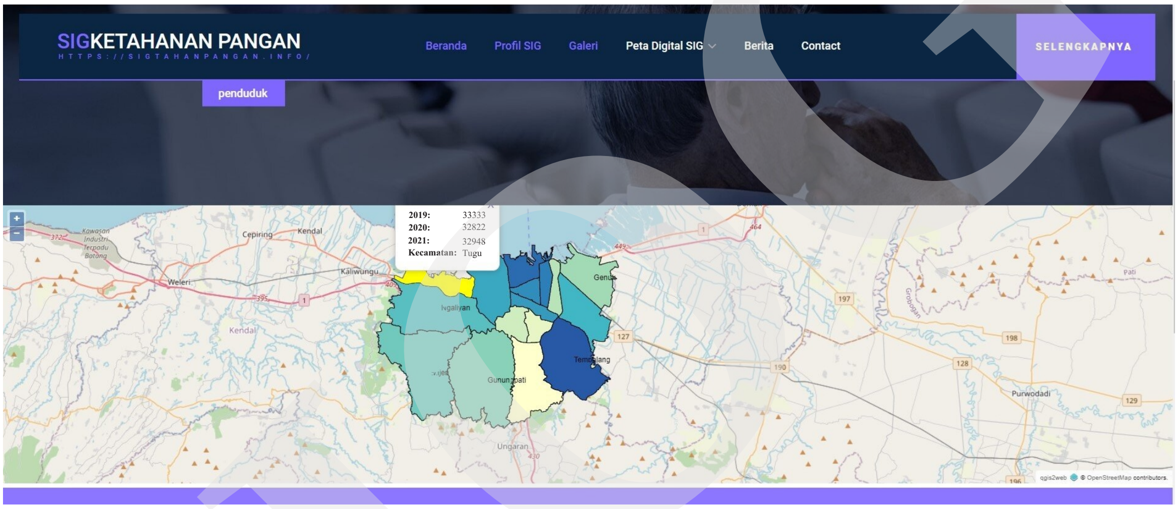

Figure 4. Map area of population by age group and sex in Semarang City.

over twenty years (mothers) is 596,814 people out of the total female population of 836,779 people. The high proportion of women in the population composition by sex demonstrates the evacuation process relative inability. This is based on women physical conditions, which are generally thought to be worse than men. With this condition, the female population will be more vulnerable than male population (Hapsoro and Buchori, 2015).

Climate Condition

Climatic conditions affect the potential of an area, both the disaster potential and the natural resource potential. Semarang has a tropical climate and two seasons; dry and rainy seasons. Semarang air temperature ranges from 26.50 to 28.90°C, with an average monthly rainfall of 206.58 mm in 2021 (BPS Semarang, 2022). High rainfall has the potential to cause floods and landslides. The observation of climate elements by months at Semarang Station is presented in Figure 5.

Land Use

Land use (2012 - 2016) in Semarang City consists of several categories, namely: rice field, garden, farm, plantation, planted trees, grassland, temporary land, pond, road, residential, office, river, *etc*. The largest land utilized by roads, residential, office, and river covering an area of 17,768,23 Ha, and the smallest land utilized by temporary land covering an area of 105,3 Ha. The graph of land utilizing of Semarang City in 2012 - 2016 is presented in Figure 6.

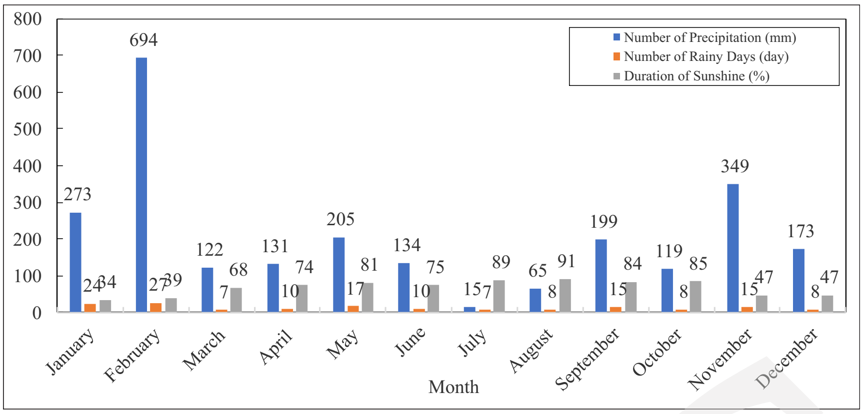

Figure 5. Observation of climate elements by months at Semarang Station.

