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Full Length Research Article

Flood Mitigation Strategies: Integrating Hydrologic Engineering Systems-River Analysis Systems for Effective Management of Paremang Watershed

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ABSTRACT

The Hydrologic Engineering System-River Analysis System (HEC-RAS) model is a model that can display water surface cross-sections in both 1D and 2D forms. That way, HEC-RAS can predict the amount of peak discharge that results in flooding. This study aims to see the distribution of flood areas in the Paremang Watershed as a basic form of mitigation activity for flood events. A flood disaster analysis was conducted using the HEC-RAS model. The HEC-RAS model data includes river water discharge data from the Soil and Water Assessment Tools (SWAT) analysis, which is an overlay of topography, land cover/use, soil characteristics and climate data from authorized agencies, and direct field observations. The results showed that the flood area was 2,722.38 ha, affected by high rainfall conditions, steep slopes accelerating water flow, and land cover dominated by rice fields, bushes and dry land agriculture. The condition increases surface flow, stimulating the amount of water discharged. This resulted in flooding in most of the downstream and middle areas of the Paremang Watershed in Luwu Regency. Therefore, mitigation in the form of land use planning is needed. The plan is led by the Ministry of Agrarian Affairs and Spatial Planning, which includes other sectors ranging from forestry, agriculture, fisheries, tourism, and public works. This could support in developing policies ranging from forest rehabilitation, social forestry, community forests, expansion of agroforestry patterns, ecotourism development, and flood mitigation such as technical buildings.

1. Introduction

Floods are one of the most frequent natural disasters in several regions in Indonesia, resulting in infrastructure damage (CRED 2020) and many fatalities (Khan et al. 2014; Nandhita et al. 2023). Floods also significantly impact grain yield reduction (Chen et al. 2018). Floods start from the fall of rainwater into large amounts of land surface runoff that is not infiltrated. Furthermore, the accumulated runoff water flows into the river, so the water volume exceeds the river’s capacity and becomes a flood (Chairil et al. 2020; Kodoatie 2013). Areas with high soil erosion can lead to the shallowing of river bodies, which reduces the river's carrying capacity, making it more susceptible to flooding. Flood disasters appear everywhere every rainy season with varying locations and levels of damage (Chairil et al. 2021b). Flood disasters appear everywhere every rainy season, with differing locations and levels of damage. Flood problems have existed since humans lived and carried out various activities in the flood plains of rivers (Ministry of Research and Technology 2008).

Flood disasters are natural phenomena that occur due to conditions of high rainfall and uncontrolled human activities in exploiting natural resources, which affect the hydrological system to the point that peak discharges become floods (Knington et al. 2017; Szwagrzyk et al. 2018). Apart from that, changes in land use that do not follow its function will be a factor in flood events (Szwagrzyk et al. 2018). The function of forests becoming non-forests will cause changes in soil moisture retention and surface runoff, thereby increasing the average annual discharge and peak discharge even though rainfall is under normal conditions (Guzha et al. 2018; Kuntoro et al. 2018).

Land-use changes are influenced by a complex interplay of economic, social, physical, and policy factors (Taking 2023). Social factors, including an increase in population. Rapid population growth in low-income or developing countries is sometimes not in line with the food fulfillment in that country (Mildinov 2023). This will stimulate the expansion of agricultural land to meet food needs converted from forests in the upstream watershed area (Margono et al. 2012). Over time, forest conversion, which leads to forest destruction, is becoming more and more common due to the low public awareness of environmental conservation and the weak monitoring function of the parties in charge. Population growth also increases residential areas, leading to the formation of densely populated areas in the upstream part of the watershed (Chairil et al. 2021a; Yang et al. 2015). Massive residential development will eliminate green open spaces and agricultural cultivation land in urban and rural areas (Khawaldah et al. 2020). In residential areas where buildings are densely packed so that the level of water infiltration into the ground is reduced, if heavy rainfall occurs, most of the water will become surface flow directly into the water drainage system so that its capacity is exceeded and results in flooding.

Floods generally occur in the downstream plains, but flood accumulation starts from the upstream areas as a hydrological system in a watershed. Last few years, floods have occurred in several watersheds in South Sulawesi, including the Minraleng watershed (Fadhil et al. 2020), the Tallo watershed (Musliadi et al. 2020), the Bila watershed (Sholichin and Qadri 2019), the Kelara watershed (Chairil et al. 2020), and also Paremang Watershed. The Paremang Watershed is one of the watersheds in South Sulawesi. It is categorized as a provincial watershed with an area of 82,828 ha. This is because the water flow of the Paremang Watershed covers four districts, namely Luwu Regency, Tana Toraja Regency, North Toraja Regency and Palopo City. Quoted from Tribun Luwu (2017), floods submerged Luwu in three sub-districts, namely Ponrang Subdistrict, South Ponrang Subdistrict and Kamanre Subdistrict, due to the overflow of the Paremang River, which not only submerged residential areas but also agricultural land. A press release by Walhi (2024) stated that the flood in the Paremang watershed is 26.16% of the watershed area caused by land conversion in the core and buffer areas of the Latimojing Mountains.

