Morphometric Analysis for Sustainable River Management: A Case Study of Ciujung Watershed, Banten, Indonesia

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Abstract. Ciujung watershed is located in Banten province, Indonesia. The Ciujung watershed is one of the watersheds that have a significant area coverage, such as Serang, Lebak, and the eastern part of Pandeglang. These areas are developing both in terms of population growth and infrastructure. Therefore, a more in-depth study of the Ciujung watershed, namely morphometric studies, is needed to optimize the utilization of the river's renewable natural resources and mitigate potential flood hazards in the watershed area. The method used is remote sensing based on DEMNAS satellite data using QGis software. The parameters analyzed were watershed shape, watershed area, river branch ratio, and river density. The results show that the Ciujung watershed is divided into 14 sub-watersheds. In general, the sub-watersheds have a bird feather shape, and some are radial and parallel, which causes some research areas to be very at risk of flooding. From the condition of river branching, most areas are unaffected by deformation. A small part of the deformed area occurs in the middle area of the Ciujung watershed. This is interpreted to be related to tectonic activity. The drainage density shows that the Ciujung watershed is based on resistant rocks and materials, so it is easily eroded and causes siltation of the river in the downstream area, which can trigger flooding.

1 Introduction

Morphometric analysis is a crucial aspect of studying river basins and watersheds. It involves the measurement and analysis of various parameters related to a basin's size, shape, relief, and drainage. These parameters provide valuable information about the hydrological characteristics of the watershed, which is essential for sustainable river management. By understanding the morphometric characteristics of a watershed, land use planning, soil and water conservation, and soil erosion can be effectively addressed [1].

Morphometric analysis is the measurement and mathematical analysis of the configuration of the earth's surface, shape, and dimension of its landforms [2]. It helps evaluate the basin's overall shape and its characteristics, such as stream order, stream length,

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drainage density, and relief ratio. These parameters play a significant role in understanding the hydrological behavior of the watershed, including factors like infiltration, runoff, erosion, and sediment transport. Furthermore, morphometric analysis allows for identifying areas prone to flooding or erosion, helping design and implement appropriate soil and water conservation practices for sustainable river management [1]. By utilizing remote sensing and GIS techniques, morphometric analysis can be conducted more efficiently and accurately. In the case study of the Ciujung watershed in Banten, Indonesia, morphometric analysis was conducted using GIS techniques to assess the watershed's physical characteristics and determine its susceptibility to flooding, erosion, and other hydrological processes. The study area's drainage patterns were mainly dendritic to sub-dendritic, indicating a well-developed and interconnected network of streams [3].

The selection of Ciujung Watershed in Banten, Indonesia, as a case study for this research is based on several factors. The Ciujung watershed in Banten, Indonesia, was chosen as the case study for this research due to its geomorphological characteristics and importance for sustainable river management in the region. The Ciujung watershed is covered by Tertiary-aged rocks in the southern or upstream part. The southern part, namely the middle and downstream parts of the watershed, is generally covered by Quaternary-aged volcanic deposits and alluvium. The Ciujung watershed is the most extensive in Banten province, with an area of 2190.5 Km2. It is characterized by its complex topography, high river flow velocity, and steep slopes, which make it prone to flooding. The watershed covers the area of Serang Regency, Lebak, and the eastern part of Pandeglang, Banten province (**Fig. 1**). The Ciujung watershed has a vital role as an essential water source for the study area. Furthermore, the watershed is also subjected to various anthropogenic activities such as deforestation, urbanization, and agriculture, further exacerbating land degradation risks and water pollution.

Fig. 1. The Ciujung watershed location

This study aims to conduct a morphometric analysis of the area around the Ciujung watershed to provide a better understanding of the area's characteristics and mitigate ongoing development. The results of this analysis are expected to help form opinions on environmental protection and regional development.

Preliminary analysis of river morphometrics in the context of ongoing river cleanup has been conducted globally. This study has a positive impact on our understanding of the physical characteristics of the Ciujung watershed and can help us design more effective and durable environmental policies.

2 Method

The method used in the research for measuring morphometry of the Ciujung River basin is a remote sensing method based on DEMNAS data, using QGIS and Microsoft Excel software. Parameters used in morphometric analysis include Watershed Area, Watershed shape, Bifurcation Ratio (Rb), and Drainage density (Dd).

2.1 Watershed Area

The watershed area is obtained from the maximum width of the watershed multiplied by the length of the main river. The higher the ratio of the watershed area to the length of the main river, the larger the river's drainage area.

