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Spatial Analysis of Flood Vulnerability and Retention Ponds

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Abstract

Flooding is one of the causes of environmental damage worldwide. Several things that can affect flooding in urban areas, Palembang experiences periodic flooding problems, especially every rainy season. The data in this article consists of primary data obtained from location surveys in retention ponds, including: documentation, topography, depth of retention ponds and secondary data from related agencies, including: location maps, climatology, regional topography. Palembang City has varying levels of flood vulnerability: high (Jakabaring, Kertapati, Plaju, and Seberang Ulu), medium (Ilir Barat and Sukarame), and low (Alang-Alang Lebar). Lowland areas with poor drainage systems require more attention. Retention ponds play an important role in managing rainwater runoff, such as the Jakabaring Sports Hall (200,000 m²), Ogan Permai Indah (22,217 m²), and Brimob Demang Lebar Daun (30,000 m²). The city's topography, which is mostly flat and low, especially around the Musi River, further increases the risk of flooding.

Introduction

Floods are one of the causes of environmental degradation worldwide (Islam & Afroz, 2025). Floods can impact communities, residents, and the natural environment as well as aquatic ecosystem services (Sibandze et al., 2024). Communities can experience socio-economic losses such as reduced productivity and environmental impacts such as inundation of property and critical infrastructure (e.g. power substations, bridges, and drainage systems) (Cea & Costabile, 2022; Deshmukh, 2010; Dharmarathne et al., 2024; Dawson et al., 2016). Floods are expected to become more frequent and more intense due to climate change, population growth, rapid urbanization, land-use changes, and increased coverage of impermeable surfaces in waterways. While floods are unavoidable events, they can be minimized by identifying flood-vulnerable areas and identifying high-risk areas for flooding (Liu et al., 2025; Subraelu et al., 2023). Flood occurrence is influenced by topographic, hydrometeorological, geological and soil factors. These factors are interrelated. Topography is an important control on the spatial distribution of hydrological landscapes (Adnyana et al., 2025; Gao et al., 2018; Güntner & Bronstert, 2004; Zhang et al., 2023).

Several things that can affect urban flooding, namely: increasing urban population so that there is a risk of changing green areas into watertight areas, climate change that causes more extreme rainfall (Feloni et al., 2022) and topographic conditions that affect hydrological phenomena

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(Fitra et al., 2024). Retention ponds are one of the reliable solutions to overcome flooding problems, overcome the rainy season, and create livable water-based urbanism (Siddiqua, 2020). This pond is also known as a wet detention pond (or preservation pond) as part of a drainage system designed to shape the contour of water flow during rainstorms and trap contaminated solid particles from runoff along highways, toll roads, and urban areas (Rae et al., 2019; Clark et al., 2010). Retention ponds are basins that capture runoff water that is moved from higher elevation areas to newly inhabited areas covered by newly constructed buildings, parking lots, and roads. Retention ponds are known as permanent ponds that allow sediment deposition and reduce pollutant concentrations (Miguez et al., 2015; Robotham et al., 2021; Stanley, 1996).

Palembang experiences periodic flooding problems, especially every rainy season as a result of reduced infiltration areas, climate change that causes hydrological changes in terms of peak discharge frequency and ebb and flow (Alia et al., 2023). Palembang City has a low and flat topography, and the height of the area is between 1.6 m + MSL and 36.0 m + MSL, with an average level between 3.0 m + MSL and 4.0 m + MSL. This condition indicates that areas below 3.7 m + MSL are areas that are vulnerable to flooding due to the high tide of the Musi River in the rainy season (Fariza et al., 2024). Based on the background above, the purpose of this article is Flood Vulnerability Mapping in Palembang City, Spatial Distribution of Retention Ponds in Palembang City, and Digital Elevation Model (DEM) Map of Palembang City.

Methods

A qualitative framework helps develop an online Posyandu information system for Payaman Village which seeks to enhance health service delivery to toddlers and elderly citizens. Qualitative methodology serves as the research strategy to deeply comprehend current health service processes alongside identifying Posyandu officers' challenges for developing an efficient and accurate data management system.