Flood modeling is needed to study and estimate floods' causative factors, extent, and effects (Nikoo et al. 2016). Flood modeling is essential to see and anticipate the geographical distribution of floods by developing mathematical principles that represent the hydrological and hydraulic processes of the flood process (Gori et al. 2019). Several models have been developed, namely the 1D hydraulic model that describes the movement of water in a river in a simple way (Pinos et al. 2019) and the 2D hydraulic model that combines realistic elements in the depiction of floods with replication of both longitudinal and cross-sectional water flows (Perez et al. 2019). Hydrologic Engineering System-River Analysis System (HEC-RAS) model analysis, namely flood simulation analysis in one and two dimensions, describes the study of water surface cross-sections in permanent and non-permanent forms that occur flowing (Abbas et al. 2020). Flood simulation with HEC-RAS modeling is an element in flood management mitigation, carrying out rapid mitigation activities in risk reduction (Nkeki et al. 2022). The flood depths and inundation were generated using the freely available 2D hydraulic model HEC-RAS and flood inundation risks were generated for a range of weather probabilities. According to the model's conclusions, 17% of the entire area is at risk of flooding, of which 9% is at high risk, 52% is at medium risk, and the remaining 35% is at low risk (Rangari et al. 2019). Kute et al. (2014) reported that the flood profile for the worst flood intensity resulting from the HEC-RAS could help adopt suitable flood disaster mitigation strategies. Flood profiles for various flood intensities can be displayed at any river cross-section. Additionally, the entire river reach can have a plot of this type of flood profile. Using HEC-RAS for flood modeling is useful for managing disaster management procedures and hydraulic studies. Simulations using HEC-RAS in the form of river flow data and data on the physical shape of river cross-sections from topographic data are also needed, which can quickly predict the time and magnitude of peak discharge that causes flooding and the volume of water in a river that becomes flooded (Ogras and Onen 2020).

The HEC-RAS Model simulation has input data, namely river discharge data, river basin area and rivers, which are indicators for carrying out hydrological simulations. Due to data limitations, a model is needed to obtain the data. A hydrological model that can provide information quickly, completely and with complexity is the Soil and Water Assessment Tools (SWAT) model (Abbasa et al. 2016; Chairil et al. 2021b). The hydrological study using the SWAT model is a comprehensive study launched by the United States Department of Agriculture (USDA). SWAT modeling simulation provides good, fast and efficient results in predicting the hydrological conditions of a watershed over a certain period (Anoh et al. 2017; Boithias et al. 2017; Byakod et al. 2017; Chairil et al. 2021b).

Based on the explanation above, the flood disaster is a natural phenomenon whose occurrence can be detected, so it is necessary to make anticipatory efforts to minimize the impact (mitigation) it causes. This research aims to analyze the distribution of flood areas in the Paremang Watershed as a basic mitigation activity for flood events. The detection of flood areas used the HEC-RAS model with the input of river water discharge data from the SWAT model in the Paremang Watershed. The discharge analysis is influenced by several factors, starting from topography, soil, climate, and land cover/use, which is used as the basis for flood mitigation.

2. Materials and Methods

2.1. Study Area

This research was carried out in the Paremang Watershed, South Sulawesi Province, with a watershed area of around 89,225.28 ha. The Paremang Watershed is located at 2° 59' 3.91" to 3° 22' 19.80" latitude and 119° 56' 26.24" to 120° 24' 9.07" longitude (**Fig. 1**).

2.2. Data Collection

This research is non-experimental and based on mapping or geographical Information systems, so data collection generally is spatial information data. The initial data collected were watershed boundaries from the Ministry of Environment and Forestry as orientation for the research location. Furthermore, the data collected was river network data and administrative boundaries from the Republic of Indonesia Geospatial Information Agency (BIG). Administrative data was used to identify areas entered by flooding. In contrast, river data was used to create detailed DEM data and identify river sections as the main water flow. DEM (Digital Elevation Model) data was obtained from Shuttle Radar Topography Mission (SRTM) Imagery with a resolution of 30 m, which is used to extract contour data to create more detailed DEM data.

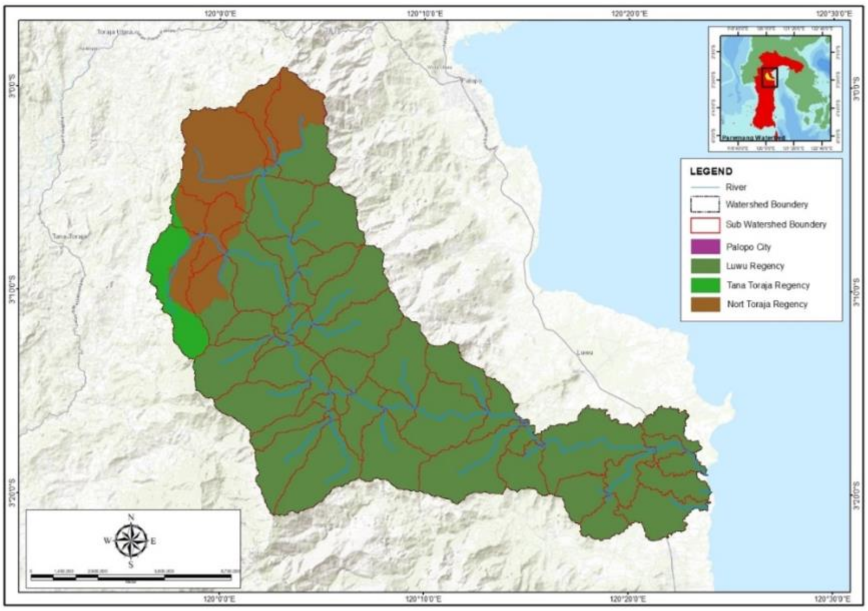

Fig. 1. Map of Paremang Watershed.

