Flood Risk Assessment and Mitigation Strategies for the Sinjai and Tangka River Catchments in Indonesia using Hydraulic Modeling and Spatial Analysis

Riswal Karamma
Civil Engineering Department, Faculty of Engineering, Hasanuddin University, Gowa, Indonesia
riswalk@unhas.ac.id (corresponding author)

Sugiarto Badaruddin
Civil Engineering Department, Faculty of Engineering, State Polytechnic of Ujung Pandang, Makassar, Indonesia
sugibadaruddin@poliupg.ac.id

Muhammad Rifaldi Mustamin
Civil Engineering Department, Faculty of Engineering, State Polytechnic of Ujung Pandang, Makassar, Indonesia
rifaldi.mustamin@poliupg.ac.id

Muhammad Ihsan Mukrim
Civil Engineering Department, Faculty of Engineering, Sekolah Tinggi Teknik Baramuli, Pinrang, Indonesia
muhammadihsan@alumni.ait.asia

Received: 7 December 2024 | Revised: 6 January 2025 | Accepted: 11 January 2025

ABSTRACT

This study aims to address the persistent flooding in Sinjai District, Indonesia, by developing a comprehensive spatial flood risk model. The development of this model was conducted using hazard, vulnerability, and capacity index data. The research first determines the weighted scores of the hazard, vulnerability, and capacity indices to categorize areas into high, medium, and low flood risk zones as a reference in developing flood mitigation. The study further uses the Unmanned Aerial Vehicle (UAV) technology to facilitate the collection of topographic data, which are then used as an input in the hydrological and hydraulic analysis. The overarching objective of this research is to provide insights and recommendations to policymakers, with the aim of informing effective strategies for reducing the flood risk. The results indicate that low-risk areas encompass 564.45 hectares, medium-risk areas extend to 645.83 hectares, and high-risk areas cover 46.19 hectares. The proposed flood control measures include the construction of retention ponds, embankments, and river normalization. These interventions have the potential to reduce up to 507.12 hectares, equivalent to 40.36% of the inundation area, thereby reducing the impact of flooding. The findings provide important guidance for policymakers in making decisions, devising mitigation strategies, and promoting sustainable development in the region.

Keywords-flood risk reduction strategy; Sinjai district; Sinjai River; Tangka River

I. INTRODUCTION

Flooding constitutes a persistent issue in Indonesia, particularly within urban areas, attributable to a combination of natural and human-induced factors. This phenomenon results in substantial consequences, including loss of life, environmental degradation, property destruction, psychological distress, and increased poverty [1, 2]. Addressing this issue necessitates a multifaceted approach that incorporates reactive measures and anticipatory strategies. The reactive measures include risk assessments and prevention, leveraging technology to analyze flood data [3]. The Sinjai Regency, a region of particular concern, has been subject to recurrent flooding, primarily due to the confluence of heavy rainfall and high tides, which have had a significant impact on urban areas, such as Biringere, Balangnipa, Bongki, Lappa, and Panaikang [4]. The region's vulnerability is attributed to its geographical position between the Sinjai and Tangka rivers [5]. An effective flood management strategy employs a Disaster Risk Reduction (DRR) framework, focusing on threats, vulnerabilities, and capacities [6, 7]. The usage of the UAVs technology for spatial risk modeling offers a promising approach, providing high-resolution data and efficient coverage [8]. Technologies such as UAVs or drones have become increasingly common for generating high-quality topographic data, which can be then used in hydraulic modeling to create more accurate Digital Elevation Models (DEMs). The integration of hydraulic modeling and spatial analysis facilitates the identification of areas with varying levels of flood risk, thereby enabling the design and implementation of effective mitigation measures. The objective of this research is to develop a spatial flood risk model for the Sinjai and Tangka watersheds. This will be achieved through hydraulic modeling and spatial analysis, using topographic data generated by UAVs. The study will map flood-prone areas and evaluate the effectiveness of proposed mitigation strategies, such as the levee construction, retention ponds, and river normalization. The findings of this study are anticipated to offer insights and recommendations to policymakers, with the objective of formulating more effective and sustainable strategies for reducing flood risk in the Sinjai region and analogous areas. Furthermore, the study will delve into the policy ramifications of the findings. Recognizing the importance of a comprehensive policy approach to flood management, this study will examine how hydraulic modeling outcomes can support the development of flood risk management policies in Indonesia. Policies that integrate both structural and non-structural solutions, such as sustainable land use management and enhancing community capacity to respond to disasters, are essential for mitigating future flood impacts.

II. MATERIALS AND METHODOLOGY

A. *Research Location*

This study employs a watershed-based approach, with a focus on the Sinjai and Tangka watersheds, which are frequently subjected to flooding that impacts Sinjai's urban areas. The selection of these locations was driven by the necessity to formulate integrated water resource management strategies that span from upstream to downstream, thereby transcending administrative boundaries, given the fact that the Tangka watershed encompasses the Gowa, Sinjai, and Bone regencies as shown in Figure 1. A comprehensive array of data sources was compiled for this study, encompassing contributions from NASA, the Pompengan Jeneberang River Basin Agency, and the Geospatial Information Agency. The satellite rainfall data from NASA's TRMM, the soil data from the river basin agency, and the DEMNAS topographic and spatial land use data were utilized in the analysis. The integration of primary data, including river topography and site conditions, further ensured the development of a spatial flood risk model for Sinjai District, thus enhancing the model's accuracy and reliability.

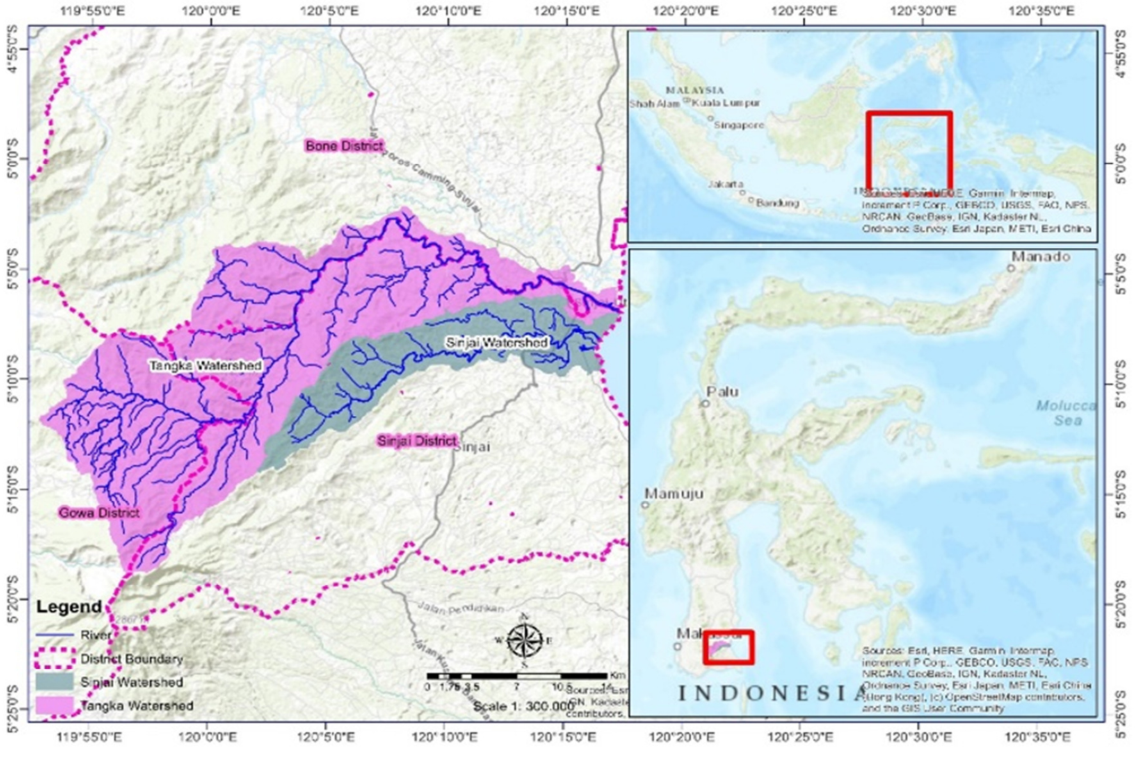


Fig. 1. Location of research watersheds.

