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WATERSHED MORPHOMETRIC CLASSIFICATION ANALYSIS USING GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT: One of the important physical characteristics of watersheds is morphometry. Watershed shape is one the earth surface morphometric features. The watershed shape has a strong relation with the characteristic peak discharge and land erosion. Therefore, the watershed shape due to the strong relation between watershed shape and peak discharge and land erosion must be classified. Watershed shape can be classified based on morphometric analysis from the perspective of linear, areal, and relief aspects. In this paper the watershed located at Serayu-Bogowonto river basin was classified into four categories based on areal aspect. The areal aspects used to classify the watershed included Gravelius's index, form factor, shape index, shape factor, circularity ratio, elongation ratio, and compactness coefficient. Four categories of watershed shapes (circular, oval, semi-oval, and elongated) were applied in this research. Seventeen watersheds at Serayu-Bogowonto river basin were selected as samples in the classification process. The Geographical Information System (GIS) technique was applied to generate watershed geometric properties such as, river length, watershed perimeter, area, diameter, and watershed length. Based on the analysis process, watersheds with broad and wide shape were difficult to classify. Such watersheds can be classified as circular, oval, semi-oval, and elongated. Finally, these watersheds can be classified under one category based on morphometric analysis results combined with the watershed figure. From the 17 watersheds, 5 were classified as circular, 3 as oval, 5 as semi-oval, and 4 as elongated shapes. GIS is a powerful tool for the analysis relating to watershed morphometric parameters.

Keywords: Morphometric, Elongation ratio, Form factor, Shape factor, Circularity ratio

1. INTRODUCTION

The drainage basin or watershed physical characteristic analysis is important in any hydrological investigation, such as assessment of soil erosion, runoff discharge, and land critical analysis. Morphometry is one of the important physical characteristics [1]. Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth's surface, shape, and dimension of its landform [2-5]. With this definition, watershed shape is considered one the earth's surface morphometric properties. A watershed is an area whose major surface runoff is conveyed to a single outlet and is the appropriate unit to study land surface processes [6]. In general, watersheds can be classified based on morphometric analysis of the following aspects: linear (one dimension), areal (two dimensions), and relief (three dimensions) aspects. Watershed parameters for linear aspect include stream length, watershed length (*Lb*), watershed area (*A*), and watershed perimeter (*P*). The parameters for areal aspect or shape parameters comprise form factor (*Rf*), elongation ratio (*Re*), circulation ratio (*Rc*), and compactness coefficient (*Cc*). Finally, the parameters for relief aspect include watershed relief and relief ratio [7]. Various important hydrologic variables, such as the size, shape, slope, drainage density, size and length of the tributaries can be correlated with the morphometric characteristics of watersheds [4,8]. The shape of watersheds has a strong relation with their characteristic peak discharge and land erosion. In this paper, watershed shape was analyzed based on areal aspects, i.e., Gravelius's index (*KG*), *Rf*, shape index (*Sw*), shape factor (*Rs*), *Rc*, *Re*, and *Cc*. The physical data used to analyze the watershed shape were length, perimeter, diameter, and watershed area.

On the basis of the general shape of watersheds, watersheds in the study area were classified into four shapes categories, i.e., circular, oval, semi-oval, and elongated. A total of 17 watersheds were selected in the study area. On the basis of areal aspect, the 17 watersheds were classified into four watershed shape categories. Given that watershed is the basic unit in hydrology, morphometric analysis at the watershed scale is an important parameter and preferable than individual channels. The interrelationship between morphometric parameters differs from that of one watershed to another under varied topographical and climatic conditions. Hence, fluvial geomorphology is connected with watershed geometry and its channel network [9].

Morphometric analysis provides a good alternative to understanding the underlying factors controlling the hydrological behavior [10]. With the use of conventional techniques, morphometric characterization of various watersheds in different parts of the globe has been carried out [11,12]. With the advancement in geospatial and computer technology, the assessment of watershed morphometry has shown good accuracy and precision. In GIS technique, various terrain and morphometric parameters of drainage basins are evaluated with ease and accuracy. In the present study, morphometric characterization of 17 watersheds of the Serayu-Bogowonto river basin area was performed in GIS environment.

2. MATERIALS AND METHODS

2.1 Materials

The study area is Serayu-Bogowonto river basin. The river basin is located at Java Island, Indonesia and occupies two provinces, i.e., Middle Java province and Special Region of Yogyakarta. Geographically, Serayu-Bogowonto river basin is located between 07°54′16″S and 07°10′04″S and 108°56′56″E and 110°08′47″E. The topographic map used in this research was in the scale of 1:25,000 with a contour interval of 12.5 m. Fifty sheets were used in this research. Fig. 1 shows the location of Serayu-Bogowonto river basin.

The total area of the Serayu-Bogowonto river basin is 7,354.631 km^2, and its perimeter is equal to 430.333 km.

