



## Watershed Morphometric Controls on Highland Flooding in Enrekang's Urban Area

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### Abstract

The earth's surface is completely divided by watersheds; urban and rural areas are sub-systems of watersheds. Flooding is influenced by climatic aspects, LULC, and morphometric characteristics. The Enrekang urban area is in the highlands. However, when it rains with high intensity, the area experiences flooding that causes social, economic, and environmental losses. This study aims to identify watersheds and reveal the morphometric factors of watersheds in the upstream part of the Enrekang urban area. The data used is NASADEM as a modernization DEM from SRTM, processed by spatial analysis techniques and mathematical calculations on the linear, areal, and relief aspects of the watershed. Data shows that in the Enrekang urban area, there is a confluence of the main stream (seventh-sixth order) from the upstream Saddang sub-watershed (SW-2) with the Mataallo sub-watershed (SW-3). In addition, the  $R_{bm}$  value of  $<3$  indicates that the stream channel has a rapid rise in flood water levels, while the decline is slow. The value of the ruggedness number ( $R_n$ ) parameter  $>2$  is an extreme classification. High ruggedness number indicates steep slopes, and thus resulting in flash floods and erosion. In terms of area, the area of water catchment in the sub-watershed upstream of urban areas is 5,930.77 sq.km., the area is classified as a large watershed. A large catchment area will produce a large flood discharge. Factors of land use change in the upstream part, triggering an increase in surface runoff. There are three district capitals located upstream of Saddang watershed which causes the conversion of green land into built areas due to the need for housing and public facilities. This data can be a reference for the government, academics, and the community for the purpose of planning flood control programs in upstream of the Enrekang Urban Area.

**Keywords:** Morphometric Characteristics, Saddang watershed, Upstream-downstream, Urban Flooding

### 1. Introduction

The earth's surface is completely divided by watersheds. Thus, urban, and rural areas are a sub-system of watersheds. The watershed region is also called catchment area (Sobatnu et al., 2017). A watershed is a land area that is bounded by a topographic ridge and functions as a unit of hydrological system where rainwater is stored, drained, and collected to a point of lake or sea (Sudirman et al., 2018). In general, the watershed ecosystem is divided into three parts, namely the upstream, the middle, and the downstream part (Isnain, 2018). Watersheds are places where rivers flow, and have an important role for human life, such as the provision of water needs, agricultural land, plantation land, and irrigation (Arsat, 2017). Watersheds are fundamental geomorphic units for the evaluation and management of extreme hydrological events such as floods (Nasir et al., 2020). The physical characteristics of watersheds, such as

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the area, slope, shape, and network of streams, greatly influence the hydrological response to precipitation. One of the factors that affect the flooding is rainfall (Nganro et al., 2020).

Land use in the watershed also determines the amount of infiltration, surface runoff, and potential erosion and sedimentation. Surface runoff is a comparison between surface flow and the volume of rain that falls (Nganro et al., 2019). Therefore, integrated watershed management is essential to maintain water system balance, reduce flood risk, and support the sustainability of water resources. A Digital Elevation Model (DEM) is a digital representation of land surface elevation relative to a reference datum (Nganro et al., 2025). The digital elevation model was utilized to delineate the watershed and drainage network (Nasir et al., 2020). With the ease and advantages provided in remote sensing and geographic information system, it will help identifying and mapping the watershed causing floods (Sudirman et al., 2018). Floods do not only occur in lowlands, but can occur in highlands (Ma'mur et al., 2024). Other factors that can cause flooding include changes in land use and land cover, slope, contour and soil type (Neves et al., 2023; Nganro et al., 2017). Land use and land cover change (LULCC) has a great role in influencing the hydrological cycle (Das et al., 2018). With global climate change, cities face the challenge of increasing flood disaster caused by heavy rainfall (Z. Wu et al., 2019).

The Enrekang urban area is in the highlands, and within the boundaries of the Saddang watershed. The geomorphology of the Saddang and Mataallo watersheds is divided into four parts, namely; volcanic falls, mountainous folding hills, strongly torn mountains/hills, and karst hills. Meanwhile, slope classes vary between <8% - >45%, but are more dominated by a land slope of 25%-45% (Uca et al., 2022). Even though this area is in a highland, it still experiences flooding in the rainy season with high intensity. The floods that hit the Enrekang urban area in 2024, caused 115 houses to be affected by the flood and 223 residents to be displaced (Audia, 2024; Jejakfakta.com, 2024; Pluz.id, 2024). Portrait of flooding in the Enrekang urban area is shown in Figure 1.

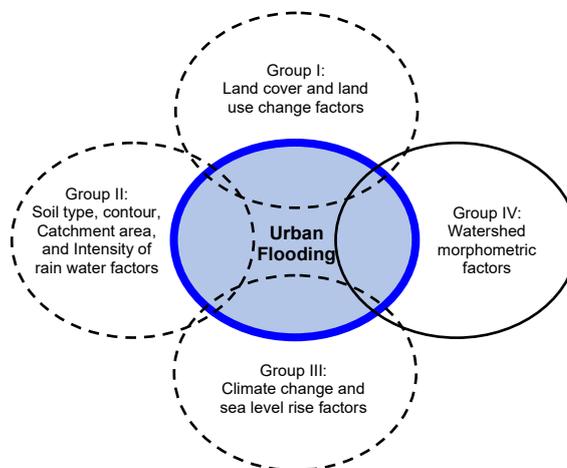


Source: Daeng Info, April 29<sup>th</sup> 2019

Source: Pluz.Id, April 27<sup>th</sup> 2024

Figure 1. Flooding in Enrekang Urban Area

Based on previous research, several studies have been summarized that reveal floods are caused by several factors such as LULC, rainfall intensity, and sea level rise as a result of climate change (Sudirman et al., 2017; Nganro et al., 2020). In addition, Watershed morphometric factors also have a significant effect. Morphometric analysis was employed to produce flood hazard maps which displayed sub-basins exposed to harmful flooding (Farhan et al., 2016). An illustration of the factors causing the flood is shown in Figure 2.



Source: (modified from Nganro et al., 2020)

Figure 2. Factor that affects flooding

Morphometric is a quantitative measurement of characteristics related to geomorphology, watershed morphometric is a term used to quantitatively express the state of a river network. This is related to the process of controlling the discharge of rainwater that falls in the watershed area (Uca et al., 2022). The morphometric aspects of the watershed include linear, area, and relief aspects (Kaliraj et al., 2015). The linear aspect includes parameters such as basin perimeter (P), basin length ( $L_b$ ), stream order (U), total number of streams ( $N_u$ ), stream length ( $L_u$ ), bifurcation ratio ( $R_b$ ); aspect areal consist of basin area (A), drainage density ( $D_d$ ), length of overland flow ( $F_s$ ), elongation ratio ( $R_e$ ), circulatory ratio ( $R_c$ ), texture ratio (T), dan compactness coefficient ( $C_c$ ); The relief aspect are basin relief ( $B_h$ ), relief ratio ( $R_r$ ), and ruggedness number ( $R_n$ ) (Sujatha et al., 2015; Anand & Pradhan, 2019; Jothimani et al., 2020; Maulana et al., 2025). The occurrence of flooding in the highlands in the Enrekang urban area is unusual because naturally, water flows from the high plains to the lower places. This is an indication that the morphometric elements of the watershed have an influence on flooding.