B. Analysis of Aerial Photo Survey

The process of mapping river landscapes using UAVs encompasses five distinct stages. Initially, a survey of the mapping site was conducted. Subsequent to this preliminary stage, pre-flight fieldwork was initiated, encompassing the establishment of Ground Control Points (GCP) and the verification of UAV functionality. The third stage involved UAV flight missions to capture river landscape data, followed by quality checks to ensure accuracy [9]. Finally, the data were processed into topographic information and integrated with DEMNAS for broader coverage, serving as input for the Hydrologic Engineering Center River Analysis System (HEC-RAS) terrain analysis to enhance flood risk assessments.

C. Hydrological Analysis using the Soil Conservation Service Synthetic Unit Hydrograph (SCS-SUH) Method

This analysis employs precipitation and topographical data from pertinent institutions to ascertain the design flood discharge. The hydrological analysis integrates rainfall intensity, topography, soil infiltration, and land use patterns [10]. The study employs the SCS unit hydrograph method via HEC-HMS to calculate the influence of soil and land use [1]:

$$U_p = C\frac{A}{T_p} \tag{1}$$

$$T_p = \frac{\Delta t}{2} + t_{lag} \tag{2}$$

$$t_p = 0.6 \cdot t_c \tag{3}$$

$$t_c = \left(\frac{0.87 \times L^2}{1000 \times S}\right)^{0,385} \tag{4}$$

For the Sinjai and Tangka rivers, simulations evaluated the existing and proposed conditions to handle a 20-year flood return period [11]. These simulations assess the effectiveness of the current measures and proposed interventions, enhancing the flood dynamics understanding and supporting robust risk management strategies for the Sinjai district.

D. Analysis of Hydraulic and Flood Propagation using HEC-RAS Application

For the purposes of this analysis, essential data includetopographic cross-sections, derived from a combination of river cross-section measurements and DEM data, along with flood discharge data representing a 20-year return period. Subsequent to the procurement of these datasets, comprising river cross-sections and planned flood discharge information, the data were entered into the HEC-RAS application for a computational analysis. The HEC-RAS run produced valuable outcomes, revealing the distribution of the flood and the corresponding water levels. These results served as a pivotal reference point for the subsequent development of flood risk reduction strategies.

E. Development of Spatial Flood Risk Model

The development of a spatial flood disaster risk model is conducted using threat/hazard levels, vulnerability data, and capacity index:

$$R = \frac{H \times V}{C} \tag{5}$$

where R is the risk, H is the hazard, V is the vulnerability, and C is the capacity. This study employs a spatial model for data processing and analysis, converting hazard, vulnerability, and flood risk reduction capacity data into spatial data. The method for developing the flood disaster risk model is presented in Figure 2.

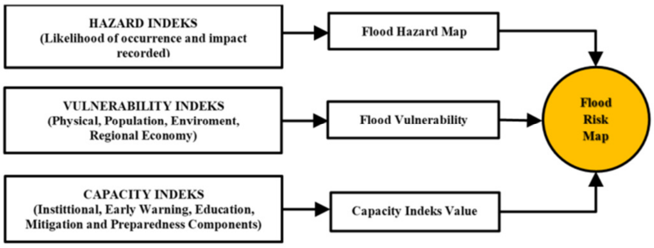


Fig. 2. Method for developing the flood risk map.

The disaster hazard index is developed based on two factors: the likelihood of an event occurring and the impact that has been previously recorded. In this study, the results of flood inundation simulations, validated with field incident data, are used as the basis for developing the hazard index. The classification of the hazard levels is presented in Table I.

TABLE I. COMPONENTS OF FLOOD DISASTER RISK INDEX

Indicator Components	Depth (m)	Class	Number in Grid
Map of flood-prone areas (validated by occurrence data)	<0.76	Low	1
	0.76 – 1.5	Moderate	2
	>1.5	High	3

The information sources utilized in the vulnerability analysis include reports from the Badan Pusat Statistik (BPS) and base map information from the Badan Informasi Geospasial (BIG) of Indonesia. The data collected from the BPS encompass socio-economic data, while the data from BIG incorporate land use, road networks, and the locations of public facilities. The variables constituting the vulnerability index analysis are illustrated in Table II. The calculation of the capacity index is based on the indicators outlined in the Hyogo Framework for Action (HFA). The HFA indicators include the following: institutional disaster management regulations, early warning and disaster risk assessment, disaster education, reduction of underlying risk factors, and preparedness development across all sectors. Each of the aforementioned indicators is assigned a weight of 1, and the specific indicators and their respective weights can be found in Table III. The classification of the capacity index is shown in Table IV. As portrayed in Figure 3, the process of risk calculation in the form of spatial data and flood risk classification can be observed. The calculated spatial risk data are subsequently classified into three categories using the equal interval criteria, as outlined in Table V.

F. Formulation of Flood Risk Reduction Strategies

Once areas susceptible to flooding have been identified through modeling, the subsequent imperative in minimizing the impact of floods in Sinjai Regency involves the implementation of structural flood control measures.

TABLE II. VULNERABILITY INDEX ANALYSIS VARIABLES

Types of Vulnerability	Variable	Weight	Score	Classification	Description
Physical	Built-up Area (Ha)	0.023	1	< 10	Built-up area in each sub-district
			2	10 – 20	
			3	> 20	
	Road network ratio (%)	0.112	1	< 30	Length of flooded roads/total length of roads in a sub-district
			2	30 – 60	
			3	> 60	
Population	Population density (person/ha)	0.575	1	< 10	Population number in each sub-district
			2	10 – 25	
			3	> 25	
Environment	Land use types	0.054	1	Mangrove, vacant land, swamp, and green open space	Land use analysis
			2	Tourism areas, ports, landfills, rice fields, and fish ponds	
			3	Residential areas, public facilities, services, cultural heritage sites, industries, and roads	
Regional economy	Land use types	0.236	0	Open area, water body	Land use analysis
			1	Forests, bushes, residential area, mangroves, swamps	
			2	Wet rice fields, dry rice fields, orchards/plantations	