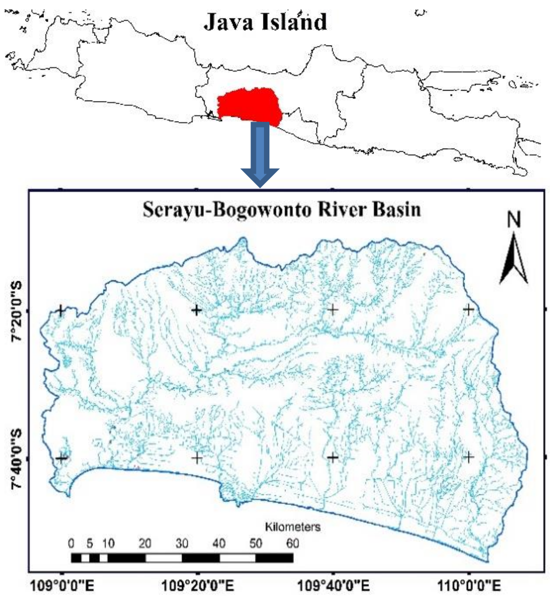


Fig.1 Serayu-Bogowonto river basin area

2.2 Methods

The following steps were followed to analyze the parameters for areal aspect or shape parameters of watershed. ArcGIS 10.6.1 was used for analyzing the watershed shape.

1. Create the shapefile for river network, contour line, stream order, and administrative boundaries;
2. Create a Digital Elevation Model (DEM) with a grid size of 25 × 25 m^2;
3. Analyze the river basin and watershed boundaries;
4. Select watershed as samples;
5. Calculate the watershed shape parameters;
6. Classify the watershed shapes.

From the topographic map the DEM was generated in GIS environment. No distinction was observed between the water-filled stream channels and land surface in the DEM. The DEM was constructed based on the contour line. From the contour line the Triangular Irregular Network (TIN) was developed. Finally, the DEM with grid size 25 x 25 m2 was developed by transforming the TIN to DEM. To draw the watershed boundary, the river network generated form the topographical map which are proposed to be defined as the watershed boundary was overlapped with DEM. By using the basin menu in the ArcGIS environment, the boundaries of each watershed of the study area were developed. The watershed area was evaluated by calculating the geometry of the derived watershed polygons, and the *Lb* was calculated by summing the length of the main stream channel and the distance from the top of the main channel to the watershed boundary. By summing the lengths of all the streams in each watershed, the total stream length was calculated.

As mentioned above, in this research the morphometric was analyzed by classifying the watershed shape based on areal aspect. Among the areal aspects, *KG*, *Rf*, *Sw*, *Rs*, *Rc*, *Re*, and *Cc* were analyzed. The formula for each areal aspect can be described as follows.

1. *KG*

$$KG = \frac{P}{2\sqrt{\pi A}} \quad (1)$$

Based on the *KG* values, the watershed shape can be classified into four categories, i.e., *KG* equal to 1.6, 1.3, 1.2, and 1.1 denoted elongated, semi-oval, oval, and circular shaped watersheds, respectively [13].

2. *Rf*

$$Rf = \frac{A}{Lb^2} \quad (2)$$

Rf is defined as the ratio of the basin area to the square of the basin length. The values between

0.13 and 0.26 show that the watershed shape is elongated [14,15].

Sw

$$Sw = \frac{Lb^2}{A} \quad (3)$$

The *Sw* values for watershed area show that the larger value, the more elongated is the watershed [4].

3. *Rs*

$$Rs = \frac{Pu}{P} \quad (4)$$

The *Rs* has a similar in interpretation to *Rc*, *Re*, and *Rf* [4].

4. *Rc*

$$Rc = \frac{4\pi A}{P^2} \quad (5)$$

$$Rc = \frac{A}{Al} \quad (6)$$

Values ranging from 0.53 to 0.62 indicate that the watershed is elongated, whereas those less than 0.53 indicate that the watershed shape is oval [4].

5. *Re*

$$Re = \frac{2}{Lb}\sqrt{\frac{A}{\pi}} \quad (7)$$

$$Re = \frac{D}{Lb} \quad (8)$$

The values can be grouped into five categories, namely, circular (0.9–1.0), oval (0.8–0.9), less elongated (0.7–0.8), elongated (0.5–0.7), and more elongated (< 0.5) [9].

6. *Cc*

$$Cc = \frac{P}{Pu} \quad (9)$$

This parameter has a similar interpretation to *Rc*, *Re*, and *Rf*. This variable gives an idea about the circular character of the basin [4].

Here P = watershed perimeter (km); A = watershed area (km^2); Al = area of circle having the same circumference as the perimeter of the watershed (km); π = pi, that is, 3.142; Lb = watershed length (km); D = diameter of a circle of the same area as the watershed area (km); Pu = circumference of watershed area (km). Lb can be defined in several ways: Eq. (1) the greatest straight-line distance between any two points on the perimeter; Eq. (2) the greatest distance between the outlet and any point on the perimeter; Eq. (3) the length of the main stream from its source (projected to the perimeter) to the outlet [16]. In this research, *Lb* were measured in two ways; Eq. (1) as the greatest straight-line distance between any two points on the perimeter and namely maximum of watershed length (*Lbm*), Eq. (2) the length of the main stream from its source to the outlet and namely river of watershed length (*Lbr*). The *Lbr* will use especially in case of ambiguous watershed shapes.