This research is very important, because it can be used as a guideline for stakeholders to create development programs related to flood prevention efforts, so that social, economic, and environmental losses due to floods can be minimized in the future. In addition, the research results are very useful for academics for the development of science focused on urban flooding. Therefore, this study was carried out with the aim of identifying the Saddang watershed, revealing the boundaries of the sub-watershed upstream and downstream of the Enrekang urban area that affect flooding. Furthermore, spatial analysis and mathematical analysis were carried out to reveal the morphometric characteristics of each sub-watershed. Thus, the morphometric factors of the watershed that affect the flooding of the highlands in the Enrekang urban area can be revealed.

## 2. Methods

### 2.1 Study Area

The study area is an urban area and the capital of Enrekang Regency. The area is in Enrekang sub-district. Enrekang district consists of six sub-sub districts and twelve villages with a population of 34,140 peoples (BPS, 2024). This area is crossed by the main road to Tana Toraja Regency. In addition, it is also crossed and flanked by two rivers, namely the Saddang River and the Mataallo River, the junction point of the two rivers is in an urban area. The Enrekang urban area is in the Saddang watershed. This watershed crosses 2 provincial areas, namely South Sulawesi Province and West Sulawesi Province (Anggraheni et al., 2016; Hatta et al., 2019). The Saddang watershed is a national strategic area in national spatial planning, a sustainable food land area in the spatial planning of the provincial area and is a national rice reserve barn (Listyosari et al., 2018). As the capital, this area functions as a center for government, offices, banking, and other services. Urban areas often experience flooding. Thus, urban infrastructure and facilities such as roads and bridges, residents' houses were washed away. The map of the study area is shown in Figure 3.

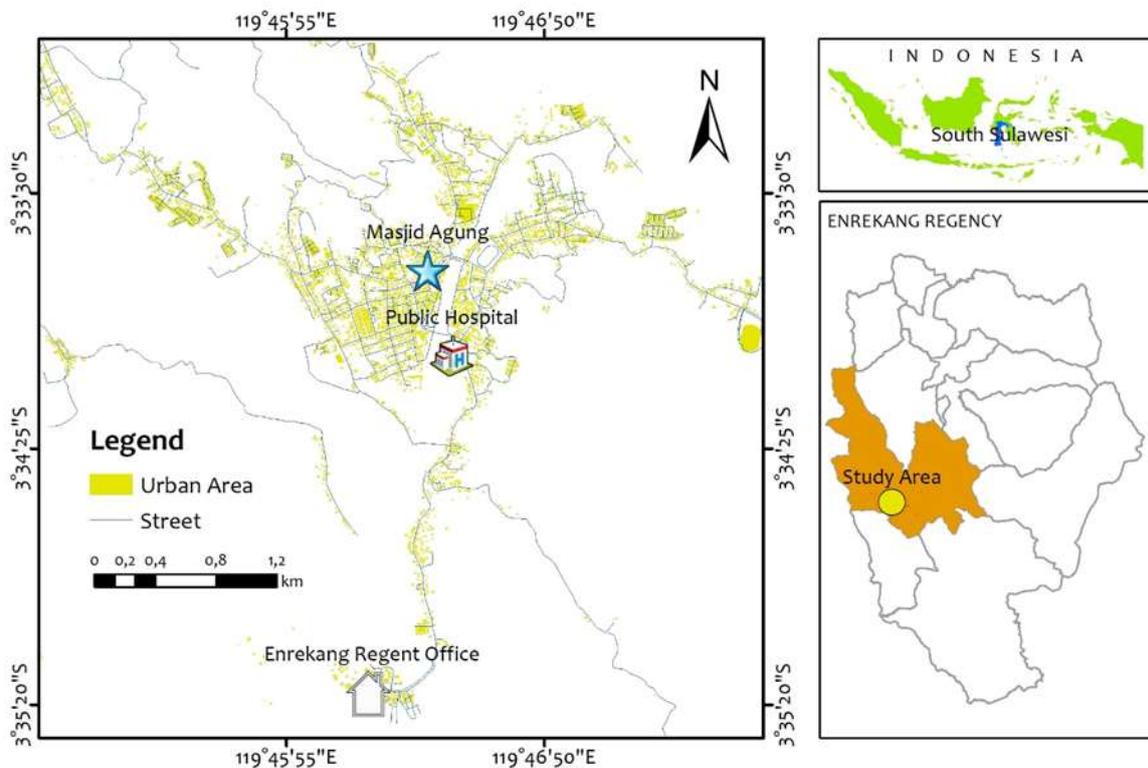
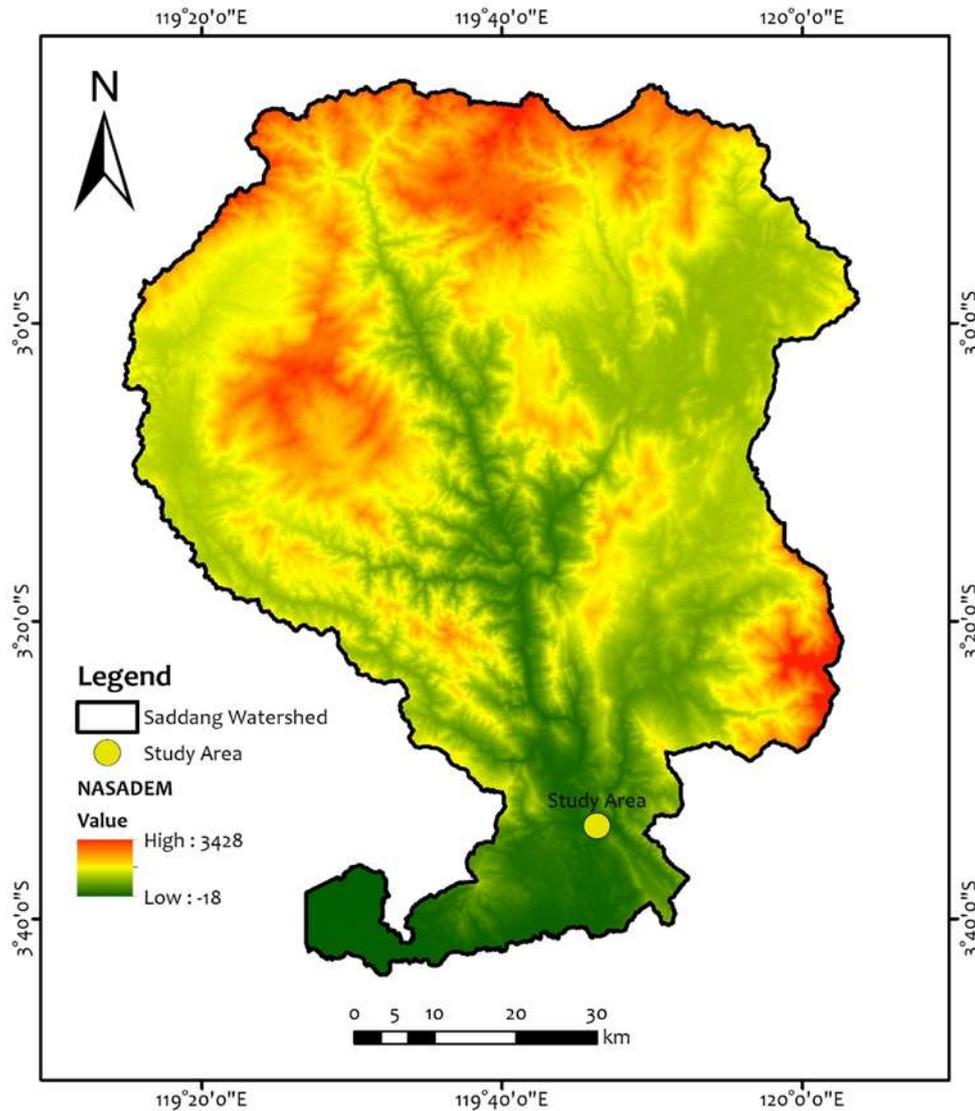


