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RESEARCH ARTICLE

Analysis Of River Ordo In The Tukad Balian Watershed (DAS), Bali Province, Indonesia

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Abstract

River order research in Tukad Balian Watershed, Bali Province uses ArcGIS Pro to process ASTER GDEM and National DEM data. The analysis is based on: the area and Perimeter of the Watershed, Watershed Length and Width, Land Slope, Average Height, Order and Level of River Branching. The results obtained for the Watershed show that the morphometric value is an area of 15485,20 hectares, a length of 23,08 km, a land slope of 0,40%, and 5 orders of branching rivers with a total of 665 river sections. The shape of Watershed Tukad Balian roundness index value is 7,2. GIS is an effective system for reducing Watershed morphometric information. The research method used is to directly calculate the morphometric parameters of the Tukad Balian Watershed, Bali Province, namely: Area and Perimeter of the Watershed; Watershed Length and weight; River slop or gradient; Average Height; Order and Level of River Branching; Flow Density; and Watershed Form. The conclusion obtained is: The Tukad Balian watershed is a standard-sized watershed with an area of 15.485,20 Ha an average height of 200 meters above sea level and the main river channel is 10,71 Km long. There a plot sections with a total length of 23,08 Km; The elongated shape of the Tukad Balian watershed is in the medium category, where the Tukad Balian Watershed will not experience major flooding.

Keywords: Morphometry, Tukad Balian River, GIS, and Medium Category.

1. Introduction

1.1 Sub Introduction

A watershed (DAS) is defined as a land area that constitutes one with the river and the children the river serves to accommodate, store, and channel source water from rainfall to lakes or seas naturally, and the land boundary is the divider topography and boundaries at sea to water areas that are still affected land activity (Government Regulation No. 37/2012 in Denaswidhi, 2020). Because it is formed and limited naturally by topographic boundaries in the form of ridges hills, and valleys then watershed rivers will respond differently to water input, in this case, rainfall enters the watershed area. Every watershed has different geophysical characteristics due to differences in topography that exist in an area, this means the hydrological conditions in the watershed, will also be different such as debit conditions flow or flood discharge, erosion, and sedimentation in the watershed area.

The morphometry of the river basin is a quantitative measure of a geomorphological aspect of the watershed area which is a natural factor that cannot be changed by humans and plays a role in processing rainfall input into surface flow. Kahirun, *et al*., (2017) say that characteristic morphometrics greatly determine the behavior of water (hydrology) in a watershed such as runoff surface, infiltration, groundwater reserves, and flood inundation behavior. Flood incidents lately often happen apart from influence weather and climate conditions are also influenced by the morphometry of the watershed itself, for example in determining the time the flow concentration becomes floods are influenced by the shape of the watershed and its length flow and average slope of the watershed that can be obtained through watershed morphometric analysis. The morphometric analysis. The morphometric aspects of watersheds are static and cannot be changed by human activity because it is formed from geomorphological processes of land. Assessment of watershed morphometric characteristics is very important as a basis for watershed-based regional management.

Tukad Balian has a width of ±20 meters and the river area (DAS) is around 149 km^2, the average water discharge is 7,80 m^3/s, and the head (height) is 35,56 m (SSM, 2013 in Suharthama, *et al*., 2015). The Tukad Balian watershed (DAS) is one of the region's river flows on the island of Bali. The flow area passes through the Tabanan Regency area with the highest land at the top of Batukaru Mount. The Tukad Balian watershed has an area of 152,9 km^2. All of these river basins are located in Tabanan Regency. The mouth of this river is in Surabrata, Lalanglinggah Village, District West Selemadeg.

Extraction of information on regional characteristics of river flow, in this case, the Tukad Balian Watershed directly using measurements from terrestrial fields will certainly require enormous energy, time, and costs, so a method of acquisition is needed fast and easy watershed morphometric data applied. Currently, this can be done

with System Information Geographic, which utilizes remote sensing images as a digital elevation model (DEM) as input data. Purwanto (2013) in Denaswidhi (2020) said that with the availability of surface elevation models digital Earth or digital surface model (DSM) and Geographic Information System (GIS), watershed properties can be extracted using the procedure automatically. Nowadays, DEM data and GIS software are easy to get online, making things easier for the community, particularly practitioners, academics, and planners in watershed management activities. This article will briefly discuss the morphometric characteristics of Tukad Balian Watershed derived from processing DEM data using GIS software.