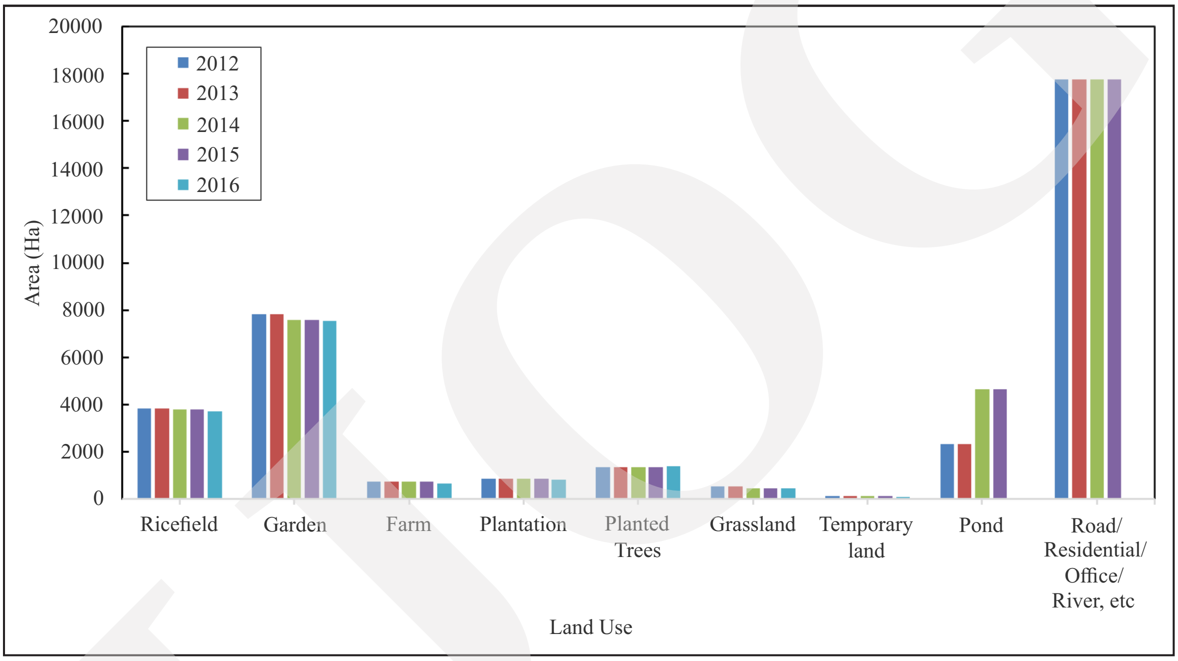

Figure 6. Land uilizing in Semarang in 2012–2016.

Land utilizing, especially rice fields, is useful for food security management; accurate land evaluation helps decision makers in planning appropriate area management (Kumar *et al.*, 2021). Area of wetland (Ha) by subdistrict in Semarang is presented in Figure 7.

The map area of wetland (Ha) by subdistrict in 2016 - 2018 was visualized on the GIS Web "SIG Ketahanan Pangan" and is presented in Figure 8.

Disasters in Semarang City

The most common disasters that occurred in Semarang in the period of 2012 - 2021 were landslides. In 2020, there were 175 landslides happened. The average disaster with the lowest frequency was tidal flooding, because this tidal flood only affected Java Sea coastal area like Semarang. List of disasters that occurred in Semarang during the years of 2012 - 2021 can be seen in Figure 9.