2.2 Watershed shape

The drainage pattern is formed from a set of drainage channels in an area, either in the form of permanent rivers or not. The development of the drainage system is influenced by slope, rock type, rock thickness, vegetation, geological structure, and natural conditions. According to [4], there are several forms of watersheds: bird feathers, radial, parallel, and complex.

2.3 Bifurcation Ratio (Rb)

River order is the position of the branching of the river in the sequence against the main river watershed. The determination of river order uses the Strahler method [5]. Segments with no bifurcation are first order, then if two first order segments merge, a second order is formed, and so on.

2.4 Drainage density (Dd)

River density indicates the number of tributaries in a drainage area. Stream density is strongly influenced by the type of rock layer, infiltration capacity, and the rock layer's resistance to erosion. Drainage density (Dd) calculation parameter is obtained from the cumulative river length value divided by the watershed area. According to [6], the river density class (Dd) is classified into low, medium, high, and very high. In general, the research stages can be seen in **Fig. 2**.

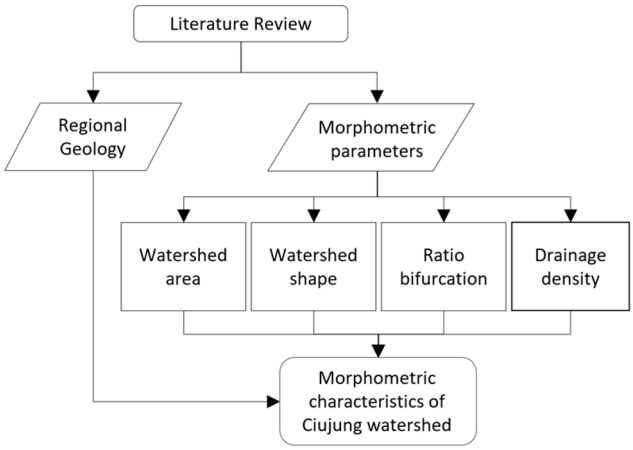

Fig. 2. Research flow chart

3 Result and discussion

3.1 Watershed Area

A watershed is a catchment area bounded by a ridge. The watershed area is also a unit used to analyze river conveyance density. The Ciujung watershed is divided into 14 sub-watersheds (**Fig. 3**). Large sub-watersheds are generally located in the southern or lower reaches of the river. The further downstream the sub-watershed area, the smaller it gets. Even in the downstream area of the main river, the calculation of the area of some sub-watersheds was not carried out because, based on observations, the drainage area has undergone changes in its river level, which community activities have influenced. **Table 1** shows the value of the area of each Ciujung subwatershed.

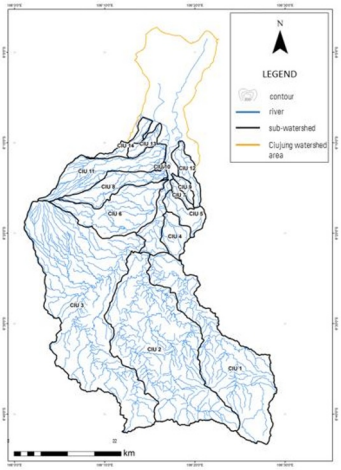

Fig. 3. Subwatershed division of Ciujung Watershed

Table 1. Area of Ciujung subwatershed

Subwatershed	Main River Length (km)	Watershed Area (km^2)
CIU 1	10,162	325,202
CIU 2	26,065	470,740
CIU 3	0,000	595,903
CIU 4	0,000	37,931
CIU 5	0,000	36,020
CIU 6	0,000	137,774
CIU 7	0,000	10,154
CIU 8	0,000	66,581
CIU 9	0,000	11,099
CIU 10	0,107	1,440
CIU 11	0,000	109,189
CIU 12	0,000	31,887
CIU 13	0,000	18,589
CIU 14	85,672	22,883

3.2 Watershed Shape

The determination of the Cisadane subwatershed's shape refers to the model's characteristics according to [5]. The watershed shape coefficient can be calculated by comparing the watershed area with the square of the main river length. Watersheds are divided into four types. They are birds' feathers, radial, parallel, and complex.

Most of the watershed shapes in the Ciujung watershed are radial and parallel (T**able 2**). The character of this watershed shape is that it has a relatively large water discharge at the meeting point of the tributaries, so it has the potential to cause flooding in the meeting point or downstream area of the subwatershed.