3. RESULTS AND DISCUSSION

The analysis was started by collecting the topographic map of the Serayu-Bogowonto river basin. Fifty sheets covering the river basin were selected. The river network, road network, contour lines, and administrative boundaries layers were selected. The layers were analyzed based on the GIS environment using ArcGIS 10.6.1. Finally, the shapefiles of the layers were created. The DEM has been obtained with a pixel size of 25 × 25 m^2 and an area of 12,600 km^2. The DEM is shown in Fig. 2. Based on the DEM data, the boundaries of the Serayu-Bogowonto river basin and the watershed inside the river basin were analyzed. On the basis of the availability of an automatic water level recorder (AWLR), 17 rivers network were selected. The availability of AWLR is very important, because in the future the research will continue to analyze the relationship between each watershed shape type and hydrological characteristics (time to peak, peak discharge, and hydrograph shape). By overlapping the selected rivers network and DEM, the 17 watersheds as samples in this research were developed and shown in Fig. 3. The geometry of the 17 watersheds was analyzed using GIS environment. Based on the watershed area, the largest watershed is Serayu watershed with an area equal to 714.004 km^2 (WS13), and the smallest is Merden watershed with an area equal to 19.028 km^2 (WS10). Table 1 shows the names and geometric data of the 17 watersheds

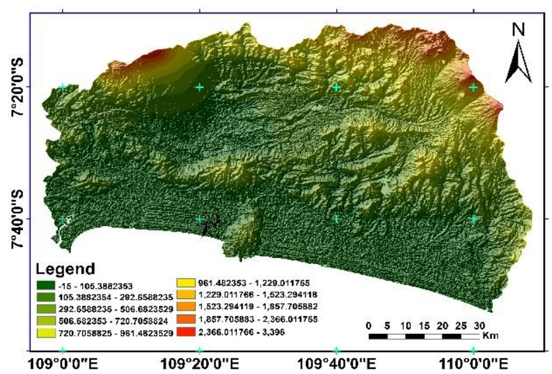


Fig.2 DEM of Serayu-Bogowonto river basin

Table 1 Names and geometries of watersheds at Serayu-Bogowonto river basin

No.	Watershed names	*P* [km]	*A* [km]	*Lb* [km]		*Al* [km]	*Pu* [km]	*D* [km]
				Lbm	*Lbr*			
WS 1	Badegolan	97.805	219.431	27.110	26.803	761.228	52.511	16.712
WS 2	Banjarnegara	125.278	688.553	39.384	30.854	1248.938	93.019	29.603
WS 3	Bendung Dagan	25.501	31.173	8.190	7.084	51.750	19.792	6.299
WS 4	Clangap Mrawu	75.804	229.739	24.814	21.873	457.265	53.731	17.100
WS 5	Kali Gending	76.340	252.085	20.465	15.287	463.764	56.283	17.912
WS 6	Kedung Gupit	47.117	70.904	17.212	16.648	176.664	29.850	9.500
WS 7	Kober	45.435	50.950	19.211	17.572	164.274	25.303	8.053
WS 8	Krasak Begaluh	71.083	183.585	22.795	18.959	402.094	48.031	15.286
WS 9	Madurejo	105.585	312.325	32.524	29.570	887.147	62.648	19.938
WS 10	Merden	23.373	19.028	8.167	7.591	43.473	15.463	4.921
WS 11	Pesucen	55.188	114.923	18.216	18.194	242.367	38.002	12.094
WS 12	Pungangan	103.852	355.699	36.052	28.349	858.265	66.857	21.277
WS 13	Serayu	145.398	714.004	42.679	33.729	1,682.313	94.723	30.145
WS 14	Slinga S Klawing	148.978	566.371	31.060	22.015	1,766.178	84.364	26.848
WS 15	Telomoyo	34.073	44.147	8.348	6.623	92.387	23.554	7.496
WS 16	Tipar Kidul	77.861	181.294	21.726	17.301	482.425	47.731	15.190
WS 17	Winong	76.232	125.889	28.929	27.218	462.450	39.774	12.658

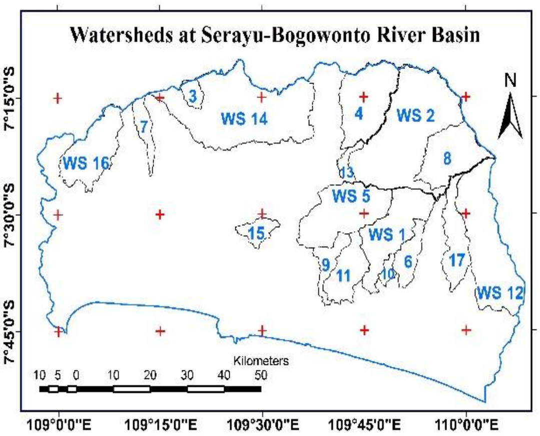


Fig.3 Watersheds at the Serayu-Bogowonto river

Next, the watershed shape was calculated based on the parameters presented in Eqs. (1–9). The main input data are the watershed geometric parameters (Table 1) and *Lbm* was used in the calculation. Table 2 presents the calculation results. Based on the watershed shape described in literature [4, 9, 13, 15], the watersheds in this research were classified into four shape categories, i.e., circular, oval, semi-oval, and elongated. The classification results of the 17 watersheds at Serayu-Bogowonto river basin for each parameter can be described as follows.