TABLE III. CAPACITY INDICATORS

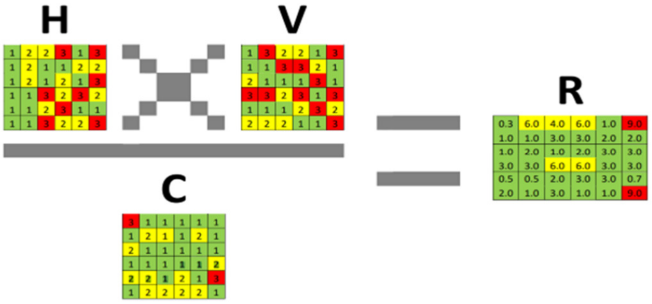
No.	Parameter	Performance Indicator	Weight
1	Institutional disaster management regulations.	The legal framework and national/local policies for DRR are already in place, with explicit responsibilities assigned to all levels of government.	1
		The availability of resources allocated specifically for DRR at all levels of government.	1
		The occurrence of community participation and decentralization through the distribution of authority and resources at the local level.	1
		The functioning of regional forums/networks specifically for DRR.	1
2	Early warning and disaster risk assessment.	The availability of regional disaster risk assessments based on hazard and vulnerability data, covering risks to key sectors in the region.	1
		The availability of systems ready to monitor, archive, and disseminate data on potential disasters and key vulnerabilities.	1
		The availability of a ready-to-operate early warning system for large-scale events, with a wide reach across all segments of society.	1
		Regional risk assessments consider cross-boundary risks to foster cooperation between regions in DRR.	1
3	Disaster education.	The availability of relevant disaster information accessible at all levels by stakeholders (through networks, development of systems for information sharing, etc.).	1
		School curricula, educational materials, and training programs that include concepts and practices related to DRR and recovery.	1
		The availability of research methods for multi-hazard studies and cost-benefit analysis, which are continuously developed based on the quality of research outcomes.	1
		The implementation of strategies to build awareness across the entire community in practicing disaster-resilient cultural practices that can reach a wide population, both in urban and rural areas.	1
4	Reduction of underlying risk factors.	DRR is one of the goals of policies and plans related to the environment, including natural resource management, land use planning, and climate change adaptation.	1
		Social development plans and policies are implemented to reduce the vulnerability of populations most at risk of disaster impacts.	1
		Sectoral plans and policies in the fields of economics and production have been implemented to reduce the vulnerability of economic activities.	1
		Urban planning and management incorporate elements of building design for public safety and health.	1
		DRR measures are integrated into post-disaster rehabilitation and recovery processes.	1
		The availability of procedures to assess the impacts of disaster risks or large-scale development projects, particularly infrastructure.	1
5	Development of preparedness across all sectors.	The availability of policies, institutional technical capacity, and strong disaster emergency response mechanisms, with aDRR perspective in their implementation.	1
		The availability of contingency plans for potential disasters, ready at all levels of government, with regular drills conducted to test and develop disaster response programs.	1
		The availability of financial and logistical reserves, as well as anticipatory mechanisms, ready to support effective emergency response efforts and post-disaster recovery.	1
		The availability of relevant procedures for conducting post-disaster reviews of the exchange of relevant information during the emergency response phase.	1

These measures, which include the construction of embankments, river normalization, and retention ponds, are designed to shield and mitigate the consequences of floods resulting from the overflow of the Sinjai and Tangka Rivers.

The strategic implementation of these structural interventions was predicated on enhancing the region's resilience to flooding, safeguarding communities and infrastructure, and reducing the overall impact of flood events. This proactive approach is consistent with comprehensive flood risk reduction strategies, thereby contributing to a more secure and sustainable environment in Sinjai regency. Using all the aforementioned activities, a flowchart can be created for further analysis, as shown in Figure 4.

TABLE IV. CAPACITY INDEX CLASSIFICATION

No.	Range of Indicator Achievement Values (%)	Capacity Index Classes	Number in grid
1	< 55	Low	1
2	55 – 85	Moderate	2
3	> 85	High	3



H

1	2	2	3	1	3
1	2	1	1	2	2
1	2	1	2	1	3
1	1	3	2	3	2
1	1	2	3	1	1
1	1	3	2	2	3

V

1	3	2	2	1	3
1	1	3	3	2	1
2	1	1	1	3	1
3	3	2	3	1	3
1	1	1	2	3	2
2	2	2	1	1	3

C

3	1	1	1	1	1
1	2	1	1	2	1
2	1	1	1	1	1
1	1	1	1	1	2
2	2	1	2	1	3
1	2	2	2	2	1

R

0.3	6.0	4.0	6.0	1.0	9.0
1.0	1.0	3.0	3.0	2.0	2.0
1.0	2.0	1.0	2.0	3.0	3.0
3.0	3.0	6.0	6.0	3.0	3.0
0.5	0.5	2.0	3.0	3.0	0.7
2.0	1.0	3.0	1.0	1.0	9.0

Fig. 3. Flood risk calculation in the form of spatial data.

TABLE V. FLOOD RISK CLASSIFICATION

No.	Flood Risk Class	Number in grid
1	Low	0.3 – 3.3
2	Moderate	3.3 – 6.3
3	High	> 6.3

III. RESULTS AND DISCUSSION

A. *Topographic Analysis*

The topographic survey, which employs UAVs or drones, constitutes a crucial component of flood control and management studies. It represents a significant element of the 2D numerical model simulation process, which is responsible for delineating flood-affected areas and determining optimal flood control measures. The data processing and quality check were carried out using the Agisoft Photo Scan Professional Version 1.4.1 software. The data processing workflow was initiated with the reconstruction of the flight path, the alignment of photographs, the input of GCPs, the construction of dense point clouds, the generation of DEM, and the production of orthophotographs. The resulting dataset comprised both raster data, including TIF files of aerial photographs and the DEM, and vector data, such as points, lines, polygons, and objects. To expand the coverage of the topographic area, in addition to the data obtained from drone measurements, DEMNAS was combined and corrected according to the drone topographic processing results.

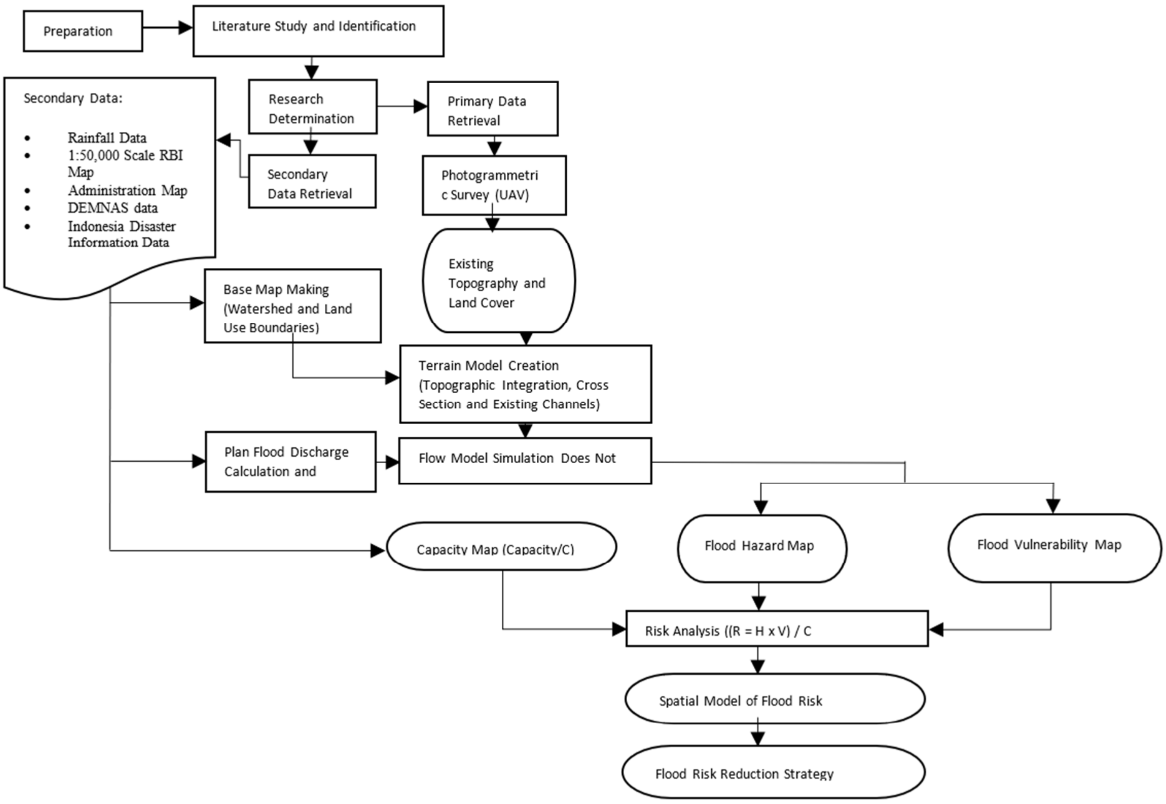


Fig. 4. Flowchart of research activities.