This study is intended to find out morphometric characteristics of the Tukad Balian Watershed automatically utilizing GIS software which aims to obtain value watershed morphometric parameters in the form of area and circumference of the watershed, length, and width of the watershed, the slope or gradient of a rover, its average height watershed, river order, channel density, and watershed form.

2. Materials and Methods

a. Data Material

The data used in this study are between other ASTER GDEM Digital Image Version 2.0, websites: (https://gdemdl.aster.jspacesystems.or.jp/index_en.html) for the Bali Island area with a resolution of 30 meters, and Boundary Watershed Map by the PEPDAS Directorate Ministry of Environment and Forestry (2018). ASTER GDEM is a digital elevation model (DEM) data that can be used to estimate the mass flow of water that may occur in river basins during high rainfall. This DEM data can be used as a basis for modeling which uses modeling basis in the form of the topographic conditions of the river basin.

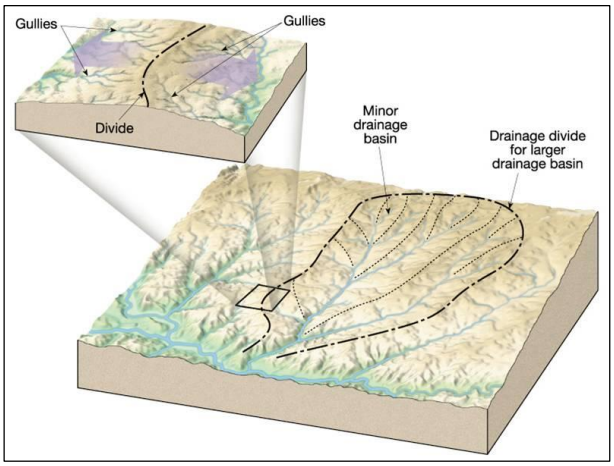

Fig 1. Boundaries of a Watershed Area (Purwanto, 2013 in Denaswidhi, 2020).

b. Research Sites

The study location in this study is the Tukad Balian Watershed area on the Island Bali at coordinates (zone UTM projection WGS 1984) 8º 29' 50'' S - 115º 6' 0'' E.

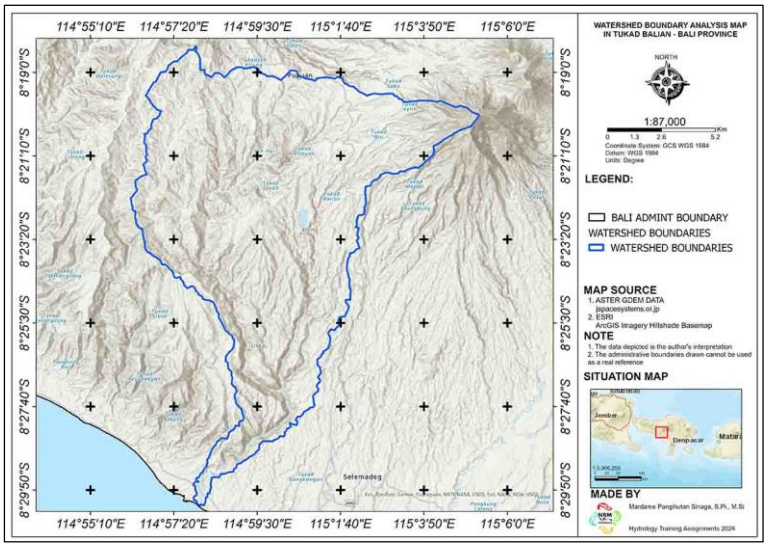

Fig 2. Tukad Balian Watershed Location.

c. Work Procedure

The morphometric parameters of the Tukad Balian Watershed that will be derived in this study are the area and circumference of the watershed; the Watershed length and width; the slope or gradient of a river; Average height of the watershed; Order or level of river branching; the flow density (flow) and shape of the watershed are explained as follows:

1). Area and Circumference

The watershed circumference is the length of the boundary line watershed which is a ridge or earth's surface mountains in meters or kilometers (km), while the watershed area is the area included in the circumference DAS (in Ha or Km^2).