Table 2 Watershed shape parameters with *Lbm*

No.	Watershed areal aspect values						
	KG	*Rf*	*Sw*	*Rs*	*Rc*	*Re*	*Cc*
WS 1	1.9	0.3	3.3	0.5	0.3	0.6	1.9
WS 2	1.3	0.4	2.3	0.7	0.6	0.8	1.3
WS 3	1.3	0.5	2.2	0.8	0.6	0.8	1.3
WS 4	1.4	0.4	2.7	0.7	0.5	0.7	1.4
WS 5	1.4	0.6	1.7	0.7	0.5	0.9	1.4
WS 6	1.6	0.2	4.2	0.6	0.4	0.6	1.6
WS 7	1.8	0.1	7.2	0.6	0.3	0.4	1.8
WS 8	1.5	0.4	2.8	0.7	0.5	0.7	1.5
WS 9	1.7	0.3	3.4	0.6	0.4	0.6	1.7
WS 10	1.5	0.3	3.5	0.7	0.4	0.6	1.5
WS 11	1.5	0.3	2.9	0.7	0.5	0.7	1.5
WS 12	1.6	0.3	3.7	0.6	0.4	0.6	1.6
WS 13	1.5	0.4	2.6	0.7	0.4	0.7	1.5
WS 14	1.4	0.6	3.3	0.6	0.3	0.9	1.8
WS 15	1.4	0.6	2.3	0.5	0.5	0.9	1.5
WS 16	1.6	0.4	2.2	0.7	0.4	0.7	1.6
WS 17	1.8	0.2	2.7	0.8	0.3	0.4	1.9

3.1 *Kg*

Musy (2001) classified watersheds into four categories: circular (*KG* = 1.1), oval (*KG* = 1.2), semi-oval (*KG* = 1.3), and elongated (*KG* = 1.5). On the basis of *KG* value (Table 2), the 17 watersheds at Serayu-Bogowonto river basin were classified as follows. No watershed was classified as circular. One watershed was classified as oval (WS3), four watersheds were classified as semi-oval (WS2, 4, 5, 15), and the remaining watersheds as elongated (WS1, 6, 7, 8, 9, 10, 11, 12, 13, 14, 17).

3.2 *Rf*

For *Rf*, the values between 0.13 and 0.26 show that the watershed shape is elongated [15]. Based on the *Rf* spread values and the watershed figures, in this research, classification was conducted as follows. If $Rf \geq 0.754$, then the watershed was classified as circular; $0.5 \leq Rf < 0.754$, oval; $0.3 \leq Rf \leq 0.4$, semi-oval; $Rf < 0.3$, elongated. The classification results show zero circular watersheds, four oval watersheds (WS3, 5, 14, and 15), ten semi-oval watersheds (WS1, 2, 4, 8, 9, 10, 11, 12, 13, and 16), and three elongated watersheds (WS6, 7, and 17). Based on the figures of WS5, 14, and 15, the watershed shapes are near and exhibit circular shapes. To ensure clarity, *Lb* will measured base on *Lbr* as input data in *Rf* analysis and will be discussed later.

3.3 *Sw*

As previously mentioned [4], the larger the value of watershed shape, the more elongated it is. Table 2 shows that the highest value of *Sw* is 7.2, and the smallest is 1.6. Based on the spread values and watershed figures, the watershed shapes were classified in accordance with the following method. If $1.6 \leq Sw \leq 1.7$, the watershed was classified as circular; $2.2 \leq Sw < 2.3$, oval; $2.6 \leq Sw \leq 3.0$, semi-oval; $Sw > 3.0$, elongated. The classification results revealed three circular (WS5, 14, and 15), two oval (WS2, and 3), five semi-oval (WS4, 8, 11, 13, and 16), and seven elongated watersheds (WS1, 6, 7, 9, 10, 12, and 17).

3.4 *Rs*

As mentioned above, *Rs* is interpreted similarly with *Rf*, *Rc*, and *Re*. Consequently, the largest *Rs* can be predicted as circular watershed, whereas small *Rs* indicates an elongated shape. Based on the spread values of *Rs*, in this research, the watershed shape was classified based on the following categories. If $Rs = 0.8$, the watershed was classified as circular; $Rs = 0.7$, oval; $Rs = 0.6$, semi-oval; and $Rs = 0.5$, elongated. The classification results revealed one watershed classified as circular (WS3), eight oval (WS2, 4, 5, 8, 10, 11, 13, and 15), six semi-oval (WS6, 7, 9, 12, 14, and 16), and two elongated watersheds (WS1 and 17).