Figure 3. Study Area

## 2.2 Research Data

Remote sensing provides a valuable data source. Particularly in order to observe large, heterogeneous or poorly accessible regions, remote sensing data are a good choice (Scharsich et al., 2017; Coulter et al., 2016; Nganro et al., 2022; Lv et al., 2019; Yang et al., 2011). The development of remote sensing technology has become an integral part of watershed mapping and management (Purboyo et al., 2024). Watershed delineation can be determined using digital elevation model (DEM) data. The data has been widely used for surface hydrological modeling (T. Wu et al., 2019). The data used to identify watersheds that affect flooding in the Enrekang urban area is NASADEM data. The data is obtained for free through the <https://opentopography.org/> web portal. NASADEM stands for NASA Digital Elevation Model, released in February 2020 (Uemaa et al., 2020). It was an update of the SRTM DEM (Nganro et al., 2025), derived by reprocessing the original SRTM interferometric SAR data using updated interferometric unwrapping algorithms by applying vertical and tilt adjustments based upon GCPs derived from ICESat to improve the vertical accuracy (Fan et al., 2023; Crippen et al., 2016; Abrams et al., 2020). The main objective of the product is to eliminate voids and other limitations present in the SRTM by using datasets that are unavailable during the original processing (Li et al., 2022). NASADEM data is shown in Figure 4.



Source: <https://opentopography.org/>, 2024  
Figure 4. Research Data

## 2.3 Analysis Techniques and Framework

Currently, computer technology can be equipped with software-based applications for the needs of digital mapping of watersheds (Buakhao et al., 2016). In this study, NASADEM data was processed using spatial analysis techniques (Prarono, 2016; Chowdhury, 2024; Francisco, 2024). This study aims to uncover the causes of flooding in the Enrekang urban area. Therefore, the watershed is divided into two parts, namely the part upstream of the urban area and the part downstream of the urban area. The

upstream and downstream parts of the watershed are determined based on the meeting point of the two rivers located in the Enrekang urban area. The junction is an outlet for the upstream watershed of urban areas. In this study, watersheds located upstream of urban areas are called upstream (SW-2 and SW-3), while the downstream part is called SW1. In addition, the morphometric characteristics of the three sub-watersheds are mathematically calculated. The formula is shown in Table 1.

Table 1. Morphometric Parameters

Aspect	No.	Morphometric parameters	Symbol	Equation/Definition	Reference
Linear	1	Basin perimeter	P (km)	Perimeter of the watershed	Horton (1945)
	2	Basin length	$L_b$ (km)	$L_b = 1.312 \times A^{0.568}$	Horton (1945)
	3	Stream order	U	Hierarchical rank	Strahler (1952)
	4	Total number of streams	$N_u$	$N_u = N_1 + N_2 + N_n$ , where $N_1$ = number of streams of the first order $N_2$ = number of streams of the second order $N_n$ = number of streams of the next order	Horton (1945)
	5	Stream length	$L_u$ (km)	$L_u = L_1 + L_2 + L_n$ , where $L_1$ = stream length of the first order $L_2$ = stream length of the second order $L_n$ = stream length of the next order	Strahler (1957)
	6	Bifurcation ratio	$R_b$	$R_b = N_u / N_n + 1$ , where $N_u$ = total number of streams of order "u" $N_n + 1$ = number of streams of the next order	Schumm (1956)
Areal	7	Basin area	A (km <sup>2</sup> )	Area of the watershed	Horton (1945)
	8	Drainage density	$D_d$ (km/km <sup>2</sup> )	$D_d = L_u / A$ , where $L_u$ = total stream length of all orders (km) A = area of the watershed (km <sup>2</sup> )	Horton (1945)
	9	Length of overland flow	$L_o$ (km)	$L_o = 1 / (2 \times D_d)$ , where $D_d$ = drainage density	Horton (1945)
	10	Stream frequency	$F_s$ (/km <sup>2</sup> )	$F_s = N_u / A$ , where $N_u$ = total number of streams of all orders A = area of the watershed (km <sup>2</sup> )	Horton (1945)
	11	Elongation ratio	$R_e$	$R_e = 1.128 \times A^{0.25} / L_b$ , where A = area of the watershed (km <sup>2</sup> ) $L_b$ = basin length (km)	Schumm (1956)
	12	Circulatory ratio	$R_c$	$R_c = 4 \times \pi \times A / P^2$ , where $\pi = 3.14$ A = area of the watershed (km <sup>2</sup> ) P = perimeter (km)	Miller (1954)
	13	Texture ratio	T	$T = N/P$ , where N = total number of stream order P = perimeter (km)	Horton (1945)
Relief	14	Compactness coefficient	$C_c$	$C_c = 0.2812 \times P/A^{0.5}$ , where P = perimeter (km) A = area of the watershed (km <sup>2</sup> )	Horton (1945)
	15	Basin relief	$B_h$ (m)	$B_h = h_{max} - h_{min}$ , where $h_{max}$ = maximum height (m) $h_{min}$ = minimum height (m)	Schumm (1956)
	16	Relief ratio	$R_r$	$R_r = B_h / L_b$ , where $B_h$ = total relief (km) $L_b$ = basin length (km)	Schumm (1956)
	17	Ruggedness number	$R_n$	$R_n = D_d \times (B_h/1000)$ , where $D_d$ = drainage density $B_h$ = total relief (km)	Farhan, Anaba, and Salim (2016)

The research stage begins by downloading NASADEM data on the web portal. Next, the analysis process begins by determining a threshold of >300, the threshold value is determined based on the level of detail of the desired stream order. After the stream order is formed, the meeting point of the stream order

in the urban area is marked (pour point) as the SW1, SW2 and SW3 outlets. The pour point is used to ensure the selection of points of high accumulated flow when delineating watershed using spatial techniques. Pour point will search within a snap distance around the specified pour points for the cell of highest accumulated flow and move the pour point to that location. The framework of this research is shown in Figure 5.