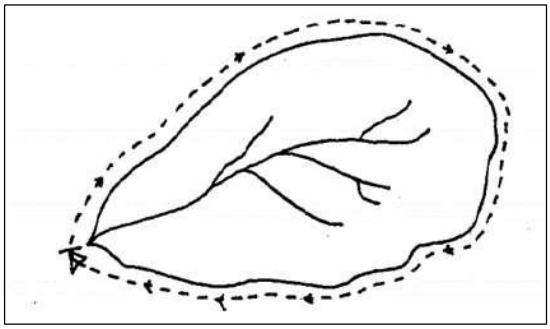

Fig 3. Illustration of the watershed circumference (Murtiono, 2001 in Denaswidhi, 2020).

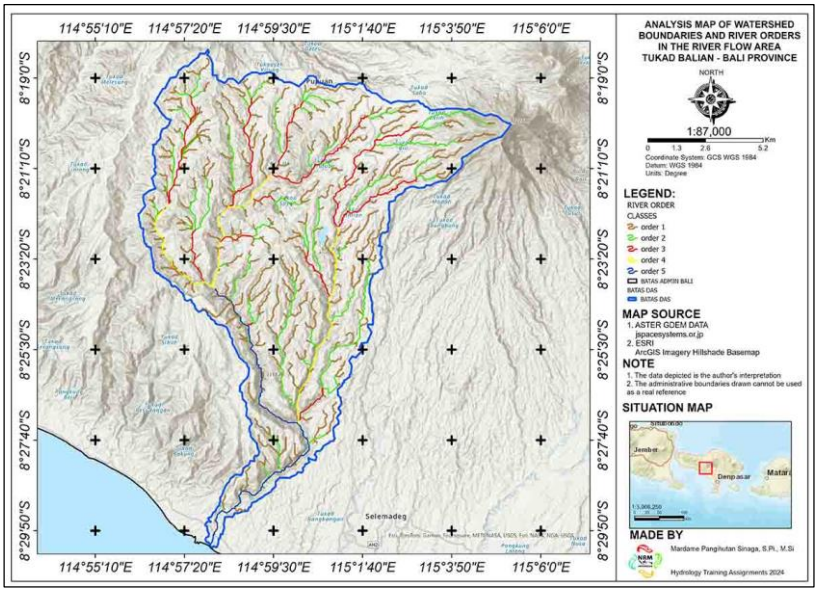

Fig 4. Map of River Orders Strahler and Watershed Boundaries.

2). Watershed Length and Width

The watershed length is the furthest distance measured from the outlet to the watershed boundary in the section upstream (meters or km) (Murtiono, 2001 in Denaswidhi, 2020). The watershed width is determined using the following formula (Seyhan,1977 in Purwanto, 2013 in Denaswidhi, 2020).

$$W = A/Lb$$

Information:

W = Watershed Width (km)

A = Watershed Area (km²)

Lb = Length of the main river (km)

3). Land Slope

The slope or land slope is a percentage comparison between vertical distance (height of land) with horizontal distance (length of flat land). The sloping of the land slope, then the potential for flooding to occur, and vice versa. The slope is steeper, then safer from flood disasters. Table 1compiled for giving values for land slope parameters.

Table 1. Slope Classification Score

Classes	Slope (%)	Description	Value
I	0-8	Flat	5.00
II	8-15	Sloping	4.00
III	15-25	A Bit Steep	3.00
IV	25-45	Steep	2.00
V	>45	Very Steep	1.00

4). Average Height

The height (elevation) of land is a measurement of the location height above sea level. Height influence on the occurrence of floods. The lower the area, then the potential for flooding to occur, and vice versa. The higher the area, the safer from a flood disaster. Table 2, compiled assigning values to elevation parameters.

Table 2. Land Height/Elevation Classification

Number	Elevation (m)	Value
1	< 10	5
2	10 - 50	4
3	50 - 100	3
4	100 - 200	2
5	> 200	1

Source: Theml (2008) in Darmawan, *et al*., (2017).