3.5 *Rc*

Altaf A., Meraj G., and Romshoo S. A., (2013) mentioned that *Rc* with range values from 0.53 to 0.62 indicate that the watershed is elongated, and values less than 0.53 denote that an oval shape. Based on the spread values of *Rc* (0.3–0.6), in this research, the watershed shape was classified based on the following categories. If $Rc = 0.6$, the watershed was classified as circular; $Rc = 0.5$, oval; $Rc = 0.4$, semi-oval; $Rc = 0.3$, elongated. The classification results indicated two circular (WS2, and 3), five oval (WS4, 5, 8, 11, and 15), six semi-oval (WS6, 9, 10, 12, 13, and 16), and four elongated watersheds (WS1, 7, 14, and 17).

3.6 *Re*

Rai P. K., Chandel R. S., Mishra V. N., and Singh P. (2018) mentioned that *Re* can be classified into five categories, namely, circular (0.9–1.0), oval (0.8–0.9), less elongated (0.7–0.8), elongated (0.5–0.7), and more elongated (< 0.5). Classification using similar categories, namely, circular ($0.9 \leq Re < 1.0$), oval ($0.8 \leq Re < 0.9$), semi-oval ($0.7 \leq Re < 0.8$), elongated ($Re < 0.7$), was conducted in this research. The classification results identified three circular (WS5, 14, and 15), two oval (WS2, and 3), five semi-oval (WS4, 8, 11, 13, and 16), and seven elongated watersheds (WS1, 6, 7, 9, 10, 12, and 17). These results are the same with the findings obtained using *Sw*.

3.7 *Cc*

Altaf A., Meraj G., and Romshoo S. A., (2013) mentioned that this watershed shape parameter gives an idea about the circular character of basins. In Table 2, the values in the *Cc* column were the same as those of *KG*. Therefore, this classification method was conducted in the same manner as *KG* classification. The classification results showed zero circular, one oval (WS3), two semi-oval (WS4 and 15), and fourteen elongated watersheds.

Table 3 shows all the classification results. The table reveals that WS1 was classified as semi-oval based on the *Rf* and elongated based on *KG*, *Sw*, *Rs*, *Rc*, *Re*, and *Cc*. Consequently, WS1 could be classified as an elongated watershed shape.

Table 3 Watershed shape classification based on *Lbm*

Par	Watershed shape categories			
	Cir.	Oval	Semi oval	Elongated
KG	None	WS3	WS2, 5	WS1, 4, 6, 7, 8, 9, 10, 11, 12 , 13, 14, 15, 16, 17
Rf	None	WS3, 5, 14, 15	WS1, 2, 4, 8, 9, 10, 11, 12, 13, 16	WS6, 7, 17
Sw	WS5, 14, 15	WS2, 3	WS4, 8, 11, 13, 16	WS1, 6, 7, 9, 10, 12, 17
Rs	WS3	WS2, 4, 5, 8, 10, 11, 13, 15	WS6, 7, 9, 12, 14, 16	WS1, 17
Rc	WS2, 3	WS4, 5, 8, 11, 15	WS6, 9, 10 12, 13, 16	WS1, 7, 14, 17
Re	WS5, 14, 15	WS2, 3	WS4, 8, 11, 13, 16	WS1, 6, 7, 9, 10, 12, 17
Cc	None	WS3	WS2, 5	WS1, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17

WS2 was classified as circular based on *Rc*; oval based on *Sw*, *Rs*, and *Re*; semi-oval based on *KG*, *Rf*, and *Cc*. Therefore, WS2 could be classified as an oval watershed shape.

WS3 was classified as circular based on *Rs* and *Rc;* oval based on *Rf*, *Sw*, and *Re*; semi-oval based on *KG*, *Rf,* and *Cc*. Therefore, WS3 could be classified as an oval watershed shape.

WS4 was classified as oval based on *Rs*, and *Rc*; semi-oval based on *KG*, *Rf*, *Sw*, *Re*, and *Cc*. Therefore, WS4 could be classified as a semi-oval watershed shape.

WS5 was classified as circular based on *Sw* and *Re*, oval based on *Rf*, *Rs*, and *Rc*; semi-oval based on *KG* and *Cc*. Therefore, WS5 could be classified as an oval watershed shape.

WS6 was classified as semi-oval based on *Rs* and *Rc*; elongated based on *KG*, *Rf*, *Sw*, *Re*, and *Cc*. Therefore, WS6 could be classified as an elongated watershed shape.

WS7 was classified as semi-oval based on *Rs* and elongated based on *KG*, *Rf*, *Sw*, *Rc*, *Re*, and *Cc*. Therefore, WS7 could be classified as an elongated watershed shape.

WS8 was classified as oval based on *Rs* and *Rc*; semi-oval based on *Rf*, *Sw*, and *Re*; elongated based on *KG* and *Cc*. Therefore, WS8 could be classified as a semi-oval watershed shape.