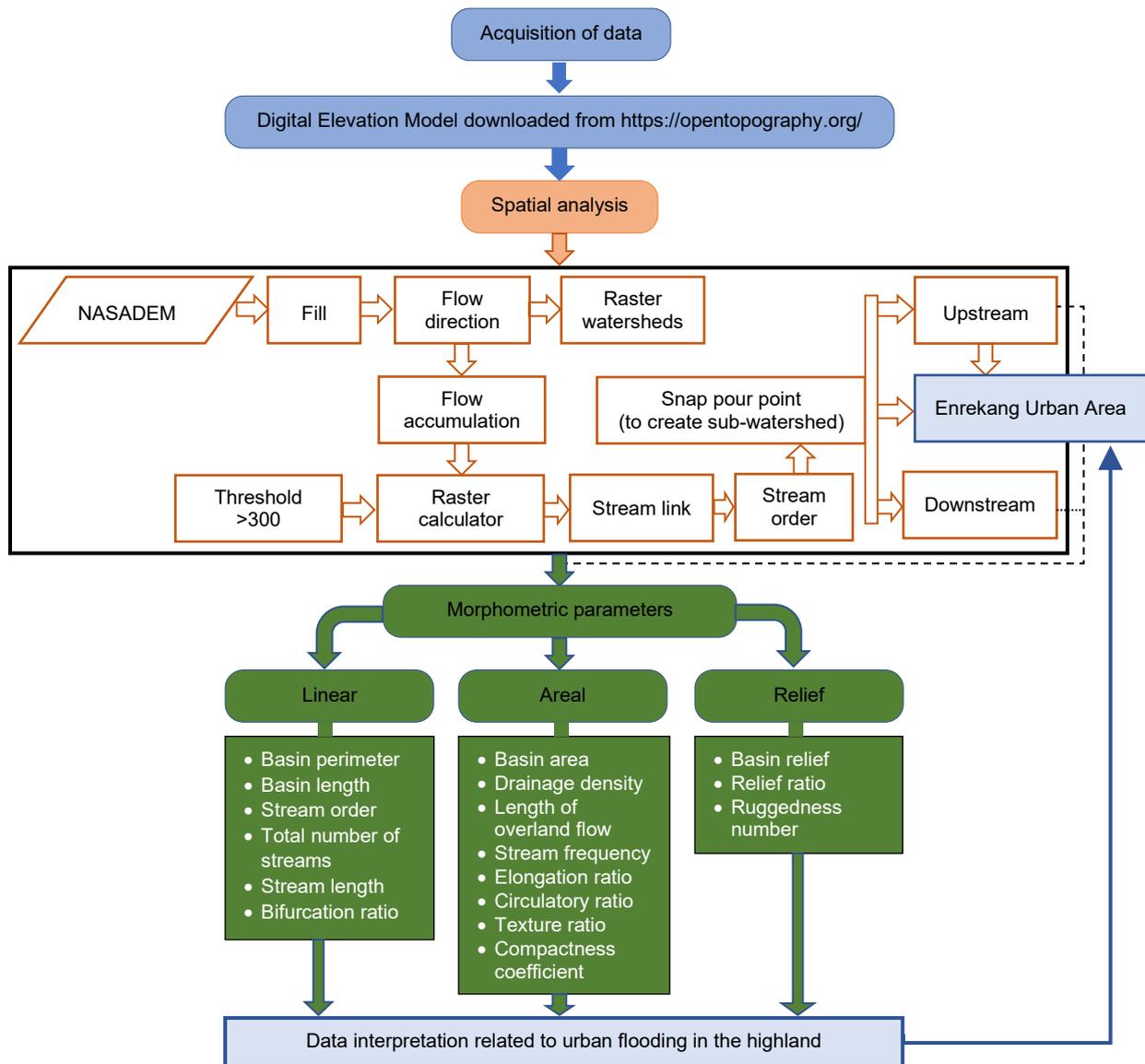


Figure 5. Framework

### 3. Results and Discussion

#### 3.1 Saddang Watershed

The main river of this watershed is the Saddang River. Furthermore, it is called and known as the Saddang watershed. The stream order reaches the seventh level. Based on the results of the analysis, the Saddang watershed covers eight district administrative areas in South Sulawesi and West Sulawesi Provinces. The district administrative areas in South Sulawesi Province are Enrekang, Luwu, Palopo City, Pinrang, and Tana Toraja Regencies, while the West Sulawesi Province area includes Mamuju, Mamasa, and Polewali Mandar Regencies. The area of a watershed, bounded by ridges or mountains. Thus, the watershed area will cross several district administrative boundaries. Within a watershed, water flows from small rivers to larger rivers and eventually empties into a lake or sea. Therefore, the application of the concept of "One Watershed One Plan" is very necessary in the management of watersheds. Good coordination and cooperation between the district government within the boundaries of a watershed is needed. Thus, the use of upstream areas is not a threat to downstream areas. In this study, flooding in the Enrekang urban area is a big picture that shows that there is no effective coordination in the management of the Saddang watershed. Map of the Saddang watershed is shown in Figure 6.