Data collection for the research occurred at Payaman Village Posyandu Lansia dan Balita through combined observational techniques with interviews as well as documentation study approaches. Direct monitoring of data collection activities and health recording for elderly patients and toddlers formed the basis of our observation process. The observation period let us uncover important information about how operations functioned while showing our attention to system flaws along with manual errors in present systems.

The study gathered information through interviews with both the Posyandu Head and village midwife in order to understand better the health monitoring processes and operational procedures. The interviews yielded qualitative data which revealed system requirements and user needs as well as healthcare worker expectations about digitalization practices. An investigation of documentation involved reviewing physical health records consisting of manual data entries as well as reports and registration logs. The research drew its theoretical elements from studies about digital health service management and health information systems and the influence of technology in community health services during a literature review.

System Development Method

The Waterfall Model served as the selected system development methodology because it consists of organized steps that follow one after the other. Each development phase must be finished to a high standard before continuing to the next step to produce accurate documentation throughout the process.

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The Waterfall Model implemented three main development phases for this research. At this stage researchers obtained necessary data through face-to-face interviews and direct observations to identify system requirements. The documentation process of user needs and system specifications confirmed that the new system would deliver efficient solutions to handle manual data recording weaknesses.

A thorough system design was developed after requirements had been properly identified. The development process included architectural definition work together with database modeling as well as user interface element specification. Online registration and real-time data integration received support from the combination of PHP and MySQL as the fundamental technological base. The development was conducted according to the specifications through separate testing of different programmed modules. Each module received unit testing before integration to ensure proper development and verification. The testing occurred for modules that included user management as well as health data entry and reporting features.

Testing of the developed system examined all functions alongside reliability mechanisms and precision operations. The testing process focused on verifying user authorization and authentication systems as well as data insertion functions together with reporting capabilities and user system access. The acceptance test involved Posyandu officers and midwives who evaluated if the system met their specifications. The system became operational at Payaman Village’s Posyandu after it passed all tests successfully. System maintenance procedures included both bug fixing and system update programs that relied on user input. The system underwent lifelong observation for maintaining its functionality while adapting effectively to upcoming enhancements.

Results and Discussion

Flood Vulnerability Mapping in Palembang City

Palembang experiences periodic flooding problems, especially during every rainy season, so it is necessary to identify flood zones. The flood vulnerability map (Figure 1) is a visual representation of the level of flood vulnerability with low, medium, to high flood risk levels. This information is very important as a reference in spatial planning, disaster risk management, and decision making related to flood mitigation in Palembang City.

The Flood Distribution Map of Palembang City shows the level of flood vulnerability in various regions based on low, medium, and high categories. Low flood vulnerability is marked with light beige, medium vulnerability with orange, and high vulnerability with red. Areas with low flood vulnerability include Sukarami and most of Alang-Alang Lebar. Zones with medium vulnerability include Kemuning, part of Kalidoni, Sako, and a small part of Bukit Kecil. Meanwhile, areas with high vulnerability are in Kertapati, Gandus, Seberang Ulu I, Seberang Ulu II, Jakabaring, and most of Plaju. Areas with high flood vulnerability are generally located near rivers or lowlands, while low zones tend to be in higher areas or have adequate drainage infrastructure. Elevation and slope also affect flood dynamics, with lowland areas (50-100 meters) and steep slopes (25-45%) being highly vulnerable to surface runoff and flash floods (Simanjuntak et al., 2024).

Elevation is an important factor controlling the geographical extent of flooded areas. It affects the intensity of runoff. Generally, water flows downwards due to gravity; rainfall collects in low-lying areas and thus areas with lower elevations are more prone to flooding (Hamidi et al., 2022). Elevation also affects the rate of water flow. The lowest area is at an altitude of 32 meters above sea level, while the highest area is at an altitude of 225 meters. The most crucial element that affects flooding is elevation. The overall relationship between elevation and flood

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occurrence: As elevation decreases, the frequency of flood occurrence increases (Purwanto et al., 2024). The distribution of flood-prone areas is mostly at a very low level with a percentage of more than 50% of the total area of Langkat Regency. Areas that are very vulnerable have physical characteristics close to rivers, flat slopes, fine soil texture, and high rainfall (Thoha et al., 2023). Retention ponds can collect stormwater runoff contaminants, which is not suitable for pollution-sensitive species and habitats in ecosystems and green spaces (such as parks, gardens, urban forests, landfills).