The data collected consist of soil characteristics, land cover data, and climate data for analysis of water discharge for input to the HEC-RAS flood model using SWAT hydrological modeling. Data of soil characteristics were obtained from the 1987 Regional Physical Planning Program for Transmigration (RePPProt) Landsystem Map at a scale of 1:250,000, which is adjusted to USDA soil data. Land cover data was obtained from the Indonesian Ministry of Environment and Forestry in 2022. Climate data consist of rainfall, maximum and minimum temperatures, air humidity, wind speed and solar radiation for the last ten years (2013–2022) from the Pompengan Jeneberang River Basin Center (BBWS), Directorate General of Water Resources, Indonesian Ministry of Public Works and Housing.

2.3. Data Analysis

2.3.1. Water discharge

Analysis of river flow in the Paremang Watershed was carried out using the Soil and Water Assessment Tools (SWAT). The model is an analysis that provides hydrological conditions with one of the outputs being discharged in a catchment area at a certain time (Anoh et al. 2017; Boithias et al. 2017; Byakod et al. 2017; Chairil et al. 2021b). The stages in developing SWAT model is described below.

2.3.1.1. Watershed boundary delineation

Watershed boundary delineation is the initial stage of SWAT modeling, which creates watershed boundaries as the subject of study using DEM data reconstructed from contour, river, and watershed boundary extraction data. In addition to determining watershed boundaries, this stage outputs data on sub-watersheds and main networks based on specified area thresholds. The DEM data also creates slope data for HRU formation and topographic input for the HEC-RAS flood model apart from watershed delineation boundaries.

2.3.1.2. Establishment of a hydrological response unit (HRU)

The HRU is the based unit in the spatial analysis produced in SWAT modeling. The HRU formed has specific information about the landscape. Overlapping data on soil characteristics, land cover and slopes formed the HRU. The overlaid data is a land cover/use, soil characteristics, and topography data in raster format. Each data is in raster form with a coordinate system in UTM (Universal Traverso de Mercator) Zone 51S in the Paremang Watershed location. Apart from that, the results of overlapping these data were set at a threshold of a percentage of total land cover area of 10%, soil characteristics of 5%, and slope of 5%.

2.3.1.3. Inputting climate data and combining HRU with climate data

At this stage, the climate data was organized according to the SWAT model using a text file format (.txt). After the climate data has been prepared, the climate data input process can be carried out using the Write Input Tables menu. Climate data is input data into the weather data definition toolbar, which consists of the rainfall/precipitation data, temperature data, relative humidity data, solar radiation data, and Wind Speed Data. Combining each climate data was carried out after the land unit was formed. The analysis period was then determined, and then the climate data was entered to obtain a daily discharge from the simulation results.

2.3.1.4. SWAT model simulation

The SWAT simulation requires climate data in the form of rainfall and temperature at stations representing the watershed area and weather generator data in the form of solar radiation, wind speed, temperature, rainfall and dew point. The simulation process was carried out daily, with a simulation output of 10 years. SWAT simulation can be run in the SWAT Simulation menu after the Watershed Delineation, HRU Analysis, and Write Input Tables stages have been completed properly. The simulation process can be done using Run SWAT in the SWAT Simulation menu. The next stage is to display the output results from the simulation.

2.3.2. Flood mapping

The HEC-RAS model evaluates risk and predicts future floods (Al-Hussein 2022). Flood modeling consists of the following stages: pre-processing, hydraulics modeling, post-processing, and flood mitigation.

2.3.2.1. Pre-processing

Pre-processing is the initial stage of HEC-RAS flood modeling, which was done by mapping flow segments and river geometry. Mapping of river sections using the QGIS application with the help of extensions in the form of HEC-GeoRAS. The data used were Paremang Watershed boundary maps, river maps, and contour maps obtained from DEM data. These data were then projected in D_WGS_1984 51S coordinate units for the Central part of Indonesia. With the help of the HEC-GeoRAS extension, river mapping, left and right river banks, flow directions and cross sections were made. Cross sections were made with a distance between cross sections of 125 m with a uniform width of cross-section, namely 100 m^2. The cross-section method in HECRAS produces the cross-sectional area of the river channel.

The process of digitizing or defining river geometry in the form of cross-sections and longitudinal sections of the river and flood plains along the river before hydraulic modeling was carried out. First, it is necessary to draw the river center line (Stream Centreline), cliff lines (Bank Lines), flow lines (Flow Path Centerlines) and cross-section lines (XS Cut Lines). This makes it easier to depict satellite imagery or DEM photos, which are used as a reference for depicting flow lines and cliffs.

The process of drawing flow lines was carried out manually following the cliff lines, while the cut lines were done automatically using the Construct XS Cut Lines tool in the HECGeoRAS program by entering the width and distance values between cuts. The results of automatically drawing cutting lines must be corrected so the lines do not intersect. Next, the cross-section export process was carried out using the HEC-GeoRAS auxiliary program as input data for hydraulic modeling using the HEC-RAS program.

2.3.2.2. Hydraulics modeling

Hydraulic modeling is intended to obtain water surface profile results and flood characteristics such as inundation area, depth, flow speed, and flow area. Generally, the input data required for hydraulic modeling are river geometry and flow discharge data. The geometric data used as input is the river geometry resulting from the digitization that has been carried out. In the geometry section, it is necessary to input the roughness value, namely in the form of the Manning coefficient. The Manning coefficient value is based on the floodplain's channel conditions and land use. Channel conditions and land cover types were obtained from the visual interpretation of satellite images. The determination of the Manning coefficient value based on the data used in his research is shown in **Table 1**.