5). Order and River Branching Level

The river order is the branching position of river flow in sequence relative to the river parent in water (Murtiono, 2001 in Denaswidhi, 2020). There are many methods of determining river order such as Strahler, Horton, Shreve, and Scheidegger. This method used Strahler because it is easier to apply and integrate with various software GIS. The number of river channels of a later order is used as a basis for determining the value branching level index (bifurcation ratio) river through

$$Rb = \frac{N_n}{N_{u+1}}$$

Meanwhile, the value of the river branching level for a watershed is determined by calculating the weighted average river branching level.

$$W_{Rb} = \frac{\sum Rb_{\underline{u}+1}(N_u + N_{u+1})}{N_u}$$

Information:

Rb = River branching level index

N_u = Number of tiver paths for order the u

N_{u+1} = Number of tiver paths for order the u+1

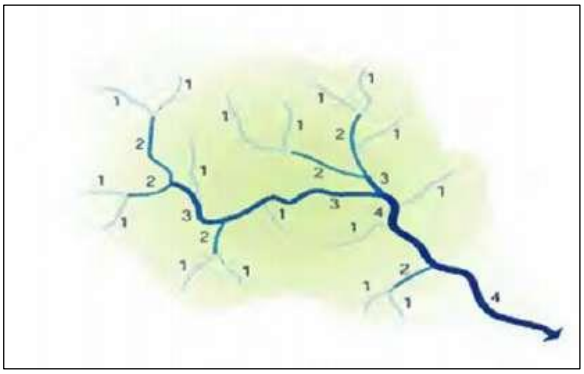

Fig 5. Determination of river order Strahler Method (Purwanto, 2013 in Denaswidhi, 2020).

The value of the river branching level can describe the hydrological conditions of a stream river in a watershed where:

- Rb < 3, the river channel has a rise the water level flooded quickly meanwhile the decline is slow.

- Rb 3-5, the river channel has a rise the flooded water level is not too fast or too slow.
- Rb > 5, the river channel has a rise in flood water level also with a rapid decline in flood water levels.

6). Flow Density

The density of the river flow (channel) is an index number that shows the number of tributaries in a watershed (Murtiono, 2001 in Denaswidhi, 2020). The flow density also reflects the average river length relative to the watershed area. To get the density index value flow needs to know the length of each segment flow in each river order. The flow density is obtained via the equation:

$$Dd = \frac{Ln}{A}$$

Information:
Dd = groove density (m/km²)
Ln = total groove length (m)
A = Watershed area (km²)

Mark the groove density index then classified as follows:

- Dd < 0,25 km/km² Low Category
- Dd 0,25-10 km/km² Medium Category
- Dd 10-25 km/km² High Category
- Dd > 25 km/km² Highest Category

Based on the limitations of this classification value, Murtiono (2001) in Denaswidhi (2020) explain that:

- Low Dd value, the rover flows through rocks with hard resistance, then transports sediment carried by the flow the river is smaller when compared to the river channel that passes through rocks with resistance and is softer under other conditions which affects it the same.
- High Dd value, the river flows through impermeable rock, this situation will show that the rainwater flow will be greater if compared to an area with Dd low over the rocks the permeability is large.

7). Watershed Form

The watershed shape has a deep significance relationship with river flow, namely influencing the centering speed genre. Quantitatively, the watershed shape is difficult to determine because it has irregularities due to the influence of natural boundaries. The ratio approach (index) circularity (circularity ratio) using the equations:

$$Dd = \frac{4\pi A}{P^2}$$

Information:
Rc = Roundness Ratio
A = Watershed Width (km²)
P = Watershed Circumference (perimeter) (km)

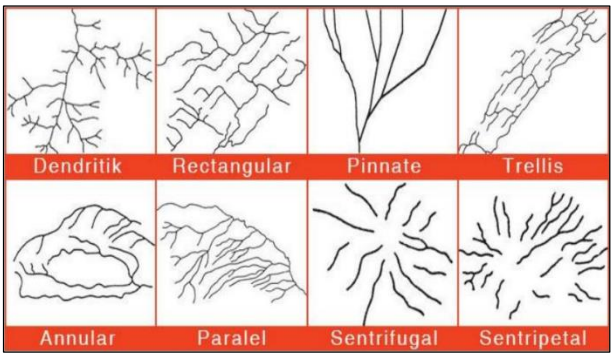

Fig 6. River Flow Patterns.

In simple terms, if the roundness index value (Rc) > 0,5 then a watershed is said to be shaped rounded, and if the Rc value < 0,5 then the watershed tens to have an elongated shape or leaf shape. The more rounded shape of the watershed has its time faster flow concentration in comparison the watershed is elongated because it is a rounded shape has risks higher flood events.

d. Data Processing

ASTER GDEM version 2.0 with 30-resolution and National DEM digital image data, website: https://tanahair.indonesia.go.id/demnas/#/demnas for the Bali Island area has model height information used in this study with the Watershed Boundary Map issued by the PEPDAS Directorate as a reference for drawing Tukad Balian Watershed Boundaries.