WS9 was classified as semi-oval based on *Rf*, *Rs*, and *Rc* and elongated based on *KG*, *Sw*, *Re*, and *Cc*. Therefore, WS9 could be classified as an elongated watershed shape.

WS10 was classified as oval based on *Rs*; semi-oval based on *Rf* and *Rc*; elongated based on *KG*, *Sw*, *Re*, and *Cc*. Therefore, WS10 could be classified as an elongated watershed shape.

WS11 was classified as oval based on *Rs* and *Rc*; semi-oval based on *Rf*, *Sw*, and *Re*; elongated based on *KG* and *Cc*. Therefore, WS11 could be classified as a semi-oval watershed shape.

WS12 was classified as semi-oval based on *Rf*, *Rs*, *Rc* and elongated based on *KG*, *Sw*, *Re*, *Cc*. Therefore, WS12 could be classified as an elongated watershed shape.

WS13 was classified as oval based on *Rs*; semi-oval based on *Rf*, *Sw*, *Rc*, and *Re*; elongated based on *KG*, and *Cc*. Therefore, WS13 could be classified as semi-oval watershed shape.

WS14 was classified as circular based on *Sw* and *Re*; oval based on *Rf*; semi-oval base on *Rs*; elongated based on *KG*, *Rc*, and *Cc*. Therefore, WS14 could be classified as an elongated watershed shape.

WS15 was classified as circular based on *Sw*, and *Re*; oval based on *Rf*, *Rs* and *Rc*; semi-oval based on *KG*; elongated based on *Cc*. Therefore, WS15 could be classified as an oval watershed shape.

WS16 was classified as semi-oval based on *Rf*, *Sw*, *Rs*, *Rc,* and *Re* and elongated based on *KG* and *Cc*. Therefore, WS16 could be classified as a semi-oval watershed shape.

WS17 was classified as elongated based on *KG*, *Rf*, *Sw*, *Rs*, *Rc*, *Re*, and *Cc*. Therefore, WS17 could be classified as an elongated watershed shape.

In summary, the classification results for each category of watershed shape at the Serayu-Bogowonto river basin are shown in Table 4. Based on the data as shown in Table 3 and given the related figures, there are some mistook classification. For example, the WS5 and WS14 can be interpreted were mistook classification. Based on the relating figures, WS5 and WS14 is near to circular shape, but the result was classified to oval and elongated. The reason is how to define the watershed length. If the watershed length defined as *Lbm*, the angle to view the watershed shape is different from view based on *Lbr*. For illustration, both views are shown in Fig.4. From this figure it is clear that WS5 and WS14 are near with oval and elongated if the angle view base *Lbm*. But if the angle of view based on Lbr, both watersheds are near with circular shape. To clarify this case, the watershed classification was done based on Lbr watershed distance. The watershed shape parameters base on *Lbr* is shown in Table 5. The classification was done in the same ways with the classification based on *Lbm* as described above. The classification was summarized in Table 6 and represented in Fig.5

Table 4 Watershed shapes classification with *Lbm*

Watershed shapes	Watershed No.
Circular	None
Oval	WS2, 3, 5, 15
Semi-oval	WS4, 8, 11, 13, 16
Elongated	WS1, 6, 7, 9, 10, 12, 14, 17

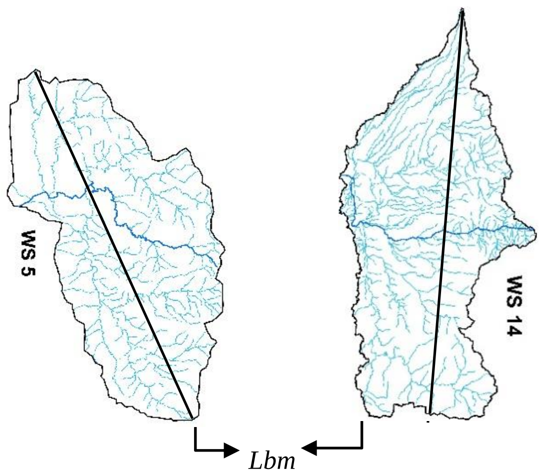


Fig.4 Watershed shapes with *Lbm and Lbr (a)*

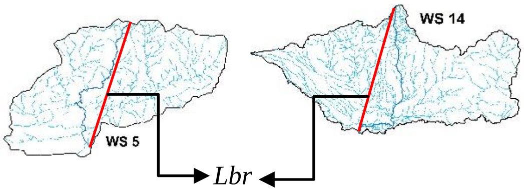


Fig.4 Watershed shapes with *Lbm* and *Lbr (b)*

Due to the river as the main view for watershed shape classification, classification using *Lbr* is better than using Lbm. From river the watershed area can be defined. Watershed is the basic area for analyzing hydrological characteristics. Therefore, classification based on *Lbr* is closed related to the hydrological characteristic analysis. All the analysis of the watershed geometries was analyzed using GIS environment and was done smoothly.