Table 1. Manning coefficient value (US Army Corps of Engineers 2015)

No.	Land cover	Manning value
1	Agriculture	0.06
2	Paddy filed	0.05
3	Shrubs	0.04
4	Forest	0.05
5	Water bodies	0.03
6	Open land	0.04

2.3.2.3. Post-processing

Post-processing is the process of analyzing flood inundation based on the results of hydraulic analysis that has previously been carried out. The results of hydraulic analysis using HEC-RAS in the form of water level and flood inundation profiles were processed using the HEC-GeoRAS tool in GIS software to produce a flood inundation model. An inundation map is a map that shows the distribution of water around a river due to it not being accommodated in the river body.

2.3.3. Floods mitigation

Simulation of flood areas using the HEC-RAS Model provides an overview of areas at risk and priorities for carrying out flood mitigation activities. One of the mitigation activities that is quicker to control floods is technical activities such as carrying out river rehabilitation (Nkeki et al. 2022; Ogras and Onen 2020). Another form of natural mitigation to control surface flow and water discharge is land use planning activities (Chairil et al. 2020).

3. Results and Discussion

3.1. Water Discharge

Water discharge analysis uses SWAT, which begins with the watershed delineation stage. This initial stage analyzes how to create watershed boundaries, dividing the watershed into several sub-watersheds. Each sub-watershed has a main network and outlets. The results of delineating the Paremang Watershed generally show no significant difference in watershed boundaries from the Ministry of Environment and Forestry. Based on the delineation results, the area of the Paremang Watershed is 89,225.28 ha, consisting of 51 sub-watersheds.

The watershed delineation process also illustrates that the Paremang Watershed covers three district administrative areas in South Sulawesi Province, which flow from west to east, specifically in Bone Bay. The three Paremang Watershed areas include Luwu, Tana Toraja, and North Toraja Regencies. Most of the Paremang Watershed starts from the upstream, middle, and downstream, and its outlets fall within the Luwu Regency area. Tana Toraja and North Toraja districts are located at the upper reaches of the western part of the Paremang Watershed.

The next stage is HRU with an overlay analysis of three data sets: slope, soil characteristics, and land cover. Slope conditions are dominated by steep slopes (25–45%) to very steep (>45%). The higher the topographic conditions, the steeper the slope conditions will be, which will speed up surface flow towards the main river (Chairil et al. 2020) (**Fig. 2**).

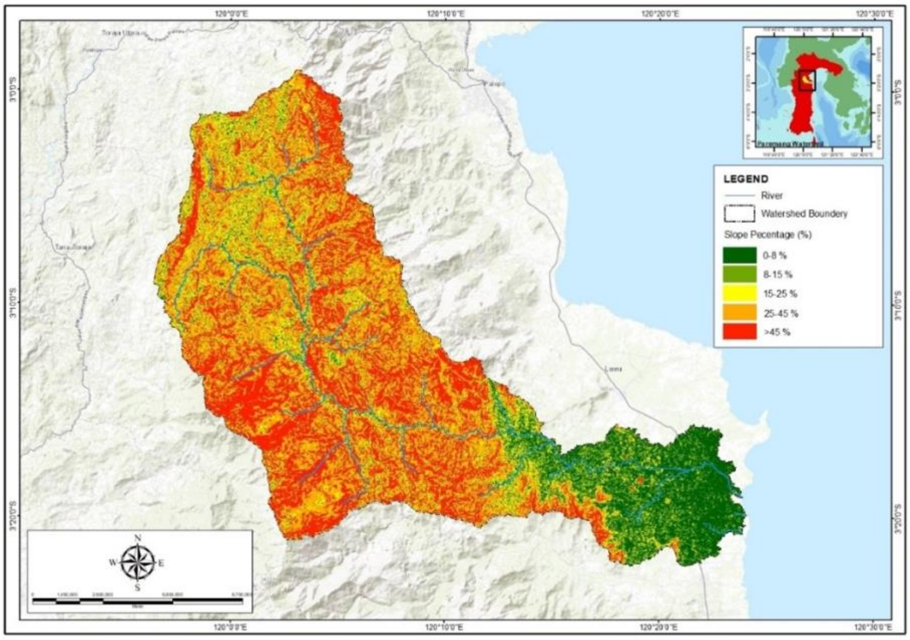

Fig. 2. Map of land slope in Paremang Watershed.

Soil conditions in the Paremang Watershed are dominated by the inceptisol soil type, which has a fairly thick soil solum, the texture is dust, dusty clay, clay, and the soil structure is crumbly, and the consistency is loose. This type of soil is easily eroded, surface flows further increase the sediment, and the water discharge in the river causes the accumulation of water to exceed the river's capacity, causing flooding (Chairil et al. 2021b) (**Fig. 3**).