The topographic analysis results are depicted in Figure 5. These topographic data were used as the fundamental input data for the 2D numerical simulation in the HEC-RAS application. The Digital Terrain Model (DTM), which integrates UAV measurements with DEMNAS data is presented. The DTM is imperative for the HEC-RAS river analysis, as it provides precise surface elevation data that are essential for modeling. It contains detailed information on the river geometry, including width, slope, and elevation, therefore enabling HEC-RAS to calculate the flow, model hydraulics, and analyze the flood potential effectively.

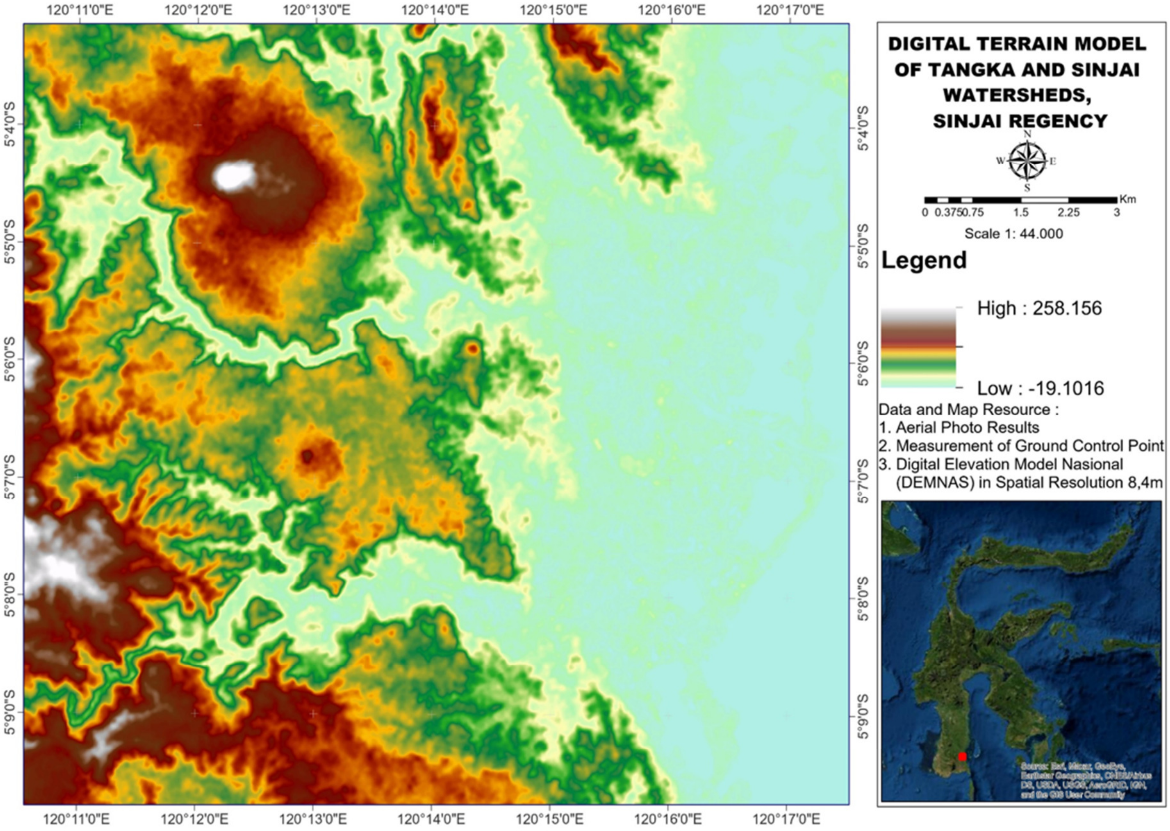


Fig. 5. DTM of DENMAS measurement and combination results.

B. Analysis of Flood Discharge Design

The design flood discharge analysis was performed deploying the HSS SCS method with HEC-HMS 4.8, which uses the watershed parameters shown in Table VI and effective rainfall data from the Mononobe analysis, as illustrated in Figure 6. These inputs enabled a comprehensive assessment of the design flood discharge.

TABLE VI. INPUT PARAMETERS FOR HEC-HMS

No.	Physical Parameters	Catchment Area	
		Sinjai	Tangka
1	Watershed Area (km^2)	133.38	466.49
2	Initial Abstraction (mm)	11.48	16.09
3	Curve Number (CN)	82	76
4	Impervious (%)	0.59	1.74
5	Time Lag (minutes)	192.32	286.54

Subsequent to the acquisition of data for the characteristics of each sub-watershed, the next step entailed the entry of these data into the HEC-HMS software. The implementation of HEC-HMS enabled the assessment of the flood discharge magnitude, as evidenced in Figure 7.

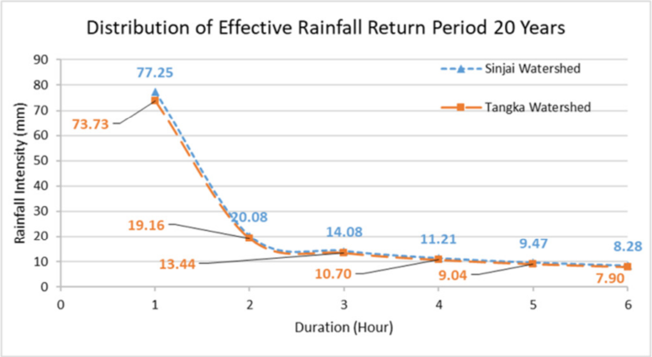


Fig. 6. Effective rainfall distribution for the Sinjai watershed and Tangka watershed.

The flood hydrographs of the Sinjai and Tangka watersheds exhibits analogous patterns. However, notable distinctions emerge in terms of the peak time and maximum discharge, with the Tangka sub-watershed registering higher values. This discrepancy can be attributed to the larger area and extended river length of the Tangka sub-watershed. Specifically, the maximum discharge for the Sinjai sub-watershed is measured at 479 m³/s, whereas the Tangka sub-watershed records a higher figure at 1072 m³/s. These findings, delineating the hydrograph characteristics, will serve as crucial input data for subsequent hydraulic simulations and analyses.

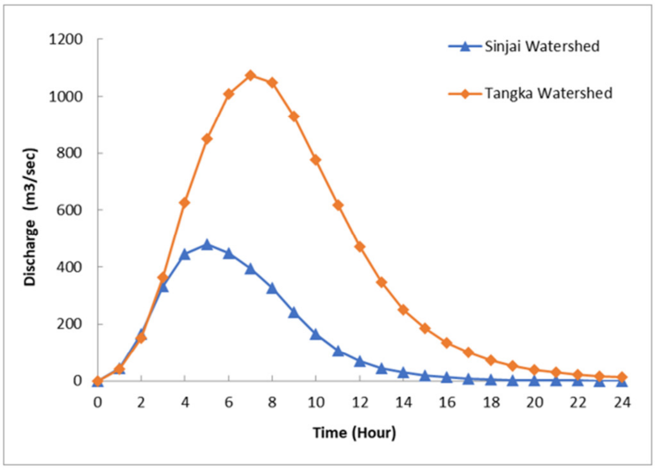


Fig. 7. Flood hydrograph of Sinjai and Tangka watersheds.