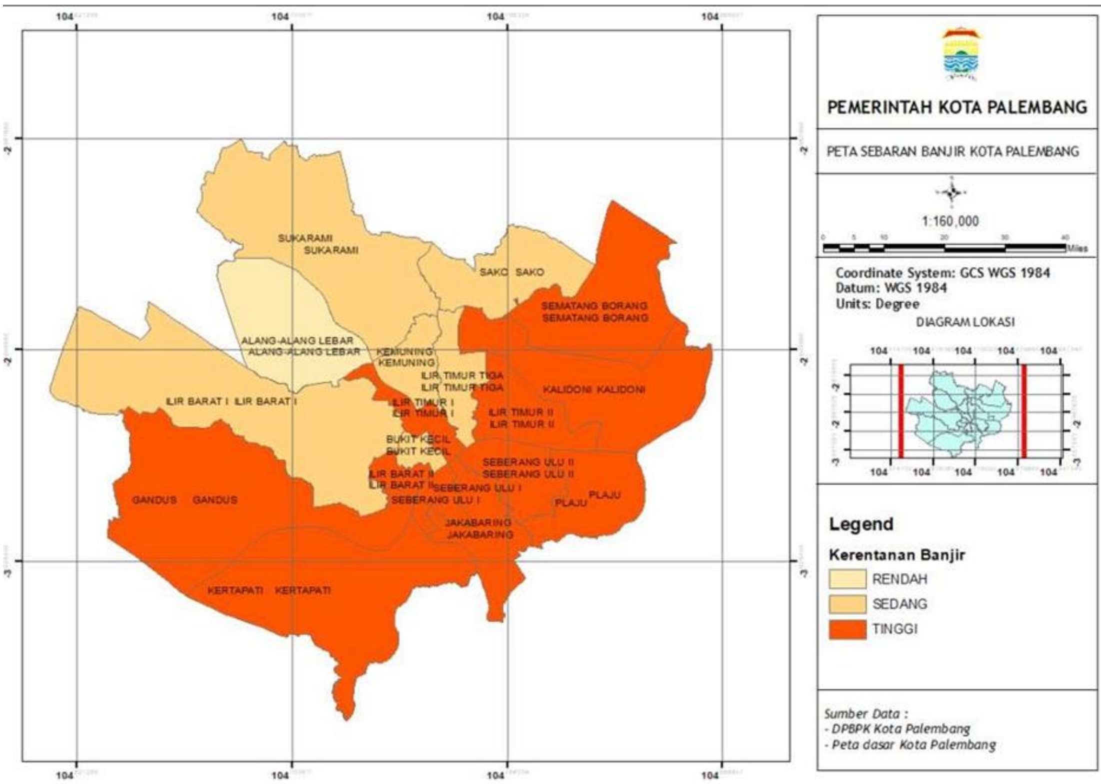

Figure 1. Flood Vulnerability Map of Palembang City

Spatial Distribution of Retention Ponds in Palembang City

Retention ponds offer water quality and flood control through natural processes and provide the most effective stormwater treatment to remove the total mass of pollutants from heavy rainfall (Che et al., 2014). Although designed as stormwater control (SCM) systems to collect polluted runoff, stormwater ponds in parks and residential developments are often considered and marketed as aesthetic water features (Grogan et al., 2023; Collins et al., 2010).

The distribution of retention pond points is strategic in various areas. In the west and southwest near green areas, retention ponds help manage rainwater (Hosseinzadeh et al., 2023; Oertli & Parris, 2019). In the densely populated central area, retention ponds function to control water runoff due to the lack of soil absorption capacity. Points near large rivers hold back potential flooding, while points in the east are likely to be around agricultural land or industrial areas to prevent inundation and maintain environmental quality.