Table 2. Classification of subwatershed shape

Subwatershed	Subwatershed Shape
CIU 1	radial
CIU 2	radial
CIU 3	radial
CIU 4	radial
CIU 5	radial
CIU 6	radial
CIU 7	parallel
CIU 8	radial
CIU 9	parallel
CIU 10	parallel
CIU 11	radial
CIU 12	radial
CIU 13	radial
CIU 14	parallel

3.3 Bifurcation ratio (Rb)

Table 3. Bifurcation ratio of Ciujung watershed

Subwatershed	River Segment				Rb			Class
	Orde 1	Orde 2	Orde 3	Orde 4	Rb1-2	Rb2-3	Rb3-4	(Verstappen, 1983)
CIU 1	81	8	2	1	10.13	4.00	2.00	Deformed
CIU 2	161	14	3	1	11.50	4.67	3.00	Deformed
CIU 3	126	20	5	1	6.30	4.00	5.00	Deformed
CIU 4	6	2	1	0	3.00	2.00	-	Undeformed
CIU 5	4	1	0	0	4.00	-	-	Undeformed
CIU 6	18	5	2	0	3.60	2.50	-	Undeformed
CIU 7	2	1	0	0	2.00	-	-	Deformed
CIU 8	14	3	1	0	4.67	3.00	-	Undeformed
CIU 9	3	1	0	0	3.00	-	-	Undeformed
CIU 10	2	1	0	0	2.00	-	-	Deformed
CIU 11	29	6	2	1	4.83	3.00	2.00	Undeformed
CIU 12	8	2	1	0	4.00	2.00	-	Undeformed
CIU 13	6	1	0	0	6.00	-	-	Deformed
CIU 14	3	1	0	0	3.00	-	-	Undeformed

Table 3 shows the summary results of calculating (Rb) values for 14 sub-watersheds in the study area. From the data analysis of **Table 3**, it is found that this watershed belongs to the deformed area (Rb<3 atau Rb>5) and undeformed area (3<Rb<5) [6]. The deformed sub-watersheds are spread in the upper to middle reaches of the Ciujung watershed. It is interpreted that the study area's active tectonics control the watersheds' headwaters. However, deformed and undeformed refer to the morphological characteristics of the river. Although geological and tectonic changes can affect river morphology, the deformation seen through the bifurcation ratio refers more to the complexity and branching in the river pattern itself. Therefore, deformation in the bifurcation ratio may reflect geomorphological conditions more than the direct influence of tectonic events.

3.4 Drainage Density (Dd)

The results in **Table 4** show that the subwatershed has a very rough-to-rough drainage density, indicating that the study area is composed of resistant and quickly eroded rocks. The level of erosion occurring in the Ciujung subwatershed is relatively high, especially in areas underlain by young volcanic deposits.

Table 4. Drainage density map of the Ciujung watershed

Subwatershed	Main River Length (km)	Watershed Area (km^2)	Drainage Density (Dd)	Class (Sukiyah, 2009)
CIU 1	10,162	325,202	0,031	Very rough
CIU 2	26,065	470,740	0,055	Very rough
CIU 3	0,000	595,903	0,000	Very rough
CIU 4	0,000	37,931	0,000	Very rough
CIU 5	0,000	36,020	0,000	Very rough
CIU 6	0,000	137,774	0,000	Very rough
CIU 7	0,000	10,154	0,000	Very rough
CIU 8	0,000	66,581	0,000	Very rough
CIU 9	0,000	11,099	0,000	Very rough
CIU 10	0,107	1,440	0,074	Very rough
CIU 11	0,000	109,189	0,000	Very rough
CIU 12	0,000	31,887	0,000	Very rough
CIU 13	0,000	18,589	0,000	Very rough
CIU 14	85,672	22,883	3,744	Moderate

4 Conclusion

The conclusions of this study include Ciujung watershed is divided into 14 sub-watersheds. The shape of the Ciujung subwatershed generally is radial and parallel. The characteristic of this watershed shape is that it has a relatively large water discharge at the meeting point of the tributaries. Based on the bifurcation ratio, the Ciujung watershed area is generally deformed. This indicates that the watershed system has undergone morphological changes that control the branching and pattern of the existing river. This deformation is not only influenced by tectonics but can also be influenced by exogenous processes that change the morphology of the Ciujung watershed. The calculation of drainage density produces a rough to very rough value. This indicates that the research area is composed of resistant and quickly eroded rocks. Based on the parameters of watershed shape, Rb, and Dd, the meeting area of river branches, the main river, and the area around the downstream of the river has very

potential for flooding due to high water discharge (in the rainy season) and siltation of the river due to the accumulation of sediment from the erosion of the upstream area.

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