Based on the later watershed boundary map of ASTER GDEM and National DEM image data is processed cropping to get the watershed area Tukad Balian is the study area.

Next, the adjustment process is carried out by map projection using Universal Transverse Mercator (UTM) projection where the West Nusa Tenggara region is in the zone WGS 1984. Projection adjustment using UTM projections in this study is intended so that image and map data processing can be done more easily because it uses distance units (meters). After all, the UTM projection is wrong a projection system that uses a base distance.

The next process is the application of the function *Fill Sink* for used DEM Data. Function *fill sink* eliminates *depression* or *sink*, namely conditions where there is an elevation difference which is striking with coverage small, for data processing in scope this hydrology can interfere with calculations then it needs to be removed first (Purwanto, 2013 in Denaswidhi, 2020).

Next, ASTER GDEM DATA and National DEM are used for determining height and topographic information using ArcGIS Pro software, in this case, the author uses ArcGIS Pro.

Calculation of morphometric parameters continued use of the device number processing software after obtaining the data required.

3. Result and Discussion

Morphometric characteristics of the Tukad Balian Watershed through digital image data processing ASTER GDEM version 2.0 and National DEM can be done using current GIS software, so obtaining information data regarding the watershed will be easier to do.

The Tukad Balian Watershed area obtained by automatic calculation of watershed boundary geometry is 15.485,20 hectares, with a circumference of 75,82 km, and a width of 14,42 km, a length of 23,08 km.

The length of Tukad Balian Watershed from the watershed outlet until the upstream part of the watershed reaches 2,08 kilometers. Watershed length calculations do not include river flow watershed bodies and are a flat distance calculation. Temporary watershed width calculated by equation width of watershed (W) reaches 14,42 kilometers. Watershed Wide does not describe the width of each watershed segment but is an average of the entire Watershed Tukad Balian area. As can be seen in Figure 4 Watershed Tukad Balian area tends to narrow and lengthen from middle to downstream.

The slope or gradient of a Watershed Tukad Balian is obtained by calculating the height difference on the main river. The use of DEM imagery makes it easier to obtain altitude information flow due to each pixel in the image DEM represents the height of a thing region. The length of the main flow (Lb) of Watershed Tukad Balian is 1073,87 kilometers downhill from the river branching segments in the Watershed Tukad Balian.

Table 3. Watershed Tukad Balian Characteristics-Bali Province.

Watershed Characteristics			
Area (Hectares)	Circumference (Km)	Width (Km)	Length (Km)
15485.20	75.82	14.42	23.08

In Table 4, the characteristics of the river channel in the Tukad Balian Watershed have a branching index (Rb) of 7,2, meaning that the river channel has a rapid rise in flood water level as well as a rapid decrease in flood water level. The length of the river is 349,25 with a density index (Dd) of 2,26 km/km^2. The density index (Dd) value is included in the medium category, which means water flow in the Tukad Balian Watershed area passes through rock with little resistance so that the sediment load and the possibility of being transported is quite high.

Table 4. River Flow Characteristics.

Watershed Characteristics				
Branching Index (Rb)	Length Total (Km)	Density Index (Dd) (Km/Km^2)	Watershed Form (Rc)	River Pattern
7.2	349.25	2.26	0.34	Dendritic

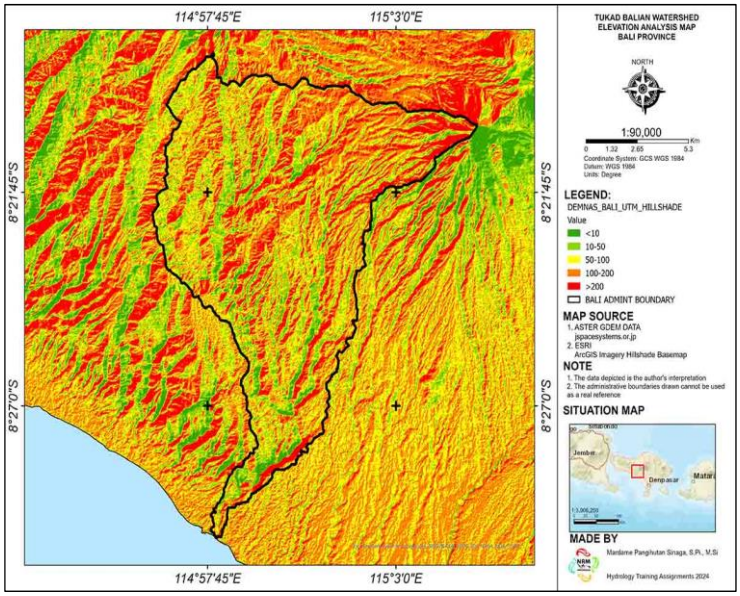

Fig 7. Bali Elevation Analysis Map.