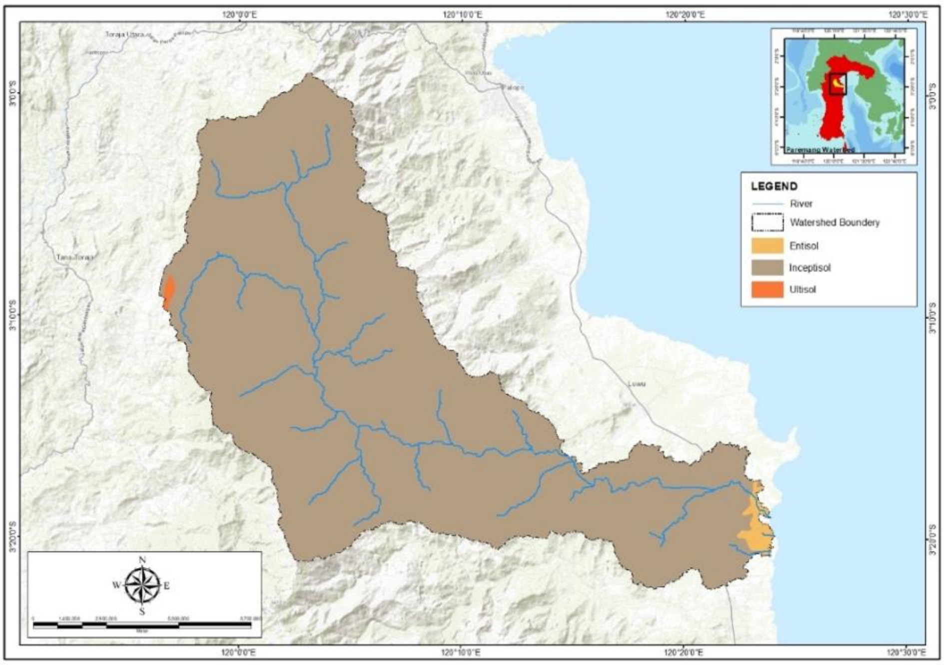

Fig. 3. Map of soil type in Paremang Watershed.

Land cover data was interpreted from Landsat Image 8. The results of this interpretation showed 13 land cover classes in the Paremang Watershed (**Table 2** and **Fig. 4**). Forests with an area of 24.27% that change in all forms of regional functions provide a decrease in the function of the hydrological cycle in the watershed (Rijal et al. 2023; Sufiyan and Magaji 2018). The reduction of hydrological will change the retention of soil moisture and the flow of water so that the discharge rate increases and the river's capacity decreases (Guzha et al. 2018; Schilichin and Wadri 2019).

Table 2. Land cover in the Paremang Watershed

No.	Land cover	Area (ha)	Wide (%)
1	Primary dryland forest	8,750.79	9.81
2	Secondary dryland forest	17,678.34	19.81
3	Settlements/built-up land	660.75	0.74
4	Plantation/garden	280.06	0.31
5	Dryland farming	444.36	0.50
6	Mixed shrub dry land farming	24,151.56	27.07
7	Savanna/grassland	838.64	0.94
8	Ricefield	14,444.36	16.19
9	Shrubs	20,421.43	22.89
10	Pond	1,008.71	1.13
11	Open land	17.21	0.02
12	Body of water	529.05	0.59
	Total	89,225.28	100.00

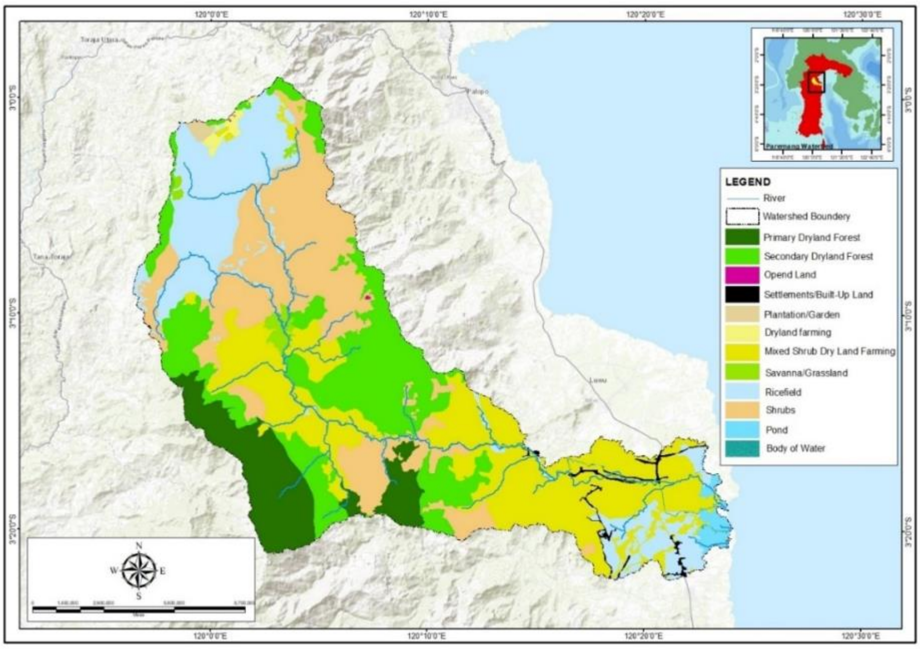

Fig. 4. Map of land cover in Paremang Watershed.

The next stage is combining the results of the HRU overlay with climate data. Most climate data is represented by looking at rainfall conditions in an area. Rainfall is also important in analyzing water discharge and flooding events (Chairil et al. 2020; Knington et al. 2017; Kodoatie 2013). Rainfall above normal causes greater surface flow, forming peak discharge and continuing for a long time, causing flooding (Knington et al. 2017). Rainfall conditions are very high in the upstream area of the Paremang Watershed compared to the downstream (**Fig. 5**).