C. Hydraulic Simulation of the Existing Conditions of the Sinjai and the Tangka Rivers

A hydraulic model of the Sinjai and Tangka rivers was constructed to simulate the existing condition of the rivers and to understand the phenomena that occur during flooding. This study serves as a reference for selecting flood control and mitigation measures in the urban area of Sinjai regency. The simulation results yielded insights into the potential flood-prone areas within the study area, informed by topographic and terrain data. Consequently, the maximum depth was ascertained based on the flood discharge. The flood height and inundation area for each return period were obtained for the upstream, middle, and downstream areas of the study object based on the results of running HEC-RAS using data from the hydrological analysis. The flood simulation results, employing the HEC-RAS 2D model, are presented in Figure 8. After the acquisition of the water surface profiles of the Sinjai and Tangka rivers during floods through the implementation of HEC-RAS, the following step entailed the modeling of the flood hazard level. This modeling process was conducted using the ArcGIS software, which facilitates the integration and visualization of spatial data to assess and categorize the extent of the flood hazard.

D. Hydraulic Simulation of the Existing Condition of the Sinjai and Tangka Rivers

The development of a spatial model to assess the flood disaster risk involves the usage of data related to the hazard levels, vulnerability, and capacity indices. The analysis of the field data collection results suggests a paucity of non-structural activities that are specifically aimed at enhancing the capacity for reducing the flood disaster risk. Specifically, the observed efforts on the ground primarily consist of structural measures, particularly the construction of embankments at various locations. A capacity review matrix reveals that only 10 out of 22 achievement indicators were met, resulting in a capacity index value of 0.45 for the Sinjai and Tangka River basin. This classification indicates that the area has low capacity. Figures 9 and 10 illustrate the hazard levels and vulnerability in the Sinjai and Tangka watersheds, respectively. Subsequently, by integrating these three parameters, flood risk mapping was performed based on (5), resulting in a visual representation shown in Figure 11. The results of the flood risk analysis in Sinjai regency reveal the distribution of risk levels across different geographical areas. The area classified as low risk occupies 564.45 hectares, the area designated as moderate risk covers 645.83 hectares, and the area categorized as high risk extends to 46.19 hectares. The findings of this risk analysis will serve as a reference point for the implementation of flood control measures.

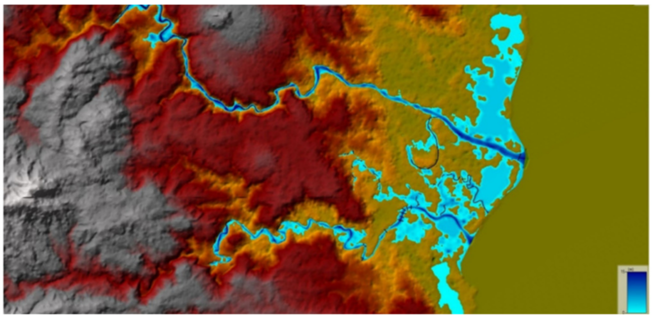


Fig. 8. Results of HEC-RAS 2D simulation.

E. Strategies for Reducing Flood Risk

According to the findings of (5), the risk of flooding is directly proportional to hazard and vulnerability, while inversely proportional to capacity. The mitigation of hazards is a primary strategy for reducing the flood risk, with flood control being a significant approach. As a critical component of water resource management, flood control involves the regulation of the flood discharge, typically through the implementation of flood control dams, enhancement of conveyance systems, such as rivers and drainage, and proactive management of land use in flood-prone areas to prevent potential damage. In Figure 12, a map detailing the locations of the flood control measures along the Sinjai and Tangka rivers is presented, exhibiting that the Sinjai Regency has demonstrated a concerted effort to diminish the impact of floods. The proposed flood control measures for the Tangka River entail river normalization. The implementation of river normalization is focused on sections of the river that are particularly affected by sedimentation issues, with three locations identified in the primary channel and two in the tributaries. As depicted in Figure 12, the normalization process is implemented in each of the two tributaries of the Tangka River, involving the excavation of sediment and waste from the community up to a depth of 1.5 meters.

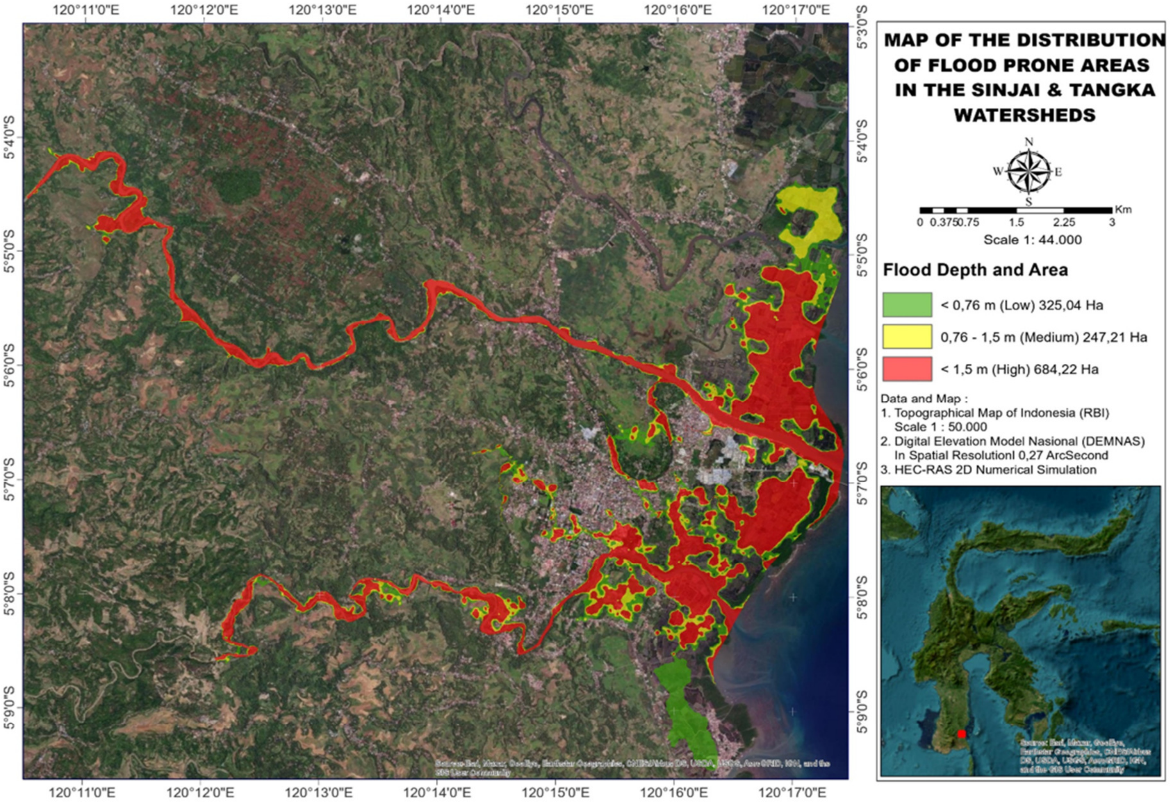


Fig. 9. Flood hazard map of Sinjai River and Tangka River.