The Water Safety Plan (WSP) supports sustainable development and construction synergistically. The main principle of WSP is to replace open spaces according to the natural hydrogeographic layout in the natural flow system through rainwater retention and detention. Open spaces have different roles and functions in the city (including air fresheners, rainwater receivers, flood mitigation, runoff infiltration, recreational activities, etc.); therefore, open

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spaces have various shapes and sizes ranging from private yards to large parks (Keyvanfar et al., 2021). The construction of new buildings through private land developers, real estate businesses by filling water bodies results in a reduction in water retention areas, so that the city loses storm water storage capacity and increases the extent of flooding due to waterlogging (Siddiqua, 2020).

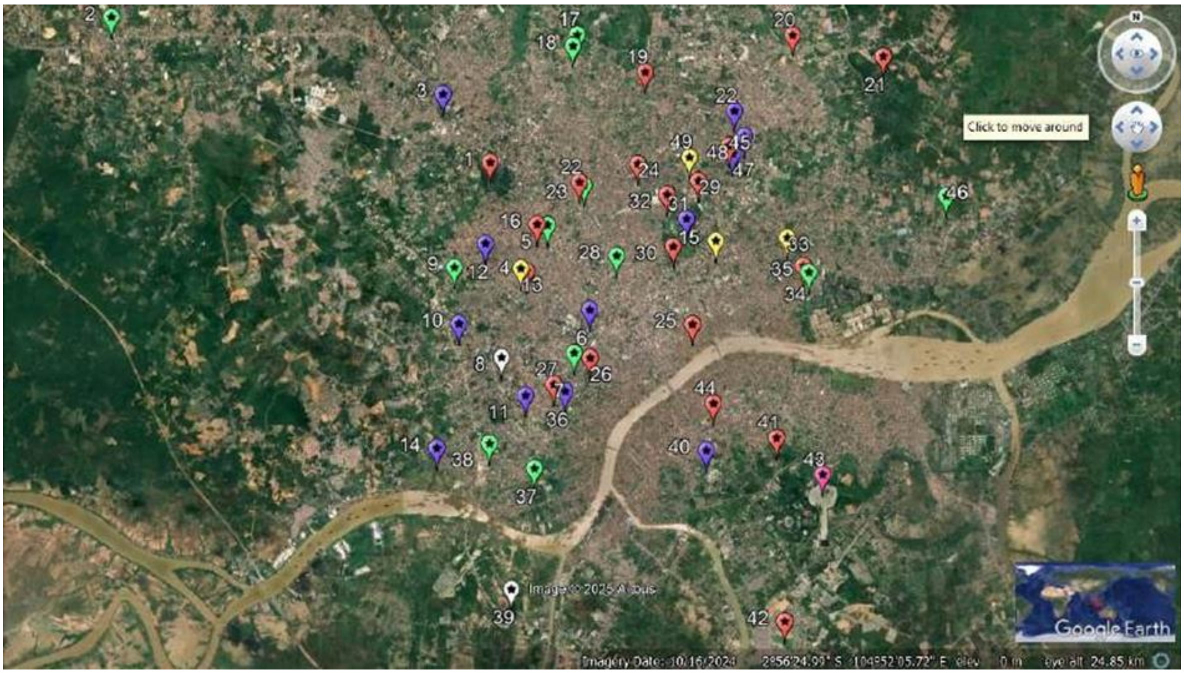

Figure 2. Map of Retention Pond Locations in Palembang City

For a pond to successfully reduce peak flows, this delay time must match the sum of the total delay time of the pond to discharge water to the adjacent watercourse plus the flood wave travel time from this location to the outlet. For the Lower pond, the flood wave travel time from the adjacent river channel to the catchment outlet is too short, and in most cases, when the peak flow is at the catchment outlet, the pond releases water stored during rainfall and thus increases the flow (Birkinshaw & Krivtsov, 2022).