In the period of 2012 - 2021, there were 381 flood incidents (BPBD Semarang, 2022). A flood is a condition in which an area is inundated by large amounts of water. The cause of the flooding is heavy rainfall, rainwater that is not absorbed in the upstream area (because of

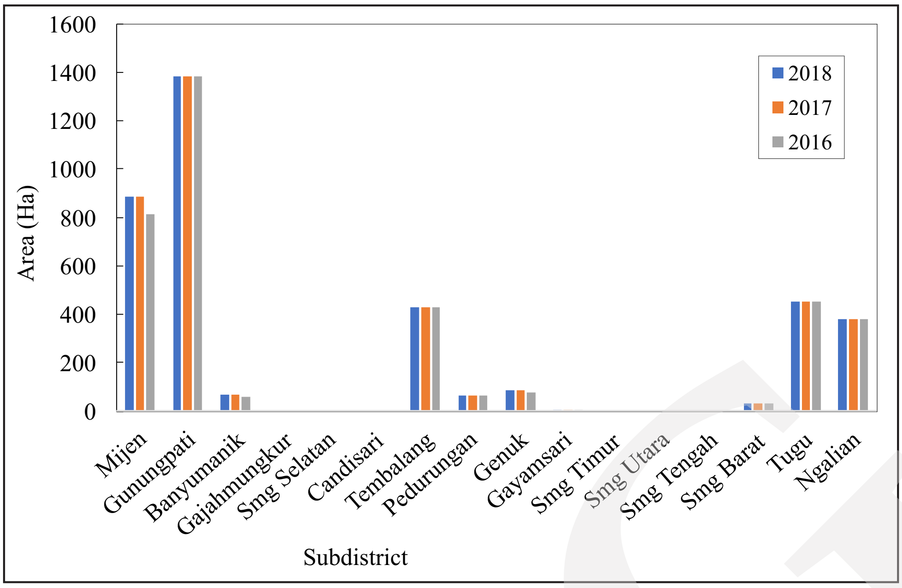

Figure 7. Area of wetland (Ha) by subdistrict in Semarang City.

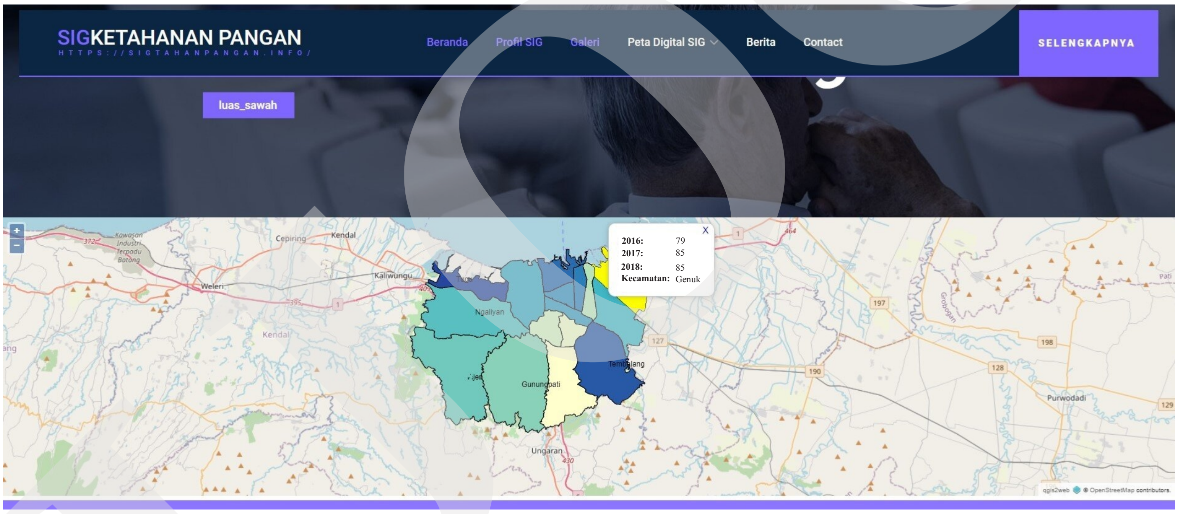

Figure 8. Map aof wetland area (Ha) by subdistrict in 2016 - 2018.

deforestation), rivers that experience narrowing or siltation (due to garbage and uncontrolled development), or topographical conditions in the form of basins that tend to become water collection areas (Aritama and Dharmadhiatmika, 2019).