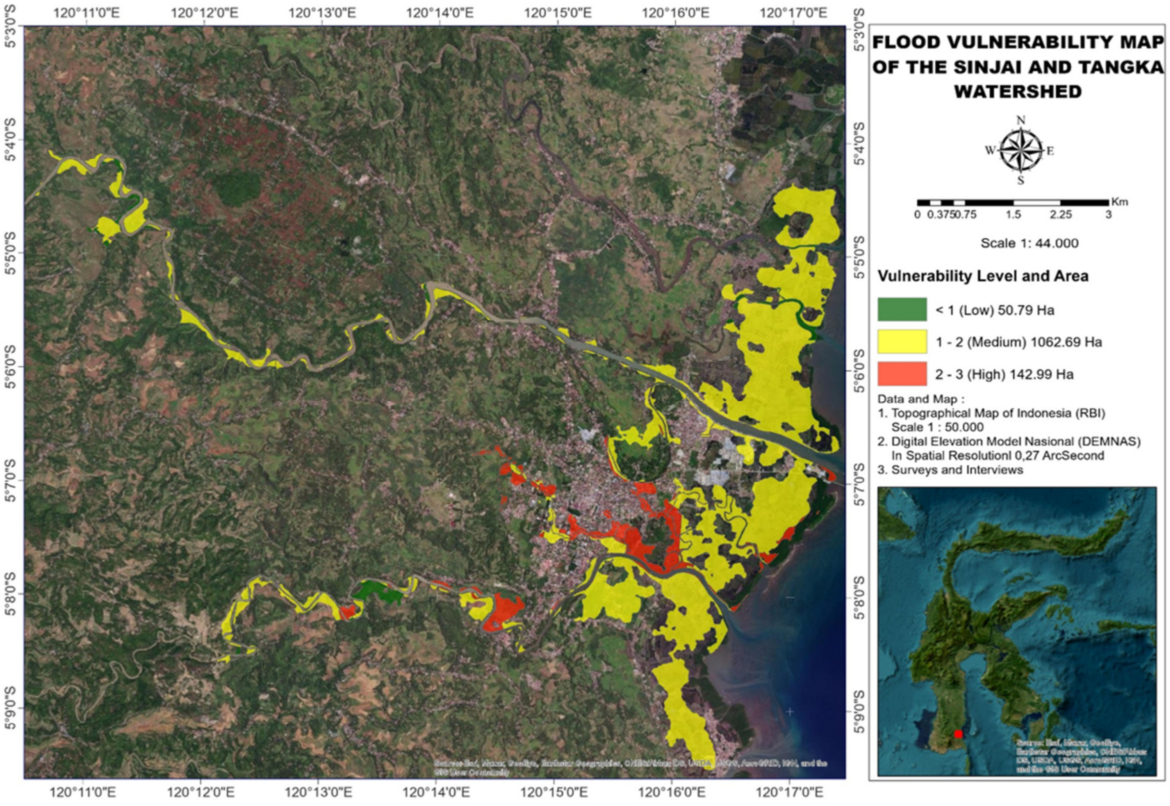


Fig. 10. Flood vulnerability map of Sinjai River and Tangka River.

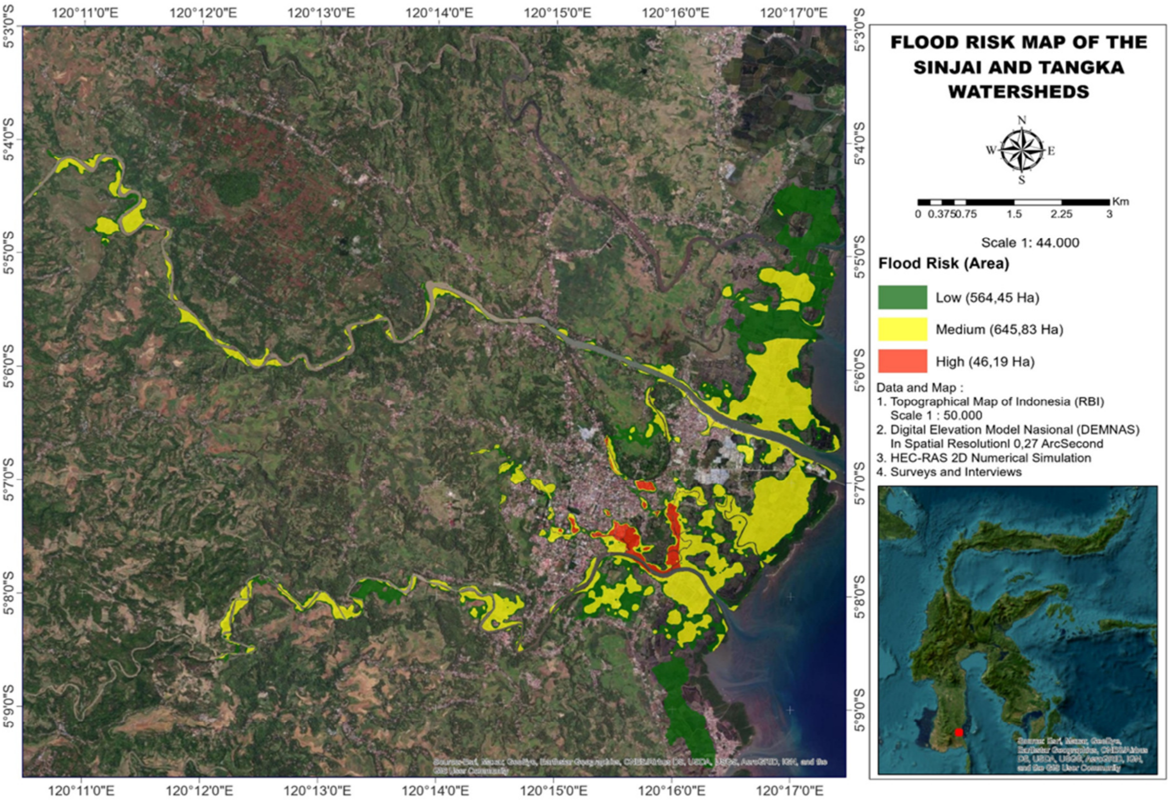


Fig. 11. Flood risk map of Sinjai River and Tangka River.