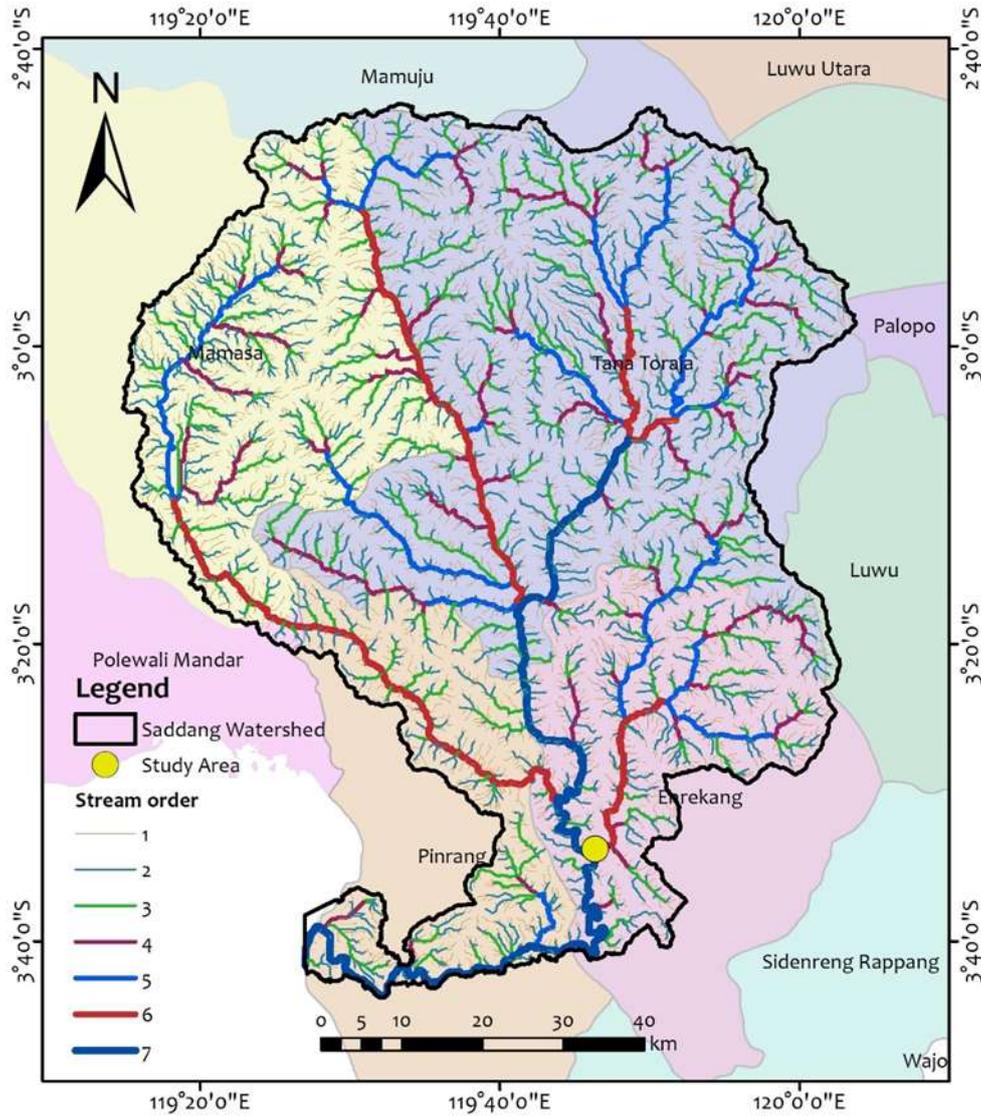


Figure 6. Saddang Watershed

The area of the Saddang watershed is 6,384.00 sq.km. Tana Toraja Regency is the largest district administrative area in the boundary of the Saddang watershed, which is 3,021 sq.km., this value is equivalent to 47.33 percent of the area of the watershed. Furthermore, followed by Mamasa Regency, covering an area of 1,417.80 sq.km., or 22.21 percent. Tana Toraja Regency and Mamasa Regency are in the northern part of the Saddang watershed. The two districts are part of the upstream of the Saddang watershed. In the perspective of regional spatial planning, the upstream part of the watershed is an area that functions to provide protection for the area below it. On the other hand, the smallest district administrative area within the boundaries of the Saddang watershed is Palopo City, which covers an area of 4.72 sq.km. or about 0.07 percent. While the second smallest is Mamuju Regency, which covers an area of 13.14 sq.km. or 0.21 percent. In detail, the data of the district administration area contained in the boundaries of the Saddang watershed is informed in Table 2 and Figure 7.

Table 2: Saddang Watershed Area

Province	Regency/City	Area	Percent
		(sq.km.)	(%)
South Sulawesi	Enrekang	1,084.89	16.99
	Luwu	27.41	0.43
	Palopo	4.72	0.07
	Pinrang	797.76	12.50
	Tana Toraja	3,021.70	47.33
West Sulawesi	Mamuju	13.14	0.21
	Mamasa	1,417.80	22.21
	Polewali Mandar	16.58	0.26
	Total	6,384.00	100.00

Data in Table 2. Extracted in the form of a graph, shown in Figure 7.

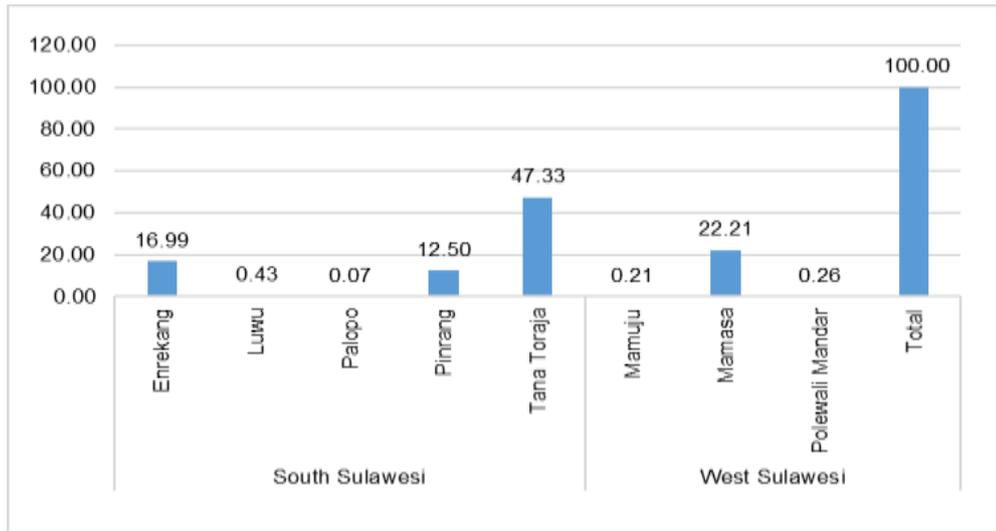


Figure 7. Area Percentage of the Saddang Watershed

### 3.2 Upstream and Downstream of the Enrekang Urban Area

The Saddang watershed is divided into 3 sub-watersheds. The first sub-watershed (SW-1) represents the downstream part of the urban area, while the second sub-watershed (SW-2) and the third sub-watershed (SW-3) represents the upstream part of the Enrekang urban area. Shown in Figure 8.