There were forty-four tidal floods, the worst of which was in 2022 that attacked the industrial area of Semarang (BPBD Semarang, 2022). The existing condition of land elevation that is lower than sea level causes greater land subsidence. The tidal flood in Semarang damages infrastructure and residential areas, households, and individuals. Also makes productive land no longer functioning properly, damages the public infrastructure, and increases bad conditions in slum settlements (Ikhwanudin *et al.*, 2020). The image on each tab of the catastrophe menu for the years 2019 - 2021 is in this web GIS: https://sigtahanpangan.info/semarang/banjir.html–.

Map of the flood disaster in Semarang City from 2019 through 2021 was visualized on the GIS Web “SIG Ketahanan Pangan” and is presented in Figure 10.

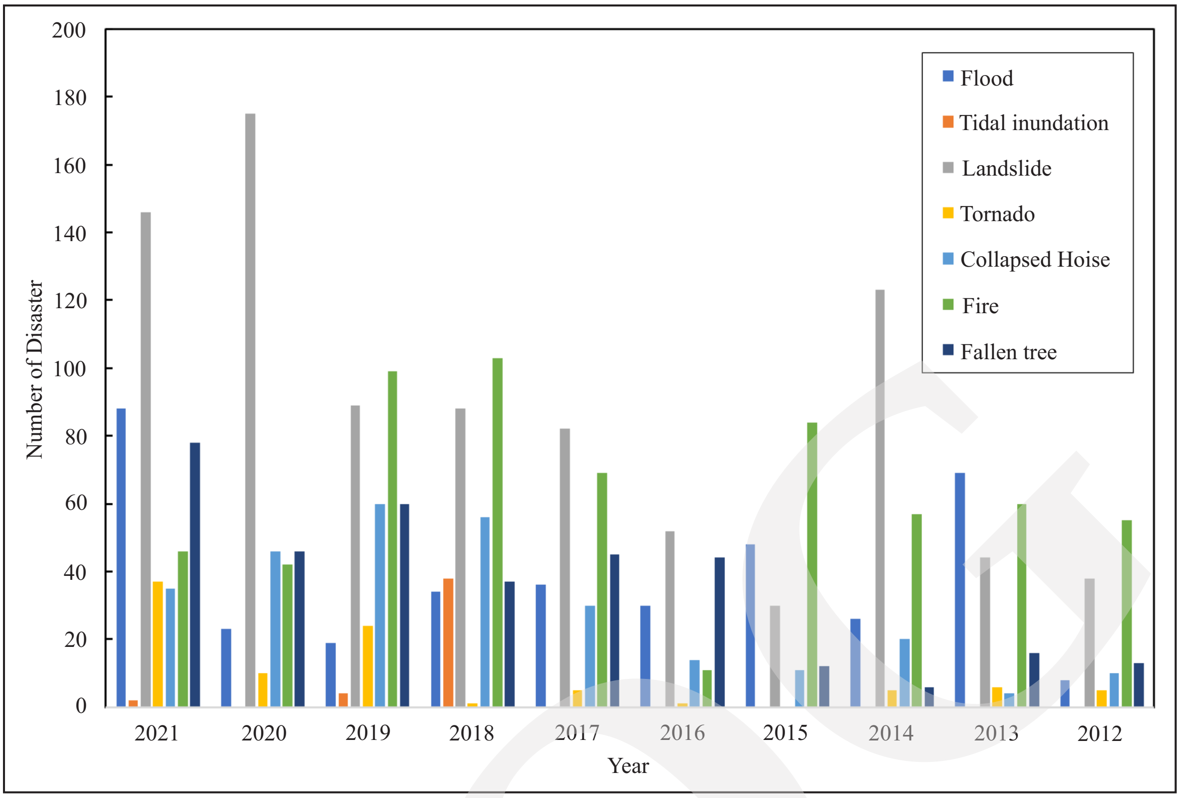

Figure 9. Disasters occurred in Semarang during the years 2012 - 2021.