Table 5 Watersheds shape parameters based on *Lbr*

No.	Watersheds shape factors values						
	KG	*Rf*	*Sw*	*Rs*	*Rc*	*Re*	*Cc*
WS 1	1.9	0.3	3.3	0.5	0.3	0.6	1.9
WS 2	1.3	0.7	1.4	0.7	0.6	1.0	1.3
WS 3	1.3	0.6	1.6	0.8	0.6	0.9	1.3
WS 4	1.4	0.5	2.1	0.7	0.5	0.8	1.4
WS 5	1.4	1.1	0.9	0.7	0.5	1.2	1.4
WS 6	1.6	0.3	3.9	0.6	0.4	0.6	1.6
WS 7	1.8	0.2	6.1	0.6	0.3	0.5	1.8
WS 8	1.5	0.5	2.0	0.7	0.5	0.8	1.5
WS 9	1.7	0.4	2.8	0.6	0.4	0.7	1.7
WS 10	1.5	0.3	3.0	0.7	0.4	0.6	1.5
WS 11	1.5	0.3	2.9	0.7	0.5	0.7	1.5
WS 12	1.6	0.4	2.3	0.6	0.4	0.8	1.6
WS 13	1.5	0.6	1.6	0.7	0.4	0.9	1.5
WS 14	1.4	1.2	0.9	0.6	0.3	1.2	1.8
WS 15	1.4	1.0	1.0	0.7	0.5	1.1	1.5
WS 16	1.6	0.6	1.7	0.6	0.4	0.9	1.6
WS 17	1.8	0.2	5.9	0.5	0.3	0.5	1.9

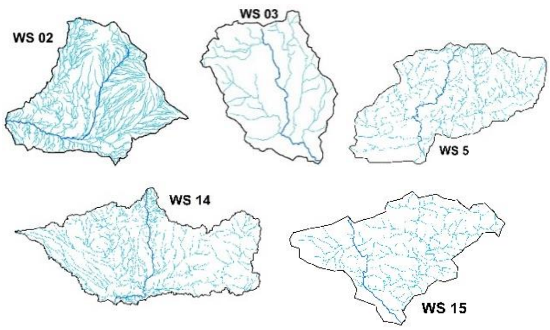
Table 6 Classification of watershed shape based on *Lbr*

Par	Watershed shape categories			
	Cir.	Oval	Semi oval	Elongated
KG	None		WS2, 3, 14, 15	WS1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17
Rf	WS5, 14, 15	WS2, 3, 4, 8, 13, 16	WS1, 6, 9, 10,11, 12	WS7, 17
Sw	WS2, 3, 5, 13, 14, 15, 16	WS4, 8, 12	WS9, 10, 11	WS1, 6, 7, 17
Rs	WS3	WS2, 4, 5, 8, 10, 11, 13, 15	WS6, 7 ,9, 12, 14, 16	WS1, 17
Rc	WS2, 3	WS4, 5, 8, 11, 15	WS6, 9, 10 12, 13, 16	WS1, 7, 14, 17
Re	WS2, 3, 5, 13, 14, 15, 16	WS4, 8, 12	WS9, 11	WS1, 6, 7, 10, 17
Cc	None	None	WS2, 3	WS1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17

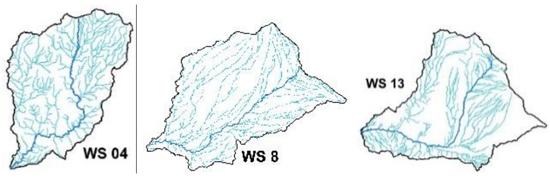
4. CONCLUSION

The watersheds at the Serayu-Bogowonto river basin were classified into four categories, i.e.,

1. Circular



2. Oval



3. Semi-oval

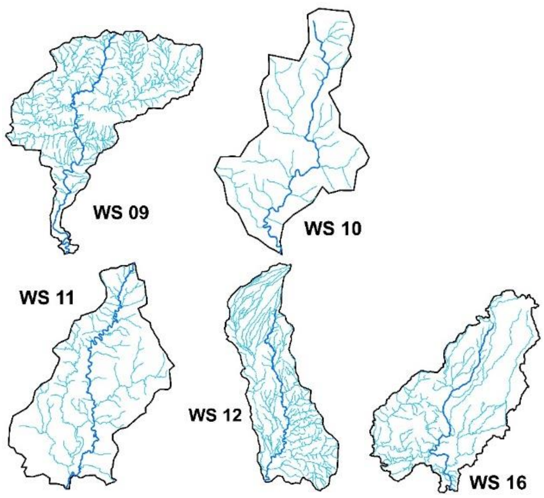


Fig.5 Watershed shape classification (a)

4. Elongated

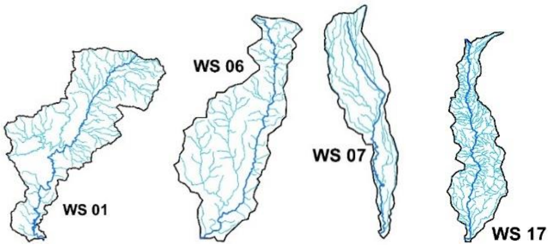


Fig.5 Watershed shape classification (b)

circular, oval, semi-oval, and elongated. From the result and discussions, it can be concluded that the length of a watershed is a very important parameter in watersheds shapes classification. The watershed shape is classified depending on the angle of view. Based on the maximum length of the watershed,from the 17 watersheds, none were classified as circular, 4 as oval, 5 as semi-oval, and 8 as elongated shapes. Based on the length of the river, the watersheds were classified as 5 as circular, 3 as oval, 5 as semi-oval, and 4 as elongated shapes. Finally, GIS is a powerful tool for the manipulation and analysis of spatial information relating to watershed morphometric parameters.