From Figure 7, it can be seen that the elevation of Tukad Balian Watershed is in the rather steep category where it dominates the entire land. Apart from that, the elevation of Tukad Balian Watershed is also in the steep and very steep categories, meaning it is not very significant.

Based on Figure 7, explains that the Tukad Balian Watershed has rather steep and very steep elevations with values of 50-100 and >200 meters above sea level. This does not have the potential for flooding to occur floods due to the elevation of higher areas, so there is no flooding.

Table 5. Land Height/Elevation Classification Score.

Number	Elevations (m)	Scores	Values	Elevation Scores
1	< 10	0.10	5	0.50
2	10-50	0.10	4	0.40
3	50-100	0.10	3	0.30
4	100-200	0.10	2	0.20
5	> 200	0.10	1	0.10

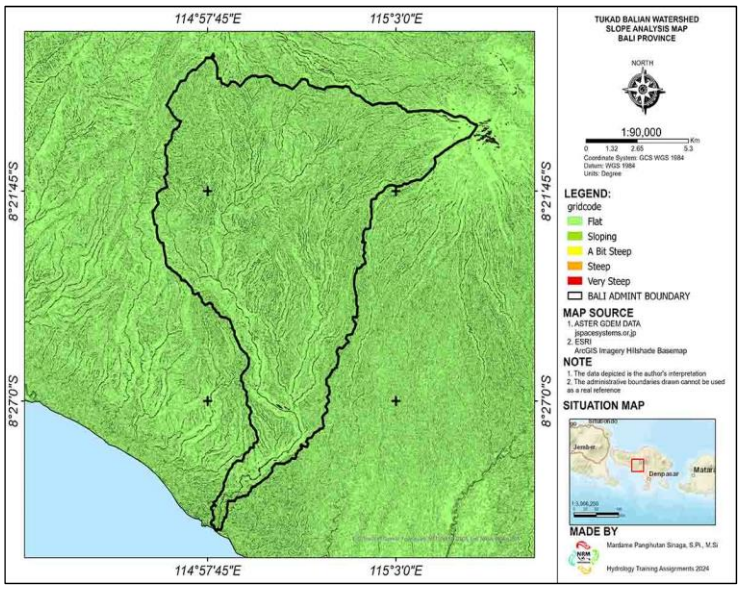

Fig 8. Tukad Balian Watershed Slope Map.

Based on Table 6 for Figure 8, the Tukad Balian Watershed has a sloping category with a slope percentage of 8-10%. The sloping category is the most dominant throughout the land, even the Tukad Balian Watershed. This means that there is a high potential for flooding because this area tends to be flat which can become a reservoir for rainwater.

Table 6. Classification Slope

Classes	Slope (%)	Classification	Score Value
I	0-8	Flat	20
II	8-15	Sloping	40
III	15-25	A Bit Steep	60
IV	25-45	Steep	80
V	>45	Very Steep	100

Table 7. Weighting Factor for Each Parameter Flood Vulnerability

Number	Parameters	Score
1	Land Slope	0.20
2	Altitude Class	0.10
3	Soil Texture	0.20
4	Rain Fall	0.15
5	Land Use	0.15
6	River Density	0.10

Source: Purnama (2008) in Darmawan, *et al*., (2017).

Order of rive branching in the region Tukad Balian Watershed obtained 5 orders in Strahler's method is the sum of the segment length of all orders that reaches 349.249,64 meters with a total of 665 segments genre. The results of the river branching index analysis weighted (W_{Rb}) in the Tukad Balian Watershed is 5,45 which can be interpreted that in the Tukad Balian Watershed, the flood water level area will rise rapidly with a slow decline, this can be the first step in watershed management, especially for flood disaster mitigation. Level river branching in the Tukad Balian Watershed such as can be seen in Table 8.

Table 8. Order of River Branching in the Tukad Balian Watershed.