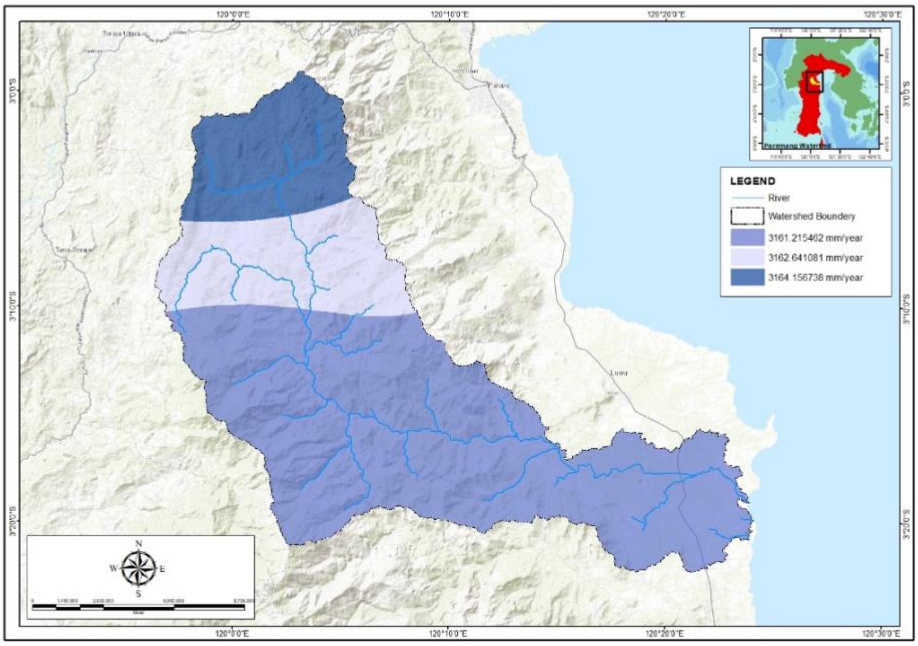

Fig. 5. Map of rainfall in Paremang Watershed.

The SWAT model was then run to obtain basic discharge data in flood-prone areas. Water discharge is the volume of water that can pass through a river or that the river can accommodate per unit of time. Water discharge is also described as the speed of water flow passing through a river cross-section. The greater and faster the water discharge, the peak discharge will become a flood overflow (Chairil et al. 2021b). Water discharge is increasing increases in the main river and heads towards the outlet of the watershed (**Fig. 6**).

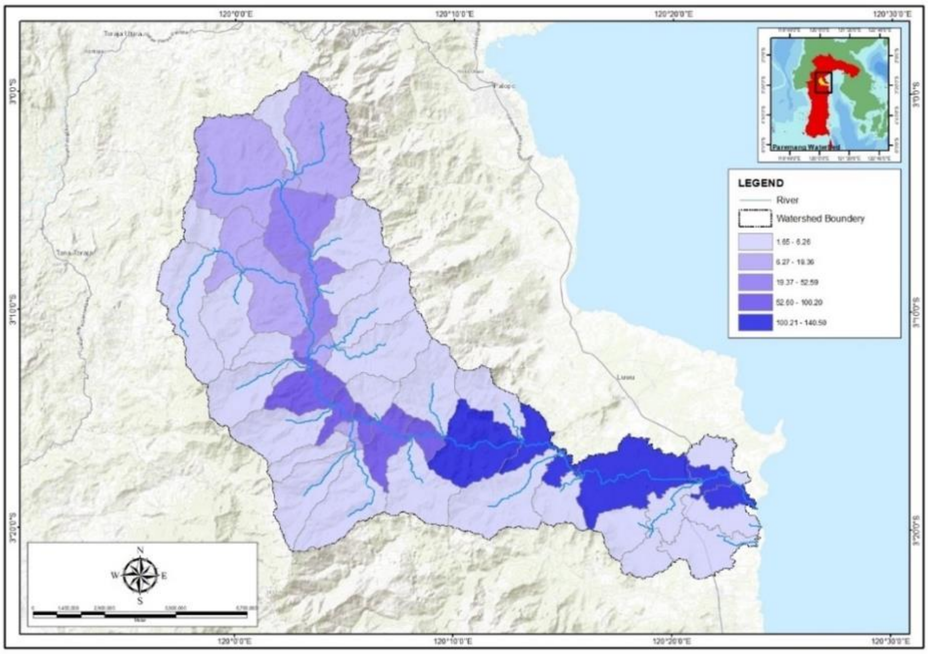

Fig. 6. Maximum water discharge in Paremang Watershed.

Discharge fluctuations are a very important characteristic of river flow because they will directly determine the availability of irrigation water and the opportunity and prediction of floods and droughts. Sharp fluctuations in discharge flow between the two seasons indicate disruption of watershed function (Chairil et al. 2021b). Apart from that, discharge fluctuations are also closely related to erosion and sedimentation events, so they can also indirectly describe the level of land quality degradation.

3.2. Floods Hazard Mapping

HEC-RAS is designed to simulate a one-dimensional flow. The HEC-RAS model produces a river water condition under the influence of hydrology and hydraulics and further river management according to needs (Abbas et al. 2020). Flood simulations with the HEC-RAS model were obtained using maximum discharge data from the SWAT model results (Ogras and Onen 2020). The results of HEC-RAS are modeling the potential distribution of flood areas based on GIS. The results of this simulation are then superimposed with administrative boundaries and produce area sizes, which are presented in detail in **Table 3**.