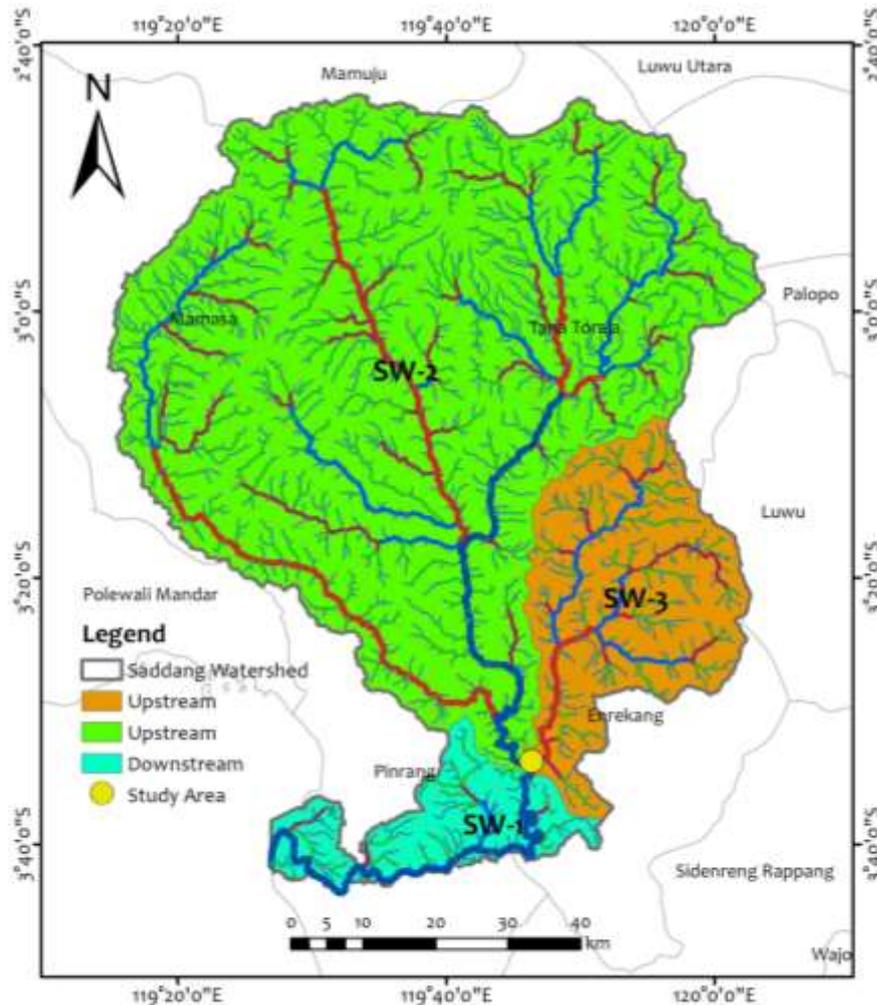


Figure 8. Upstream and Downstream of the Enrekang Urban Area

SW-1 is the downstream part of the Saddang watershed, SW-2 and SW-3 are the upstream part of the Saddang watershed. SW-3 is the Mataallo sub-watershed. SW-2 and SW-3 are areas that affect flooding in the Enrekang urban area with an area of 5,930.77 sq.km. Meanwhile, SW-1 which is downstream has no effect on flooding in urban areas with an area of 453.23 sq.km. Information about the area of the Saddang watershed in the upstream and downstream is shown in Table 3.

Table 3. Area of Upstream and Downstream of the Enrekang Urban Area

Province	Regency/City	Upstream	Downstream	Upstream	Downstream
		Area (sq.km.)		Weighted (%)	
South Sulawesi	Enrekang	981.06	103.83	15.37	1.63
	Luwu	27.41		0.43	
	Palopo	4.72		0.07	
	Pinrang	448.36	349.40	7.02	5.47
	Tana Toraja	3,021.70		47.33	
West Sulawesi	Mamuju	13.14		0.21	
	Mamasa	1,417.80		22.21	
	Polewali Mandar	16.58		0.26	
	Total	5,930.77	453.23	92.90	7.10

Furthermore, there are 8 parts of the regency administration area that affect flooding in urban areas, namely Enrekang, Luwu, Palopo City, Pinrang, Tana Toraja, Mamuju, Mamasa, and Polewali Mandar Regencies, the administrative area is in the upstream part (SW-2 and SW-3). In terms of the area that affects floods, Tana Toraja Regency and Mamasa Regency are the two areas that have a big influence on flooding in the Enrekang urban area, respectively by 47.33 percent and 22.21 percent. Meanwhile, in the downstream part (SW-1), there are only 2 regencies, namely Enrekang Regency and Pinrang Regency. This area has no effect on flooding in urban areas. In detail, the percentage of areas affected by flooding in the Enrekang urban area, is shown in Figure 9.

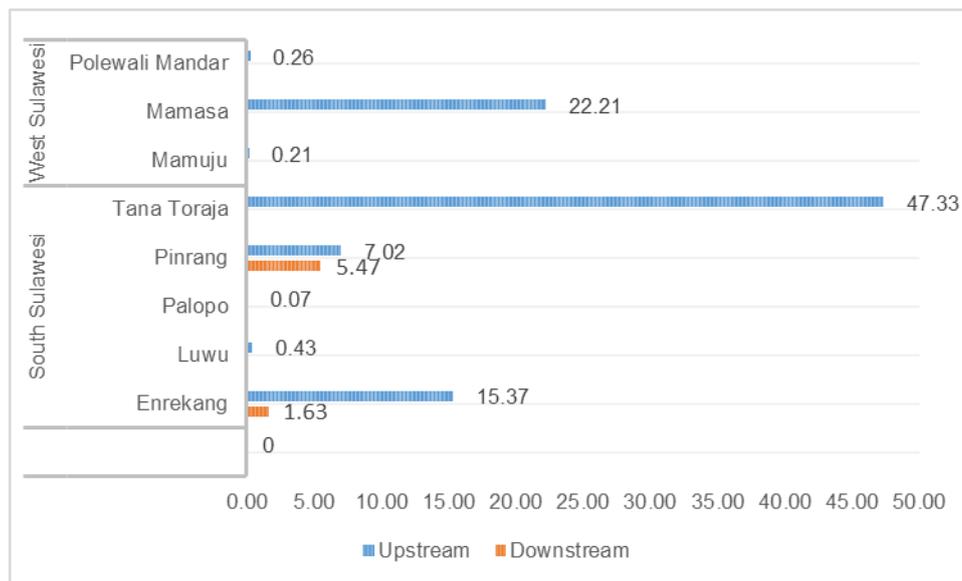


Figure 9. Percentage Area of Upstream and Downstream of the Enrekang Urban Area

### 3.3. Watershed Morphometric Characteristics

The morphometric characteristics of SW-1, SW-2, and SW-3 were obtained using spatial analysis and mathematical formulas. The parameters found based on spatial analysis include perimeter (P), stream order (U), and basin area (A). Meanwhile, parameters such as elongation ratio ( $R_e$ ), circulatory ratio ( $R_c$ ), and ruggedness number ( $R_n$ ), are determined by mathematical formulas. In detail, the explanation of the morphometric characteristics of the three sub-watersheds are:

- Perimeter (P)**; It is the length of the circumference of the watershed and as a limiting polygon between the watershed or sub-watershed and other sub-watersheds. The data shows that the value of P is SW-1 = 170.00 km; SW-2 = 390.00 km; and SW-3 = 190.00 km. Perimeter can represent the size of a watershed.
- Basin length ( $L_b$ )**; is the length of the main river measured from the estuary to the farthest limit of upstream. In this study, the basin length of the three sub-watersheds (SW-1, SW-2, and SW-3) were measured based on upstream and downstream boundaries. Basin length SW-2 = 42.78 km; SW-2 = 163.69 km; and SW-3 = 67.17 km.
- Stream order (U)**; is a hierarchy of stream branches in the watershed, the smallest order (order-1) is in the upstream area and has no other branches that enter it. Stream order hierarchy of SW-1 = 7; SW-2

= 7; and SW-3 = 6 levels. The highest stream order hierarchy in SW-2 is the seventh order and is the main river of the upstream Saddang sub-watershed. Meanwhile, in SW-3, the highest hierarchy is the sixth order which is the main river of the Mataallo sub-watershed. There is a confluence point and the surrounding area that is affected by flooding when it rains. Flooding occurs if the capacity of the river is not enough to accommodate the large amount of flood discharge (Devianto et al., 2017). Stream order is an element of morphometric parameter, and can be used as an indicator to determine areas that are prone to flooding, watersheds in the sixth order with sub-dendritic to dendritic drainage patterns, susceptible to flooding and gully erosion from slow surface runoff (Ganie et al., 2024). In addition, SW-2 and SW-3 can be categorized as parallel watersheds, because they are composed of two sub-watershed branches and meet in the downstream (in the Enrekang urban area). Therefore, when it rains in the two sub-watersheds at the same time, there will be a relatively large flood (Naharuddin et al., 2018). Illustration of the confluents SW-2 and SW-3 is shown in Figure 10.

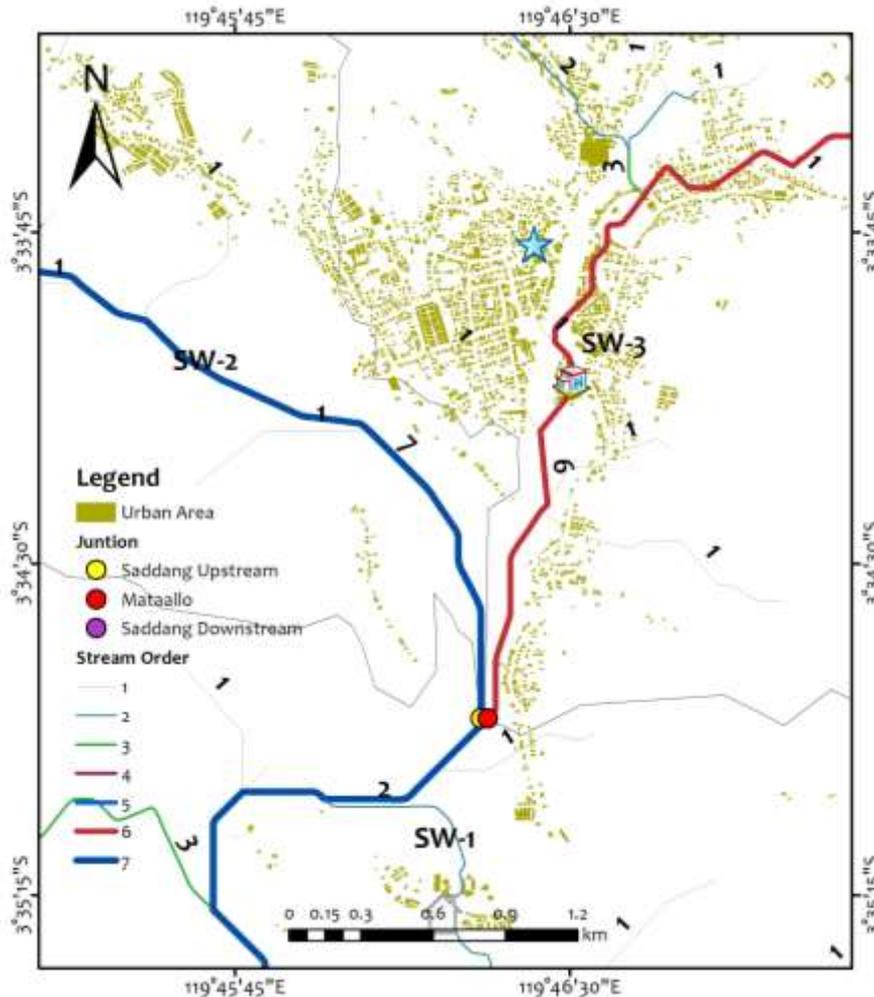


Figure 10. Confluents of Sub-Watershed (SW-2 and SW-3)

- d. **Total number of streams ( $N_u$ );** is the sum of all stream segments from the first order to the highest order. Value of SW-1 = 1,740.00; SW-2 = 19,012.00; and SW-3 = 3,978.00. This value is the accumulation of stream segments for each sub-watershed. SW-1 consists of first order to seventh order, SW-2 first order to seventh order, and SW-3 is calculated from first order to sixth order.
- e. **Stream length ( $L_u$ );** is the total length of a stream in a watershed or sub-watershed. stream lengths are accumulated from all levels of the stream order. Stream length SW-1 = 640.12 km; SW-2 = 6,454.63 km; and SW-3 = 1,344.76 km. The data showed that the stream length correlated with the physical size of the sub-watershed, the longer the stream length, the larger the size of the sub-watershed.
- f. **Mean bifurcation ratio ( $R_{bm}$ );** is a comparison between the number of stream segments in the first order with the second order  $R_b$  (1-2), the second order with the third order  $R_b$  (2-3). And so on to the highest order. In this study, the average bifurcation ratio was used to interpret the physical characteristics of each sub-watershed.  $R_{bm}$  value SW-1 = 3.27; SW-2 = 1.36; and SW-3 = 1.28. The  $R_{bm}$  value of SW-1 is at intervals of 3-5 which means that the geological control is moderate, while for

SW-2 and SW-3 it has values smaller than 3, indicating that the geological structure is relatively homogeneous. In addition, the  $R_{bm}$  value of  $<3$  indicates that the stream channel has a rapid rise in flood water levels, while the decline is slow (Nifen et al., 2017).