Table 1. Spatial Distribution of Retention Ponds in Palembang City

Pin Color	Pin Numbers	Area (m²)
Pink	43	> 200.000
White	8, 39	30 – 80
Red	1, 4, 7, 16, 19, 20, 21, 22, 24, 25, 26, 29, 30, 32, 34, 41, 42, 44, 45	10 – 30
Green	2, 5, 9, 17, 18, 23, 27, 28, 35, 37, 38, 46	5 – 10
Blue	3, 6, 10, 11, 12, 14, 31, 36, 40, 47, 48, 50	1 – 5
Yellow	13, 15, 33, 49	< 1

This data illustrates the grouping of pins by color that represents the variation in area. The pink pin is only found at number 43, covering an area of more than 200,000 m², making it the largest in this data. The white pins consisting of numbers 8 and 39 have an area of between 30 and 80 m². Furthermore, the most dominant red pins with numbers 1, 4, 7, 16, 19, 20, 21, 22, 24, 25, 26, 29, 30, 32, 34, 41, 42, 44, and 45 cover an area of10 to 30 m². The green pins including numbers 2, 5, 9, 17, 18, 23, 27, 28, 35, 37, 38, and 46 have an area of between 5 and 10 m².

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Meanwhile, the blue pins covering numbers 3, 6, 10, 11, 12, 14, 31, 36, 40, 47, 48, and 50 cover areas between 1 and 5 m². Finally, the yellow pins with numbers 13, 15, 33, and 49 cover the smallest areas with an area of less than 1 m². These data show significant variations in area, from very small to very large.

Retention ponds are an effective stormwater management technique, especially as part of Low Impact Development practices. This technique can significantly reduce runoff volume and is studied for its treatment efficiency, resilience to climate change, sediment management, and effectiveness of runoff reduction (Hidayah et al., 2024).

Table 2. Area and Depth of Retention Ponds in Palembang City

Level	Sub-District	No	Retention Pond	Area (m²)	Depth (m)
Low	Alang-Alang Lebar	1	Punti Kayu	10.000	1-1,5
		2	Talang Kelapa	8.070	1,5-3
		3	Raflesia	3.000	
Moderate	Ilir Barat I	4	Siti Khadijah	11.085	0,8-1,5
		5	Simpang Polda	5.655	0,8-1,5
		6	Sport Hall	4.070	0,8-1,5
		7	Kemang Manis	12.000	2,5-3
		8	Brimob Jln. Demang Lebar Daun	30.000	4
		9	SMP 22 Pakjo	8.000	4
		10	Kancil Putih	3.125	2
		11	SDN 3 Palembang	2.000	4
		12	MAN 3 Palembang	1.250	4
		13	Nissan Jln. Demang Lebar Daun	448	1,5-2
		14	Lambidaro	1.700	3
		15	Sumur Tinggi	800	
	Sukarame	16	Ario Kemuning	16.267	0,8-1,5
		17	Griya Buana Indah	6.000	1,5-2
		18	Waduk RC	6.461	-
		19	Sukawinatan	11.245	-
	Sako	20	Sangkuriang	12.000	2,5-3
		21	Bumi Nusa Cendana	14.000	2,5-3
	Kemuning	22	Talang Aman I	16.898	0,8-1,5
		23	Talang Aman II	5.202	0,8-1,5
		24	Senduduk Putih	22.590	0,8-1,5
	Ilir Timur III	25	Sungai Bendung Jln. Ali Gatmir	15.000	4
	Bukit Kecil	26	Kambang Iwak Besak	22.126	2
		27	Kambang Iwak Kecil	7.886	0,8-1,5
Hight	Ilir Timur I	28	RSMH	8.091	-
	Ilir Timur II	29	Simpang Patal Pusri (Kolam Kiwal)	21.000	0,8-1,5
		30	IBA	12.037	0,8-1,5
		31	Lapangan Golf	2.000	2-3
		32	Pertamina Golf	15.000	2-3

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		33	Telkom (Lemabang)	687	-
		34	Arafuru I	11.649	-
		35	Arafuru II	6.340	-
	Ilir Barat II	36	Tanjung Burung	2.680	-
	Gandus	37	Taman Purbakala	5.393	0,8-1,5
		38	Poligon	7.000	3-4