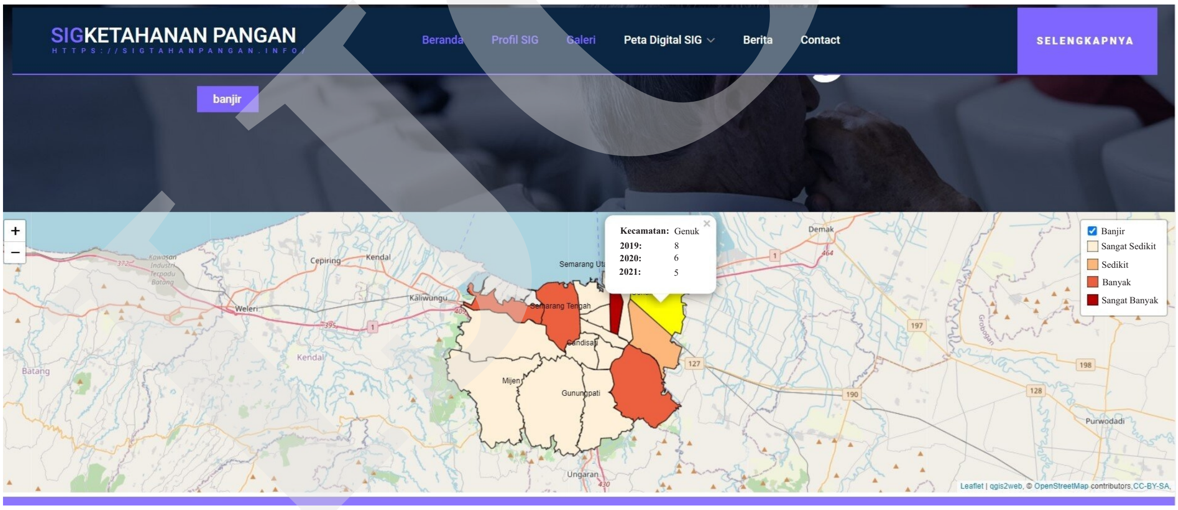

Figure 10. Map of the flood disasters area in Semarang City from 2019 through 2021.

Landslide in Semarang is a disaster with the highest frequency, which is 867 incidents (BPBD Semarang, 2022). Landslide is natural that can cause casualties, the loss of homes, and environmental damage. Landslides are not only caused by natural phenomena but also by human activities (Sudaryatno *et al.*, 2019). Heavy rainfall and earthquakes can trigger landslides (Hadi *et al.*, 2021). Several parameters that can be used in the analysis of landslide disasters are slope, elevation, distance from fault, distance from hydrology feature, distance from road, rainfall, and NDVI (Sudaryatno *et al.*, 2019).

Indonesia has a tropical climate that always brings rain every year. Indonesia is crossed by a plate subduction path, namely the crossing of the Eurasian, Pacific, and Australian Plates, which often cause earthquakes (Karnawati, 2005; Widiastutik and Buchori, 2018). The view GIS on this menu is on the image of each tab of the disaster menu in this web GIS: https://sigtahanpangan.info/semarang/longsor.html. This menu shows the landslide disaster in 2019 - 2021. The GIS map of the landslide disaster in Semarang City from 2019 to 2021 was visualized on the GIS Web "SIG Ketahanan Pangan" and is presented in Figure 11.

There were 626 fire disasters in Semarang in 2022 (BPBD Semarang, 2022). Fire is a disaster based on the cause of its occurrence and is classified as a natural disaster: lightning, earthquakes, volcanic eruptions, droughts, and others, as well as a non-natural disaster caused by human negligence: gas leaks, electrical short circuits, cigarette butts, sabotage, and the low level of the building construction safety system against fires (Nurwulandari, 2017).

Another disaster in this city was the fall of 357 trees (BPBD Semarang, 2022). Triggers for the occurrence of fallen trees include the load force received by the trunk or top of the tree exceeding its resistance capacity and the presence of sudden strong winds and/or rainwater falling on and storing in the tree canopy, which increased the load capacity.