	Characteristics Of River Orders (Strahler)		
River Order	Number of Streams	Length Total (Meters)	Biforcation Ratio (Rb)
1	336	178257.34	2.21
2	152	85913.77	1.65
3	92	44727.52	1.80
4	51	22969.55	1.50
5	34	17381.46	

The shape of Watershed Tukad Balian (Rc) is elongated/leaf-shaped with a value of 0,34, while the pattern is Dendritic. With watershed form that extends concentration time flow in the Tukad Balian Watershed area is not very good quickly become a flood with paying attention to rainfall conditions and gradients slope of the Tukad Balian Watershed. Tukad Balian Watershed shape elongated ones can also be associated with watershed width (W) as stated above, the average width of the watershed as a whole it's not very high.

The quantitative value of measuring parameters - Watershed Tukad Balian morphometric parameters can be derived from DEM digital image data and Geographic Information Systems so it can obtain a general picture of the condition of the Tukad Balian Watershed from land morphology aspect for need further planning example land use analysis, watershed hydrological analysis, determining the suitability of land for an area certain uses and disaster mitigation especially floods and landslides. Further, with the use of GIS depiction of a watershed can be visualized in map form, namely Figure 9 to provide more understanding for people who don't know the watershed concept easily.

Table 9. Watershed Tukad Balian Morphometric Parameters

Watershed Morphometric Parameters		Value	Units
Area	A	154.852	Km^2
Circumference	P	75.82	Km
Length	Ln	10.71	Km
Width	W	14.46	Km
Main Line Length	Lb	10.71	Km
Watershed Slop	-	0.40%	%
River Branching	W_{Rb}	5.45	-
Groove Density	Dd	2.26	Km/Km^2
Watershed Shape Index	Rc	0.34	-

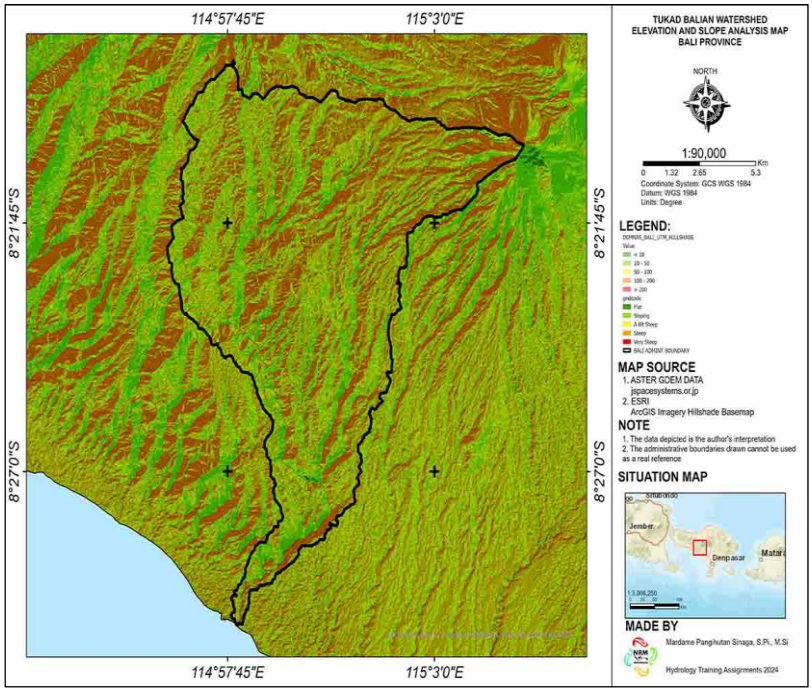

Fig 9. Tukad Balian Elevation and Slope Map.

Conclusion

Results of morphometric analysis of the Watershed Tukad Balian from ASTER GDEM digital data using ArcGIS Pro conclusions can be obtained as follows: Watershed Tukad Balian is a standard-sized watershed with an area of 15485,20 ha with an average of 200 meters above sea level and main river channel has 10,71 kilometers. There are 18956 plot segments in total length reaching 23,08 kilometers. Watershed Tukad Balian shape is elongated based sphericity index approach and has a value of 0,34. River channel density in Watershed Tukad Balian is in the medium category with a value flow density of 2,26 km/km^2. GIS is a system that is effective and easy to use in deriving watershed morphometric information from DEM image digital data for an activity more watershed planning and management carry on. The elongated shape of the Tukad Balian Watershed is in the medium category, where the Tukad Balian watershed will not experience major flooding.

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