In the low category, retention ponds are spread across Alang-Alang Lebar District with a total of three locations, namely Punti Kayu (area 10,000 m², depth 1-1.5 m), Talang Kelapa (area 8,070 m², depth 1.5-3 m), and Raflesia (area 3,000 m² without depth information). For the moderate category, retention ponds are spread across various districts. In Ilir Barat I District, there are ponds such as Siti Khadijah (area 11,085 m², depth 0.8-1.5 m), Simpang Polda (5,655 m²), and Kemang Manis (12,000 m², depth 2.5-3 m). The largest location in this district is Brimob Jln. Demang Lebar Daun (30,000 m², depth 4 m). Sukarame District has the Ario Kemuning pond (16,267 m²) and Griya Buana Indah (6,000 m²). Sako and Kemuning Districts also have several ponds, including Sangkuriang (12,000 m²) and Talang Aman I and II. Ilir Timur III District has the Sungai Bendung pond on Jln. Ali Gatmir with an area of 15,000 m² and a depth of up to 4 m. In the high-level category, retention ponds are found in several locations such as Ilir Timur I, II, and Jakabaring Districts. The largest pond in this category is the Jakabaring GOR (200,000 m², depth 3-5 m). In Ilir Timur II, there are ponds such as Simpang Patal Pusri (21,000 m²) and Pertamina Golf (15,000 m²). Gandus District has a Polygon pond (7,000 m², depth 3-4 m), while Kertapati District has the largest pond, namely the Keramasan Integrated New Area (70,036.8 m²). Kalidoni District has several ponds, including Kedamaian (15,000 m², depth 2-3 m) and SMP 37 (7,500 m²).

Retention ponds are one of the methods used to overcome flooding, but the presence of retention ponds does not guarantee that the area is free from flooding, so it is necessary to see the effectiveness of retention ponds in controlling flooding (Juliandar, 2021). This shows the importance of evaluating and planning retention systems to reduce flood risk and provide a more reliable water source for the campus. Reducing flood flow in the Unsam environment will have a long-term positive impact, such as reducing the risk of property damage due to waterlogging, which can reduce the cost of maintaining and repairing campus infrastructure (Irwansyah et al., 2024).

Map of Digital Elevation Model (DEM) Palembang City

The existence of retention ponds in Palembang City plays an important role in managing rainwater runoff, preventing flooding, and stabilizing the city's water system which is dominated by lowlands. Based on the Digital Elevation Model (DEM) map, most areas of Palembang City are at low elevation, with relatively flat topographic contours, especially around the Musi River and its tributaries. This topographic condition makes Palembang vulnerable to waterlogging when heavy rain occurs, especially in the eastern and southern areas of the city.

The flood vulnerability map shows that areas with a high risk of flooding include areas such as Jakabaring, Kertapati, Plaju, and Seberang Ulu. These areas are located in lowlands with inadequate drainage systems. The existence of retention ponds such as in the Jakabaring Sports Hall (200,000 m² with a depth of 3-5 m), Ogan Permai Indah (22,217 m² with a depth of 3-5 m), and Silaberanti is very important in reducing the impact of inundation and accommodating water flow from high rainfall. In areas with a moderate risk of flooding such as Ilir Barat and Sukarame, retention ponds such as Brimob Demang Lebar Daun (30,000 m², 4 m depth) and

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Kemang Manis (12,000 m², 2.5-3 m depth) help prevent inundation that can occur due to limited urban drainage. In addition, the Sukarame area also utilizes the Ario Kemuning retention pond (16,267 m²) to manage water runoff. In areas with low flood risk such as Alang-Alang Lebar, retention ponds such as Punti Kayu (10,000 m²) and Talang Kelapa (8,070 m²) are still needed to anticipate changes in rainfall patterns and urbanization that can accelerate surface water flow.