Discussion

Disasters Mitigation

Flood

Floods are the most frequent disasters in Indonesia and have an impact on many parties (Pratiwi, 2022). It is very important for policymakers to know the characteristics of flood hazards in order to choose mitigation measures in the future (Purwitaningsih *et al.*, 2022). The rapid development of cities and changes in the characteristics of rain due to climate change cause flooding and inundation in rainy seasons (Sedyowati *et al.*, 2020). Communities benefit economically from drainage channels used for fish and vegetable cultivation. The current flood control project not only reduces the flood risk level by 30%, but also increases the resulting economic efficiency of the flood risk management system by up to 90% over the project of six-year effective life (Sedyowati *et al.*, 2020). To overcome these problems, the government of Semarang chose Banger Polder drainage system.

Indications of land subsidence in Semarang can be known from several data sources. Based on measurements and data, land subsidence in hilly areas of Semarang is smaller than that in coastal areas. From field observations, land subsidence in former swamps and ponds shows the largest decline, for example in Tanah Mas

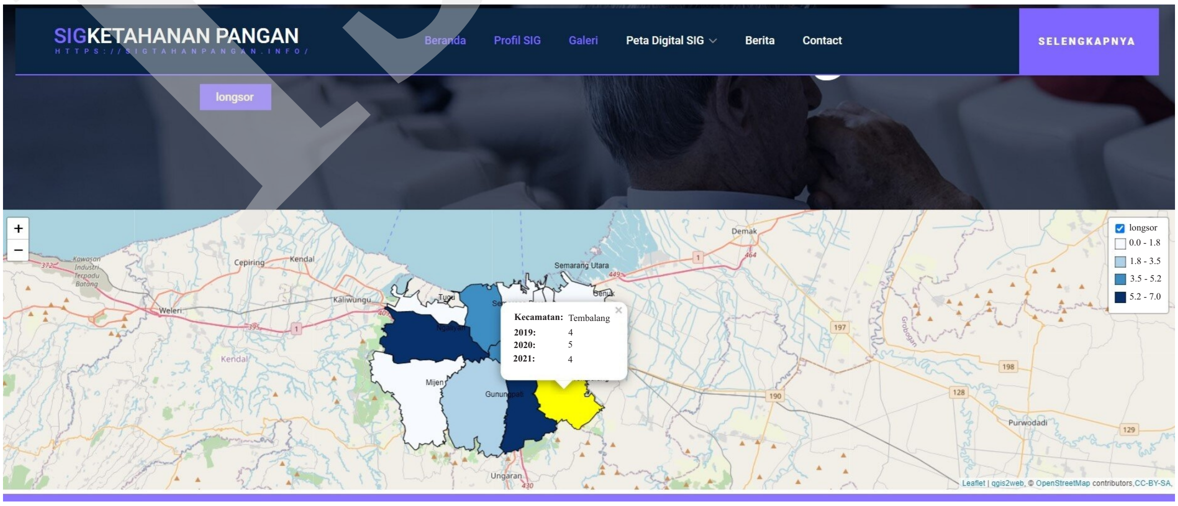

Figure 11. The GIS map of the landslide disasters in Semarang City from 2019 to 2021.

housing complex, Tanjung Mas Beach, with a decrease of between 5.5 and 7.23 cm per year (Ikhwanudin *et al.,* 2020). Another thing to do in disaster mitigation is to activate the EWS (Early Warning System). Effective and comprehensive management of disaster risk preparedness is necessary to protect lives, livelihoods, and to reduce the cost of disaster damage. This can be done by procuring EWS (Seng, 2013). According to the BBPD (2020), there were already fourteen EWS in Semarang in attempt to flood and landslide mitigation spread across fourteen villages, which are presented in Table 1.

Fire

Structural mitigation is related to the form of physical mitigation, namely the provision and construction of facilities and infrastructure. Meanwhile, nonstructural mitigation is related to the formulation of disaster management policies such as public commitment and implementation of methods and operations, including participatory mechanisms, information dissemination, and knowledge development, which should be carried out to reduce the disaster risk. Mitigation scenarios are through prevention, mitigation, preparedness, an early warning system, recovery, and development (Nurwulandari, 2017). The influence of this community capacity variable is very important in determining the risk of a fire disaster. Losses and casualties can be minimized by increasing community capacity (Januandari *et al.*, 2017). Fire mitigation can be accomplished through fire education and training, as well as an examination of active fire protection systems such as fire extinguishers, hydrants, sprinklers, and fire alarms. An analysis of life-saving also means: emergency stairs and exit signs (Karimah *et al.*, 2019).