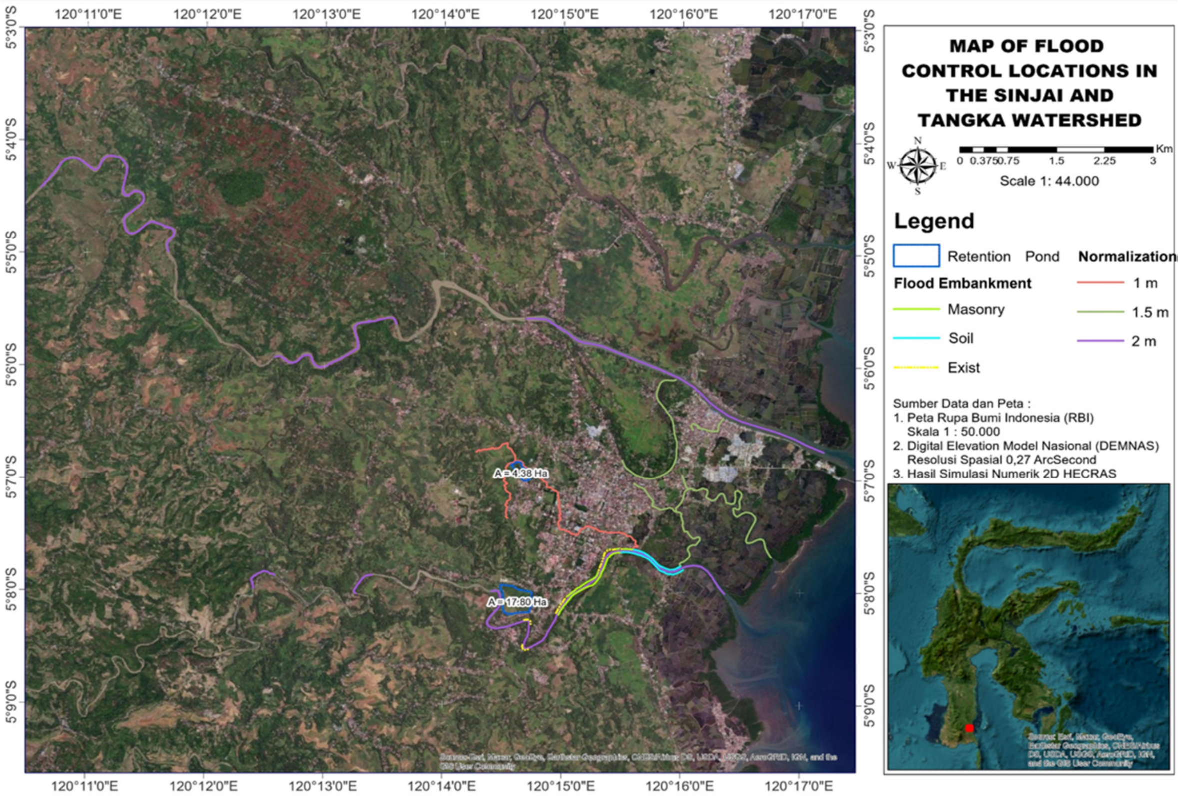


Fig. 12. Flood control location map of Sinjai River and Tangka River.

Moreover, the flood control measures implemented for the Sinjai River include river normalization, the construction of flood embankments, and the establishment of retention ponds. Normalization is carried out in the river channel that has sedimentation problems, where there are three locations in the main river and two locations in the tributaries. Similar to the tributaries of the Tangka River, as shown in Figure 12, the process of river normalization involves the excavation of sediment and waste from the community up to a depth of 1.5 m and 1 m, respectively, in each of the three tributaries of the Sinjai River. A proposed plan involves the construction of a flood embankment composed of soil and the installation of parapets, with the objective of mitigating the risk of flooding in areas with high economic value, including agricultural and plantation regions. The final proposal includes the construction of two ponds: a 17.80-hectare Sinjai River retention pond and a 4.38-hectare retention pond situated in the upstream segment of the Sinjai River tributary, known as the Cakkempong River. The primary function of these retention ponds is to temporarily contain floodwaters, which are subsequently released once the downstream water levels recede, thereby mitigating the risk of flooding caused by an overflow in the Sinjai River tributaries. The phenomenon of flooding in urban areas of Sinjai is multifaceted, with one of the primary causes being the influx of tidal water and floods from the Sinjai River itself. To assess the effectiveness of these flood control measures, an overlay analysis is conducted, which involves comparing the flood risk area before and after implementation. The flood risk map subsequent to the implementation of these measures is presented in Figure 13.

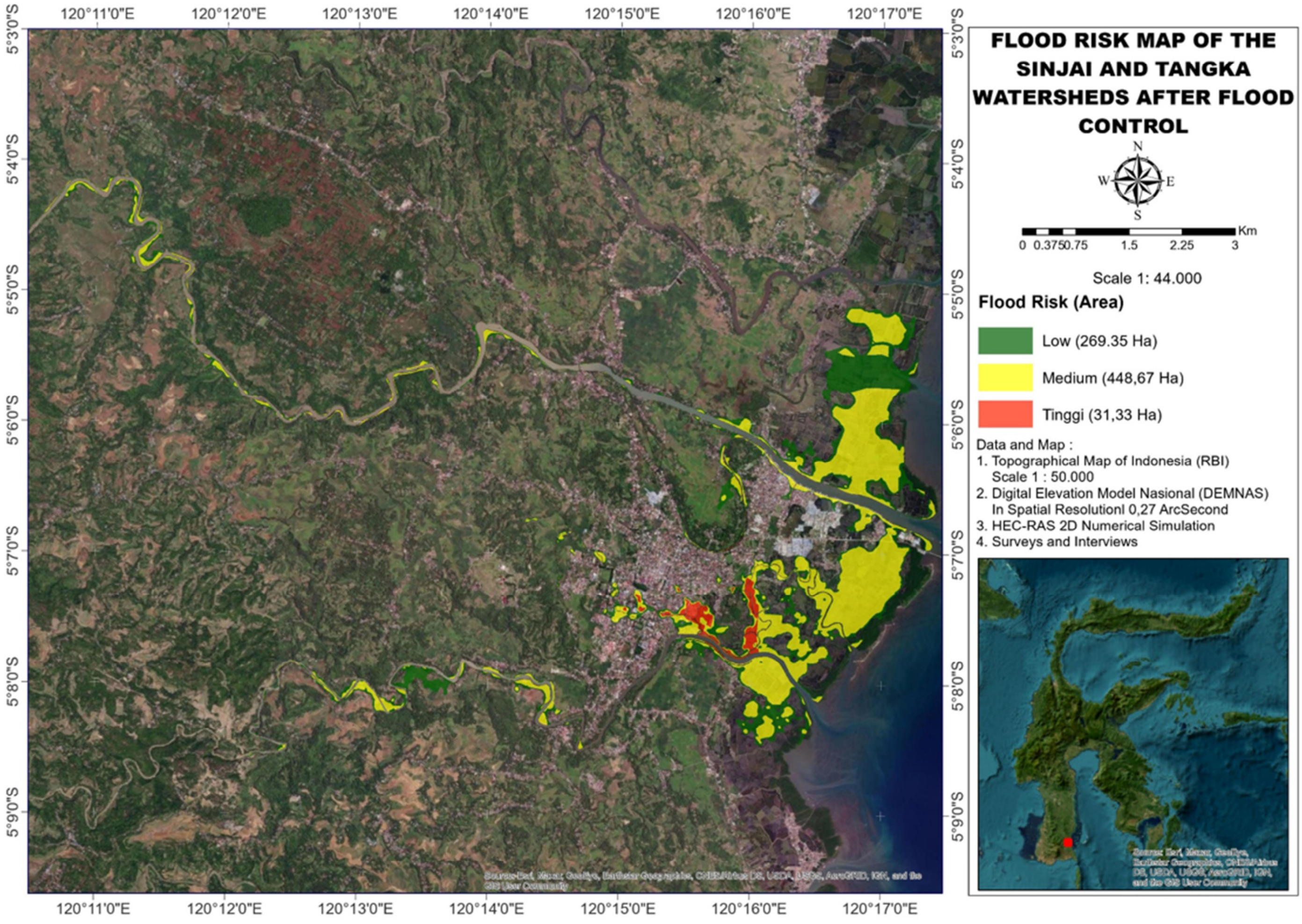


Fig. 13. Flood risk map of Sinjai River and Tangka River after flood control measures.

A comparison was made between Figures 11 and 13 to analyze the flood risk areas before and after the implementation of the flood control measures, respectively. The comparison results of the flood area distribution before and after the implementation of the flood control measures are presented in Table VII and Figure 14. The implementation of flood control measures has been shown to result in a significant reduction in the flood inundation area, amounting to 507.12 hectares. The evaluation of the risk classification reveals that the incorporation of these measures into the spatial model leads to a decline in high-risk flood areas by 14.86 hectares (32.17%), moderate-risk areas by 197.16 hectares (30.53%), and low-risk areas by 295.1 hectares (52.28%).