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6. REFERENCES

[1] Prieto-Amparán J.A., Pinedo-Alvarez A.P., Vázquez-Quintero G., Valles-Aragón M.C., Rascón-Ramos A.E., Martinez-Salvador M., and Villarreal-Guerrero F., A Multivariate Geomorphometric Approach to Prioritize Erosi on-Prone Watersheds, MDPI Sustainability, 11, 2019, pp.5140,DOI:10.3390/su11185140.

[2] Indarto and Hidayah E., Preiminary Assessmen t of the Morphometric and Hydrological, Fourm Geografi (Indonesian Journal of Spatial and Regional Analysis),33(1),2019, pp.113-128, DOI:10.23917/forgeo.v33i1.7858.

[3] Nugroho A.R.B., Sukiyah E., Syafri I., and Isnaniawardhani V., Identification of Tectonic Deformation Using Morphometrical Analysis of Lamongan Volcano Complex, International Journal of GEOMATE, 2020, Vol.19, Issue 71, pp.55-60,Japan,DOI: https://doi.org/10.21660/ 2020.71.18490.

[4] Altaf A., Meraj G., and Romshoo S.A., Morphometric Analysis to Infer Hydrological, Behaviour of Lidder Watershed, Western Himalaya, India, Geography Journal, Volume 2013, Article ID 178021,http://dx.doi.org/ 10.1155/2013/178021.

[5] Balla F., Kabouche N., Khanchoul K., and Bouguerra H., Hydro-sedimentary flow modelling in some catchments Constantine highlands, case of Wadis Soultez and Reboa (Algeria), 2017, Journal of Water and Land Development, No.34, pp.21-32, DOI:10.1515/jwld-2017-0035.

[6] Zardari N.H., Naubi I., Abbasi S.A., Jamali K. A., and Miano T.F., An Improved Method for Watershed Management - A case Study of ArcGIS Application to the Skudai Watershed, Malaysia, International Journal of GEOMATE, 2019, Vol.17, Issue 64, pp.145-151, DOI: https://doi.org/10.21660/2019.64.190725.

[7] Angillieri M.Y.E., and Fernandez O.M., Morho metric analysis of river basins using GIS and remote sensing of an Andean section of Route 150, Argentina. A comparison between manual and automated delineation of basins, Revista Mexicana de Ciencias Geologicas, 34, No. 2, 2017, pp.150-156.

[8] Asfaw D., and Workineh G., Quantitative analysis of morphometry on Ribb and Gumara watersheds: Implications for soil and water conservation, International Soil and Water Conservation Research, 7, 2019, pp.150-157.

[9] Micun K., and Roj-Rojewski S., Morphological characteristics and lithological conditions of the spring-heads in the Knyszyńska Primeval Forest, Journal of Water and Land Development. No. 40 (I–III) 2019, pp.27-37, DOI: 10.2478/jwld-2019-0003.

[10] Fenta A.A., Yasuda H., Shimizu K., Haregewe yn N., and Woldearegay K., Quantitative analy sis and implications of drainage morphometry of the Agula watershed in the semi-arid northern Ethiopia, 2017, Appl. Water Sci., pp. 3825–3840, DOI 10.1007/s13201-017-0534-4.

[11] Strahler A.N., Quantitative geomorphology of drainage basins and channel networks, in Handbook of Applied Hydrology, V. T. Chow, Ed., section 4-11, McGraw-Hill, New York, NY, USA, 1964.

[12] Mohammed A., Adugna T., and Takala W., Mo rphometric analysis and prioritization of watersheds for soil erosion management in Upper Gibe catchment, J. Degrade. Min. Land Manage,6(1), 2018, pp.1419-1426, DOI: 10.15243/jdmlm. 2018.061.1419.

[13] Musy, André, e-drologie. Ecole Polytechnique Fédérale, Lausanne, Suisse, 2001.

[14] Sreedevi P.D., Owais, S.H.H.K., and Ahmes S., Morphometric Analysis of a Watershed of South India Using SRTM Data and GIS,

Journal Geological Society of India, 73, 2009, pp.543-552.
[15] Sreedevi, P.D., Sreekanth, P.D., and Khan H.H., Drainage morphometry and its influence on hydrology in a semiarid region: using SRTM data and GIS, Environ Earth Sci 70, 2013, pp.839-848. https://doi.org/ 10.1007/s12665-012-2172-3.
[16] Zavoianu I., Morphometry of drainage basins, Elsevier, 2011.

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