Table 3. Area of potential flooding in Luwu Regency, Paremang Watershed

No.	Subdistrict	Area (ha)
1	Bajo	81,33
2	North Belopa	58,25
3	Bua Ponrang	902,05
4	Kamanre	991,41
5	South Ponrang	689,35
	Total	2.722,38

The results of the flood potential analysis show that the area of potential flooding is in Luwu Regency, covering an area of 2,722.38 ha. Kamanre, Buo Ponrang, and South Ponrang Districts have the most widespread flood potential of 991.41 ha, 905.05 ha, and 689.35 ha. This is based on the visualization of flood inundation from the water level profile in each transverse section, interpreted as flood inundation. Based on the map of the potential distribution of floods in the Paremang watershed area shows that the potential is in the downstream part of the watershed (**Fig. 7**). The factors that cause flooding are quite related to each other, ranging from high rainfall, slope conditions, and land cover (Guzha et al. 2018; Szwagrzyk et al. 2018). The worst flooding condition is the increasing sediment yield (Chairil et al. 2021b; Munoth and Goyal. 2019).

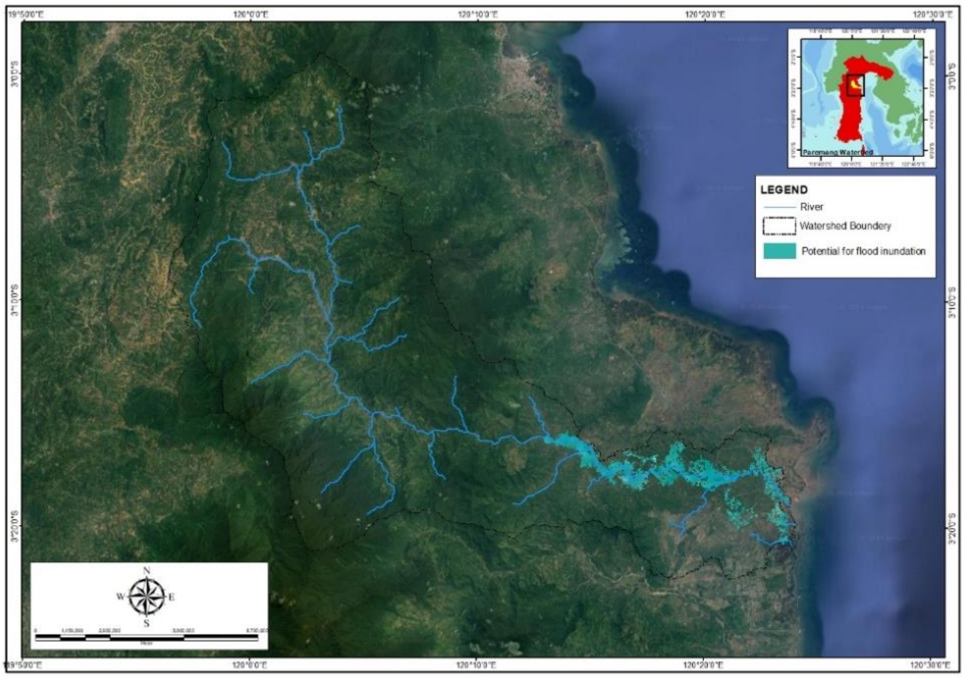

Fig. 7. Map of area of potential flooding in Paremang Watershed.

3.3. Floods Mitigation

The spread of flooding appears to impact dryland agricultural land cover areas, even densely populated areas in the Paremang Watershed. This resulted in crop failure for the local community and large losses. Apart from that, flooding in dense settlements will disrupt daily life and can even claim lives (CRED 2020). Apart from flood locations, which directly impact dense residential areas, they also impact public services, public infrastructure and locations of economic activity centers.

Based on the impact of the simulated flood event in the Paremang River Basin, mitigation activities need to be carried out by improving the parameters that cause flood discharge (Chairil et al. 2021b). Only land cover parameters can be used for long-term land use planning management activities. Land use planning is a systematic land assessment that finds the best land use alternatives while considering economic, social, and environmental conditions (Chairil et al. 2020). This planning has been included in the Spatial Planning Law. The law stipulates that all levels of government make land use plans starting from the Provincial, Regency and Village levels. Even every land use plan that has been analyzed must undergo a further analysis called a strategic environmental assessment. The study includes an analysis of carrying capacity, ecosystem services, climate change vulnerability, utilization of natural resources, biodiversity, and disaster risks, one of which is flooding (**Fig. 8**).