Fallen Trees

Carrying out tree planting designs should pay attention to places that match the dimensions of tree growth; selecting the right tree species that can ensure their suitability at the planting location; selecting tree species that are native to the area; selecting appropriate plants that pay attention to the cultivation aspect; protecting trees from potential human damage; taking good care of trees (Sulistyantara, 2014), managing and monitoring trees at the risk of breaking or falling (Ningrum, 2020), planning and placing tree planting points through state analysis, pruning and cutting trees regularly (Aritama and Dharmadhiatmika, 2019).

Using Economic and Policy Systems

Several mitigations that can be done in an earthquake are allocating a specified pre-earth-

Table 1. Disaster Early Warning System in Semarang

No	Village	Subdistrict	Disaster EWS
1	Pudak Payung	Banyumanik	Flood
2	Bendan duwur	Gajahmungkur	Flood
3	Karangroto	Genuk	Flood
4	Jatibarang	Mijen	Flood
5	Wates	Ngaliyan	Flood
6	Wonosari	Ngaliyan	Flood
7	Mayangsari	Ngaliyan	Flood
8	Karangtempel	Semarang Timur	Flood
9	Meteseh	Tembalang	Flood
10	Mangkang Wetan	Tugu	Flood
11	Mangkang Kulon	Tugu	Flood
12	Plumbon	Tugu	Flood
13	Sukorejo	Gunungpati	Landslide
14	Kalipancur	Ngaliyan	Landslide

quake budget; minimizing the value of total cost; and minimizing the risk of a large loss (Dodo *et al.*, 2004). In addition to engineering methods, other mitigation actions that can be taken are increasing monitoring capacity and improving early warning by building more observation stations (Fang *et al.*, 2017). Institutional strengthening indicators and emergency response capability indicators according to Regulation of Government of The Republic of Indonesia Number 33 of 2006 have six indicators; infrastructure and utilities, strategic and important buildings, housing area and public facilities, buildings and industrial areas, school buildings, and flood-resistant buildings. The disaster management plan called a "Contingency Plan" is as a guide for what to do before and when the disaster occurs (Permanahadi and Widowati, 2022).

Using Information Technology

Markov chain algorithm is a method for generating the probability value of something with probability calculations. Markov chains are to make predictions with matrix values for seven natural disasters that occurred in the city of Semarang, with the prediction results in 2020 were 35% flood, 22% landslide, 3% tornado, 2% house collapse, 30% fire, and 8% fallen trees. Meanwhile, in 2021, the percentages of flood predictions were 22%, rob floods was 3%, landslides was 22%, tornadoes was 2%, houses collapsed was 8%, fire was 33%, and trees fell was 9% (Hidayati *et al.*, 2021). Another Information Technology used here is GIS: dimensions of flood security (Ujianti *et al.*, 2022), flood modeling which used a combination of GIS and fuzzy logic methods (Nugraha, 2018). GIS for disaster management was applied in Taiwan (Hsu *et al.*, 2005). The role of GIS in a natural disaster is in: prediction, mitigation, laws and government policies, findknowing out the impact on the biogeochemistry of the earth crust, and this role in 2004 was applied in earthquake management in India (Singh *et al.*, 2019). This technology is using garbage sorting games, DIFMOL, and ILMIZI for environmental disaster mitigation learning (Rahmayanti *et al.*, 2020), and using Google Earth Pro to learn media for mitigation and adaptation of a landslide disaster (Suharini *et al.*, 2020). In this research, GIS maps that visualized the number of disaster events in various subdistricts in the city of Semarang had already displayed in Figures 10 and 11.

Conclusions

The disasters that occurred in Semarang City in 2012–2021 were fires, fallen trees, floods, landslides, hurricanes, and collapsed houses. The most common disasters were landslides. Disaster mitigation is needed in general, specifically using information technology to predict future disasters, so that people understand how to prevent and prepare the coming disasters.

Acknowledgments

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