- g. **Basin area (A)**; is an area bounded by a topographic ridge that functions to receive, store, and drain surface water through tributaries to rivers and empties into lakes or in the sea. Basin area SW-1 = 461.60 km<sup>2</sup>; SW-2 = 4,901.01 km<sup>2</sup>; and SW-3 = 1,021.39 km<sup>2</sup>. The basin area determines the volume of runoff that occurs when it rains. The larger the basin area, the greater the potential for flow discharge. Data shows that there are 8 regencies that are included in the boundaries of the Saddang watershed, including Luwu, Mamasa and Tana Toraja. There are three district capitals located in the upstream of the Saddang watershed, namely Mamasa, Rantepao, and Makale. In the Mamasa sub-watershed, the land cover has changed, the most dominant of which occurs in changes in dry agricultural land cover, this condition reduces the quality of the sub-watershed (Soma et al., 2023). In addition, in other research it is stated that there will still be a decrease in forest cover and a significant increase in agricultural land in the Mamasa sub-watershed in 2026 and 2031 (Utami A et al., 2025). Likewise, in Rantepao, Tana Toraja Regency, the city is developing along with population growth, the need for housing is increasing and causing the conversion of agricultural and plantation land into residential areas. Changes in land use in the urban area of Rantepao have had an impact on increasing flood discharge (Sriwati, 2014). Based on the watershed characteristics identification guidelines, the area of the Saddang watershed is 6,384.00 sq.km. classified as large watersheds, for SW-2 and SW-3 are classified as medium watersheds (Nifen et al., 2017).
- h. **Drainage density ( $D_d$ )**; is the ratio of the total length of the stream segment to the area of the watershed. The ratio indicates the level of density of the flow network.  $D_d$  value SW-1 = 1.39 km/km<sup>2</sup>; SW-2 = 1.32 km/km<sup>2</sup>; and SW-3 = 1.32 km/km<sup>2</sup>. Drainage density ( $D_d$ ) of  $<2$  km/km<sup>2</sup> means very coarse or low category (Malik et al., 2019). Low  $D_d$  value, small sediment transport because the stream channel passes through rocks with hard resistance (Astuti et al., 2021).
- i. **Length of overland flow ( $L_o$ )**; is the average distance traveled by rainwater runoff as a surface flow before entering the nearest stream segment. The value of  $L_o$  SW-1 = 0.36 km, while for SW-2 and SW-3 it has the same value of  $L_o$  = 0.38 km. The shorter the  $L_o$  value, the faster of runoff reaches the stream, on the other hand, if the  $L_o$  is longer, then the runoff flows on the surface is longer.
- j. **Stream frequency ( $F_s$ )**; is the number of stream segments in a watershed or sub-watershed per unit of area. This parameter measures how often the stream channel develops in an area.  $F_s$  value of SW-1 = 3.77/km<sup>2</sup>; SW-2 = 3.88/km<sup>2</sup>; and SW-3 = 3.89/km<sup>2</sup>.
- k. **Elongation ratio ( $R_e$ )**; is a morphometric parameter that functions to determine the level of elongation of a watershed.  $R_e$  value of SW-1 = 0.12; SW-2 = 0.06; and SW-3 = 0.09, the three sub-watersheds have several  $<0.5$ , so they are categorized as elongated.
- l. **Circulatory ratio ( $R_c$ )**; is a morphometric parameter that classifies the degree of roundness and shape of a watershed. The data shows that the value of  $R_c$  SW-1 = 0.20; SW-2 = 0.40; and SW-3 = 0.36. The  $R_c$  value of the three sub-watersheds is  $<0.5$ , so it is categorized as an elongated shape.
- m. **Texture ratio (T)**; is a morphometric parameter used to determine the density of stream channels in a watershed. T value of SW-1 = 10.24; SW-2 = 48.75; and SW-3 = 20.94, the numbers are  $>8$ , so it can be stated that the three sub-watersheds have a very fine texture ratio.
- n. **Compactness coefficient ( $C_c$ )**; This parameter serves to determine how compact or rounded a watershed shape is.  $C_c$  value of SW-1 = 2.23; SW-2 = 1.57; and SW-3 = 1.67, the numbers are  $>1$ , so the shape of the sub-watershed is elongated. The elongated watershed causes the surface flow rate to be slower. Therefore, the water concentration is also slower (Astuti et al., 2021).
- o. **Basin relief ( $B_h$ )**; is the difference between the highest contour and the lowest contour in a watershed. The data show that the  $B_h$  value of SW-1 = 49.00 m; SW-2 = 2,600.00 m; and SW-3 = 3,200.00 m. The highest basin relief value is in SW-3.
- p. **Relief ratio ( $R_r$ )**; is the comparison between the difference in the maximum height of the relief basin with the length of the watershed.  $R_r$  value SW-1 = 0.001; SW-2 = 0.0016; and SW-3 = 0.048, the numbers are  $<1$ , so they are classified as low relief watersheds.
- q. **Ruggedness number ( $R_n$ )**; is a morphometric parameter that describes the level of topography roughness based on the combination of basin relief with drainage density. The data showed that the value of  $R_n$  SW-1 = 0.07; SW-2 = 3.42; and SW-3 = 4.21. The ruggedness number ( $R_n$ ) value at SW-2 = 3.42; SW-3 = 4.21 are categorized as an extreme number. A ruggedness  $<1$  means flat topography; a value of 1–2 indicates undulating topography, and the value of  $>2$  is categorized as extreme topography (Alam et al., 2021). High ruggedness number indicates steep slopes, and thus resulting in flash floods and erosion (Obeidat et al., 2021).

## 5. Conclusions

The Enrekang urban area is located on highland, but floods still hit when it rains. The flood disaster is influenced by the morphometric characteristics of the watershed located upstream of urban areas. In the morphometric linear aspect, namely stream order, there is a confluence of SW-2 and SW-3 in urban areas. The confluence is formed by two sub-watershed branches in the upstream part of the urban area, namely Saddang upstream (SW-2) and Mataallo sub-watershed (SW-3). These two sub-watersheds are parallel in shape. This condition causes flooding in the Enrekang urban area when it rains. In addition, the average bifurcation ratio ( $R_{bm}$ )  $<3$  in SW-2 and SW-3 means that the stream channel has a rapid rise in flood levels,

while the decline is slow. Characteristics of  $R_{bm}$  and stream order, each having an effect. The seventh stream order in SW-2 and the sixth stream order in SW-3 are the highest stream orders. The higher stream orders the greater the discharge received. In terms of morphometric area, SW-2 and SW-3 are moderate watershed classifications. The larger the watershed, the greater the potential for surface runoff produced. In addition, the factor of land use change greatly affects the change in the surface runoff coefficient in an area. In the upper reaches of the Sadding watershed, there are three district capitals that continue to develop. The need for housing and public facilities in urban and rural areas causes green areas as water infiltration to decrease. This will have an impact on increasing flood discharge. Furthermore, in the aspect of morphometric relief, the ruggedness values of SW-2 and SW-3, where value  $>2$  are categorized as extreme topography. High ruggedness number indicates steep slopes, and thus resulting in flash floods and erosion. Based on this morphometric data, the potential for flooding in the Enrekang urban area will continue to occur in the future. Therefore, stakeholders need to sit together to formulate development program policies. The alignment of RTRW (regional spatial plan) between provinces and districts is very necessary, so that human activities in the upstream part do not have an impact on flooding in the downstream part. For structural mitigation, dams on SW-2 and SW-3 are required for urban flood control functions.

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