TABLE VII. COMPARISON OF FLOOD RISK BEFORE AND AFTER FLOOD CONTROL MEASURES

No.	**Flood Risk Classification**	**Affected area before flood control measures (Ha)**	**Affected area after flood control measures (Ha)**	**Reduction of affected area (%)**
1	Low	564.45	269.35	52.28
2	Medium	645.83	448.67	30.53
3	High	46.19	31.33	32.17
Total		1,256.47	749.35	40.36

When calculating the percentage reduction in threatened areas before and after the intervention, the overall decrease in the inundation area amounts to 40.36%. It is imperative to acknowledge that, despite these substantial reductions, flood control measures are incapable of completely eliminating flood inundation, given the considerable discharge of the Sinjai River and the spatial constraints that limit the construction of retention ponds. Furthermore, alterations in the water level, flow velocity, and downstream flood volume have been observed as a consequence of these measures.

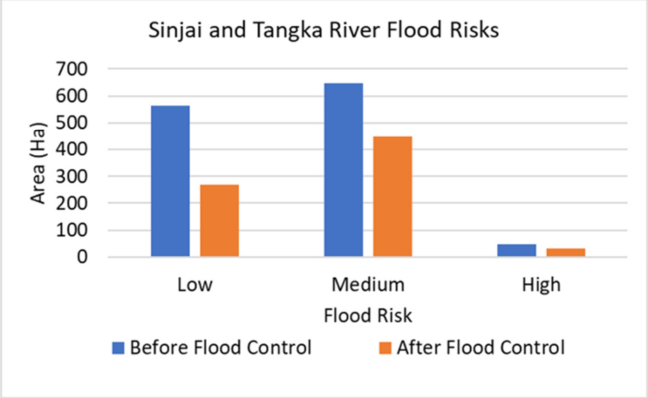


Fig. 14. Comparison of flood risk before and after flood control measures.

IV. CONCLUSIONS

Flood disasters persist as a considerable threat in numerous regions worldwide, particularly in tropical countries such as Indonesia, which frequently encounters heavy rainfall and intricate river systems. This study demonstrates that a combination of hydraulic modeling and spatial analysis, supported by Unmanned Aerial Vehicle (UAV) topographic data, can serve as an effective tool for understanding the flood risks and designing appropriate mitigation strategies, especially in areas with limited data, such as Sinjai and Tangka. The findings of this study suggest that the implementation of structural mitigation strategies, such as the construction of embankments, retention ponds, and river normalization, has the potential to significantly reduce the flood risk. The model developed in this study identifies that the proposed mitigation measures have the potential to reduce the extent of flood-prone areas by up to 40.36%, including a significant reduction in high and medium-risk areas. The efficacy of this strategy underscores the necessity of integrating infrastructure with policy interventions that encompass land use planning, sustainable water management, and community capacity, thereby ensuring a more effective and sustainable flood risk management. The findings reported herein are of relevance not only to Sinjai and Tangka, but also to other regions worldwide facing similar challenges in flood risk management, particularly in areas with a limited access to comprehensive hydrological data. The model, developed through a synthesis of UAV technology and hydraulic modeling, provides a quantifiable and economical approach to address data limitations, hence certifying an accurate representation of flood risk distribution. This research underscores the global community's need for collaboration between technology development and data-driven decision-making in disaster management. In light of the escalating flood risks attributable to climate change, the study provides a framework for flood risk management in developing countries and other regions grappling with data and resource constraints.

In the future, there is a need to integrate infrastructure-based solutions and sustainable spatial planning policies to reduce natural disaster risks, including flooding. The findings of this study can serve as a foundation for enhancing the capacity of local communities to cope with the flood risks, as well as strengthening more proactive policies for disaster management at both national and global levels. Consequently, this study makes a substantial contribution to the international literature on flood management in tropical regions, while also providing a replicable model for implementation in various parts of the world facing similar challenges in flood mitigation.

REFERENCES

[1] M. R. Mustamin, F. Maricar, and R. Karamma, "Hydrological Analysis In Selecting Flood Discharge Method In Watershed Of Kelara River," *INTEK: Jurnal Penelitian*, vol. 8, no. 2, pp. 141–150, Dec. 2021, https://doi.org/10.31963/intek.v8i2.2874.

[2] M. R. Mustamin, F. Maricar, and M. P. Hatta, "Effects of Nipa-Nipa Regulation Pond on Flood Control of Tallo River," *IOP Conference Series: Earth and Environmental Science*, vol. 1134, no. 1, Jan. 2023, Art. no. 012002, https://doi.org/10.1088/1755-1315/1134/1/012002.

[3] A. R. Suleman, S. Badaruddin, M. Mustamin, Z. Saing, and M. R. Mustamin, "Flood mitigation of Bila River in Sidrap Regency Indonesia based on eco-drainage retention pond," *Water Practice and Technology*, vol. 18, no. 5, pp. 1184–1195, Apr. 2023, https://doi.org/10.2166/wpt.2023.051.

[4] Muhlis, Fatmawati, I. Rahim, and Syamsia, "Detection of Potential Natural Disasters Due to the Rate of Land Change in Sinjai Indonesia Regency with Geospatial Technology," *PalArch's Journal of Archaeology of Egypt/Egyptology*, vol. 17, no. 9, pp. 1702–1721, 2020.

[5] N. Afni, "Arahan Pengendalian Banjir Berbasis GIS di Kecamatan Sinjai Utara Kab. Sinjai," *Plano Madani : Jurnal Perencanaan Wilayah dan Kota*, vol. 4, no. 1, pp. 22–31, Apr. 2015, https://doi.org/10.24252/jpm.v4i1.1010.

[6] Y. Kassem, H. Gökçekuş, and N. Alijl, "Flash Flood Risk Assessment for Girne Region, Northern Cyprus," *Engineering, Technology & Applied Science Research*, vol. 12, no. 3, pp. 8728–8737, Jun. 2022, https://doi.org/10.48084/etasr.4939.

[7] N. Kumar and R. Jha, "GIS-based Flood Risk Mapping: The Case Study of Kosi River Basin, Bihar, India," *Engineering, Technology & Applied Science Research*, vol. 13, no. 1, pp. 9830–9836, Feb. 2023, https://doi.org/10.48084/etasr.5377.

[8] F. Fadlina, M. A. Thaha, F. Maricar, and M. P. Hatta, "Spatial Modeling For Flood Risk Reduction In Wanggu Watershed, Kendari,"

International Journal of Engineering Trends and Technology - IJETT, vol. 70, no. 12, pp. 219–226, Dec. 2022.

[9] R. Urban *et al.*, "The Suitability of UAS for Mass Movement Monitoring Caused by Torrential Rainfall—A Study on the Talus Cones in the Alpine Terrain in High Tatras, Slovakia," *ISPRS International Journal of Geo-Information*, vol. 8, no. 8, Aug. 2019, Art. no. 317, https://doi.org/10.3390/ijgi8080317.

[10] A. R. Suleman, H. Djufri, M. R. Mustamin, and M. L. Palembangan, "Structural Mitigation of Bila River, Sidrap Regency," *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, vol. 12, no. 6, pp. 3573–3577, May 2021, https://doi.org/10.17762/turcomat.v12i6.7146.

[11] *Regulation of the Minister of Public Works and Public Housing concerning Establishment of River Bounda*, 28/PRT/M/2015. 2015.