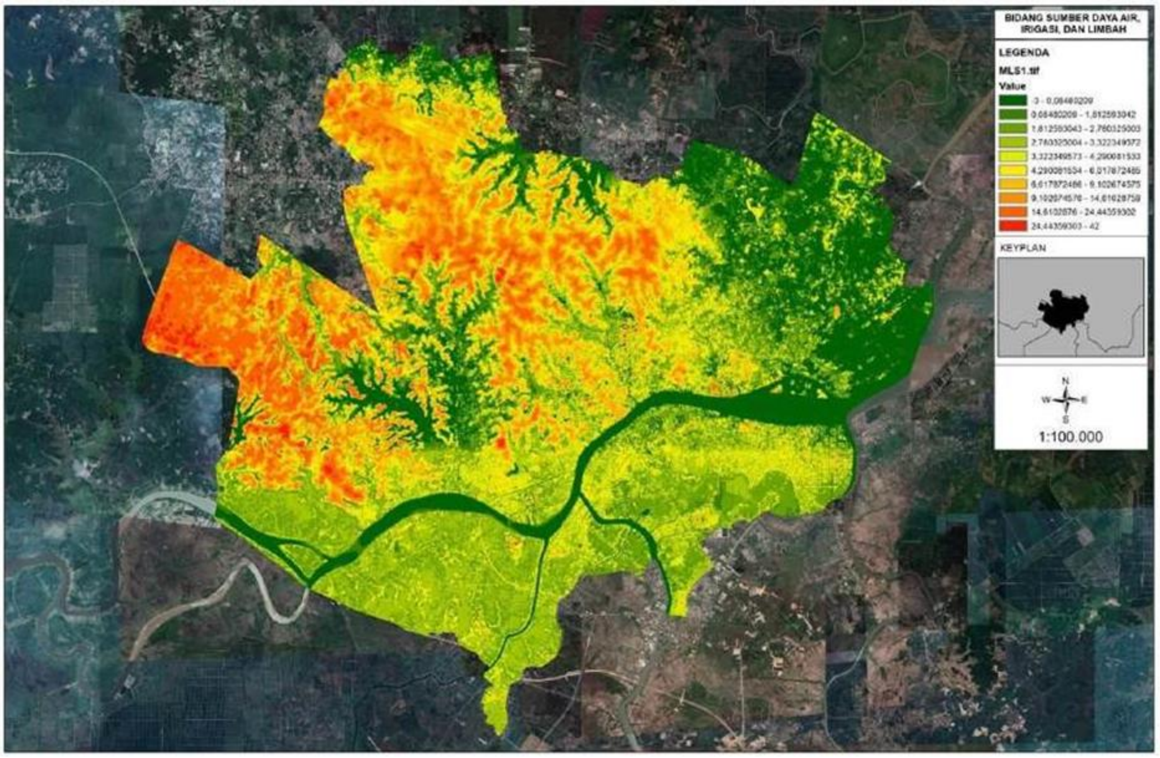

Figure 3. Digital Elevation Model (DEM) Map of Palembang City

Overall, the existence of retention ponds in various areas of Palembang City is in line with the need for flood risk management based on topographic and elevation conditions seen on the DEM map. With the presence of retention ponds strategically distributed, the risk of flooding can be minimized, both in areas with low and medium elevations. However, maintenance and optimization of the capacity of the retention ponds are needed so that their function remains effective in dealing with increasingly extreme weather changes. Recovery efforts that shorten the hydrological distance and distance to the groundwater table, such as the removal of artificial embankments or reconstruction of side channels, may have a positive effect not only on single functions, but also on the multifunctionality of the ecosystem as a whole (Sendek et al., 2021). Water Safety Plan (WSP) can manage rainwater in open spaces by functioning as a landscape element or for irrigation purposes (Keyvanfar et al., 2021).

Conclusion

Palembang City with high flood vulnerability such as Jakabaring, Kertapati, Plaju, and Seberang Ulu requires special attention because it is located in the lowlands. Zones with moderate vulnerability are in Ilir Barat and Sukarame, while areas with low vulnerability such as Alang-Alang Lebar have higher topographic conditions and adequate drainage infrastructure. Retention ponds are strategically spread across various sub-districts and play an important role in managing rainwater runoff, stabilizing water systems, and preventing flooding. The largest retention pond is at the Jakabaring Sports Hall with an area of 200,000

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m² and a depth of 3-5 meters. Areas with high flood risk utilize large retention ponds such as Ogan Permai Indah (22,217 m²) and Silaberanti to reduce the impact of inundation. In medium and low risk zones, ponds such as Brimob Demang Lebar Daun (30,000 m²) and Punti Kayu (10,000 m²) are still needed to maintain the stability of the water system. Based on the Digital Elevation Model (DEM) map, most of Palembang City is at low elevation with flat topographic contours. This condition makes the city vulnerable to flooding, especially around the Musi River and its tributaries.

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