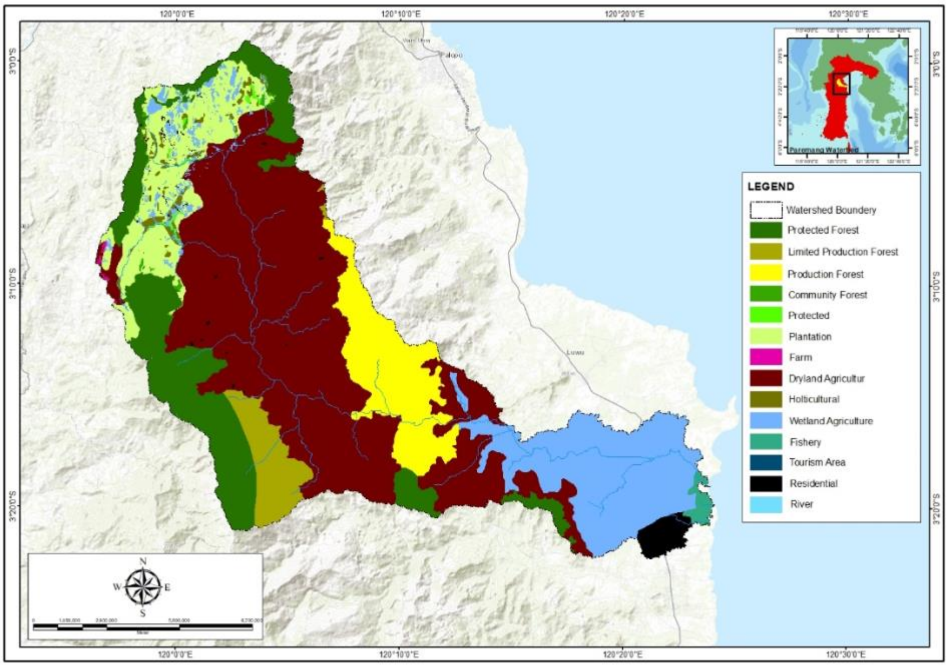

Fig. 8. Land use planning in Paremang Watershed.

Institutionally, land use planning is led by the Ministry of Agrarian Affairs and Spatial Planning of the Republic of Indonesia. The analysis section of land use planning is based on the function of forest areas under the authority of the Ministry of Environment and Forestry. The upstream part of a watershed should be dominated by the function of protected forests as protection of life support systems to regulate water management, prevent flooding, control erosion, and maintain soil fertility. Forests in protected areas will regulate the balance of water discharge and reduce erosion, which can increase sediment and affect river capacity (Chairil et al. 2021b). At the provincial level, each forest area, including protected forests, has a management unit called the Forest Management Unit as the vanguard and the driving force in forest management and protection efforts (Kartodihardjo et al. 2012).

The Ministry of Environment and Forestry has implemented several policies to increase forest cover in forest areas, such as Forest Restoration and Rehabilitation (Purnomo and Anand 2014). However, the forest rehabilitation policy is not comparable to the community's conversion of forests to agriculture (Chairil et al. 2023). Thus, the President of the Republic of Indonesia launched a Social Forestry policy through the Ministry of Environment and Forestry (Maryudi et al. 2012; Purnomo and Anand 2014). The Social Forestry Policy provides certainty of community land and forestry assistance. In addition to being within the forest area, the ministry, up to the Forest Management Unit Level, can provide financial assistance to the community in building community forests outside the forest area.

Land use outside forest areas is certainly more influenced by the regional or district government, especially in agriculture, plants, fisheries, and settlements. Regarding these fields, the Regency must still look at the policies in each ministry. The Paremang Watershed has a very large dryland agricultural plan in the watershed’s upper reaches. In regulating this, the Ministry of Agriculture needs to develop an agroforestry pattern, a heterogeneous planting pattern of forestry, plantation, animal feed, and horticultural crops. Agroforestry can produce sustainable agricultural products in a particular rural area in the watershed's upper reaches (Bliska et al. 2013). This policy needs to be followed by further assistance such as seed assistance, capital loans, and maintaining the price of agroforestry plants. Other land cover types, such as plantations, intensive agriculture, and rice fields, require soil conservation efforts disseminated by the surrounding community (Nugroho et al. 2021).

One sector that can withstand changes in land cover is the tourism sector. Ecotourism is related to government policies at the central level, such as those of the Ministry of Tourism and local governments, which protect the environment and culture of protected areas (Seifi and Ghobadi 2017). The government and community continue to develop ecotourism with unique prehistoric, cultural, and natural ecosystem values to reduce land conversion into agricultural land. Ecotourism will play a role in developing sustainable tourism for local governments and communities with economic, social and ecological values (Nurinsyah et al. 2015; Zambrano and Mario 2010; Seifi and Ghobadi 2017). Ecotourism development is based on local communities to eliminate poverty (Kuuder and Manu 2012). Ecotourism is also a tool for environmental management for local governments and avoids land use that does not follow its designation (Nurinsyah et al. 2015).

Technically, mitigation needs to be carried out on every land use planning that has been planned technically faster (Kodoatie 2013). Technical flood mitigation activities can rapidly impact flood reduction, such as building reservoirs, dams, and river normalization (Chairil et al. 2020; Kodoatie 2013). Another thing that is done is to make river channels and build retaining walls. In addition to river normalization, household waste management and handling of river pollution must also be carried out (Amru et al. 2022). In terms of institutions, technical mitigation will be carried out by the Public Works sector at the Ministry and local government levels.

4. Conclusions

The Paremang Watershed has a very high water discharge due to high rainfall conditions, steep slopes accelerating water flow, and land cover dominated by rice fields, bushes and dry land agriculture. The condition increases surface flow, stimulating the amount of water discharged. This also results in an increase in sediment, which will reduce the river's capacity. So flooding occurs in the middle to downstream areas of the watershed, mostly in Luwu Regency. These floods have a major impact on agricultural land, causing crop failure and residential areas, which can cause casualties and material losses. This encourages the need for mitigation by considering the parameters that cause flood discharge. Only land cover parameters can be used for management activities in land use planning. The plan is led by the Ministry of Agrarian Affairs and Spatial Planning of the Republic of Indonesia in collaboration with several ministries or sectors ranging from forestry, agriculture, fisheries, tourism, and public works. To increase forest cover, forestry policies start with forest rehabilitation, social forestry, and community forests. The agricultural sector is expanding agroforestry patterns, followed by seed assistance, capital loans, and agroforestry plant prices. One sector that can withstand changes in land cover is the tourism sector. The tourism sector develops ecotourism to protect the environment and culture of protected areas. Technical flood mitigation activities such as building reservoirs, dams, and river normalization are carried out by the Public Works sector.

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