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Drainage Network Characteristics of Omi (Kampe) Dam Basin, Kogi State, Nigeria

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Abstract: *This study examines the relationship between the different morphometric parameters and characters of the drainage terrain. To do that, Omi dam basin in Bauchi state, Nigeria drainage characteristics was delineated using Shuttle Radar Topographic Mission (SRTM) data. The Aspect, Drainage, and Slope maps were prepared using ArcGIS 10.2.1 software. The Omi Dam is fourth-order stream that exhibits dendritic pattern. The trails drainage patterns are also observed in some areas of the basin, which may be due to the effect of regional tectonics. The mean bifurcation ratio is 1.6 showing normal basin which is somehow controlled by structural disturbances. Drainage density (0.3) shows very coarse drainage texture also having positive correlation with stream frequency. The elongation ratio is 0.33 along with circulatory ratio (0.31) shows elongated nature of the basin. The low values of drainage density and stream frequency imply that surface run-off is not quickly removed from the basin, making it liable to slight flooding.*

***Key words**: Drainage, Morphometric, Omi, Flood, Shuttle, Radar, Topographic, Mission*

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I. Introduction

Watersheds are physical entities of discrete landforms useful for statistical, comparative and analytical studies. Though there are a number of known methods of numerically and qualitatively describing drainage basins. One of the most commonly performed methods is the drainage basin morphometry. The characteristics of drainage basins depend on the slope, regional tectonics, geology of the watershed area, and aerial climate. The method of quantitative analysis of drainage basins was developed by Horton (1945) and modified by Strahler (1964) to evaluate the nature of the drainage basins, relationship with character of the terrain, for deriving means to safeguard and manage the natural resources and combating natural hazards.

Morphometric analysis represents a relatively simple approach in describing the hydro-geological behavior, landform processes, soil physical properties and erosion characteristics and, hence, provides a holistic insight into the hydrologic behavior of watersheds (Strahler, 1964). The hydrological response of watersheds is interrelated with their physiographic characteristics, such as size, shape, slope, drainage density and length of the streams (Gregory and Walling, 1973).

The drainage basin morphometric information is very important in any undertaking to control incidence of flooding in an area. In this present study, basin morphometric parameters using GIS was used to examine the flood potentials of the Omi basin. This will provide information about floods in the drainage basin. The data on the drainage basin morphometric parameters will enhance the management of flooding in the area. The study will also evaluate the drainage characteristic of the Omi dam basin using remote sensing and GIS and determine its usage in environmental monitoring and watershed management. This study used the morphometric technique to give a vision of the different geo-hydrological features of the drainage basins of the study area to help in the determination of its importance in environmental management and monitoring. The study is also expected to provide base-line information for future research in surface and groundwater hydrology.

II. Study Area

The Omi dam is primarily an irrigation dam, whose project was conceived in 1979. Constructed with the capacity of about 250 million cubic meters, Omi (Kampe) dam lies between latitude $8^o34'$N – $8^o38'$N and longitude $6^o37'$E – $6^o42'$E. Located in the Yagba west and extends to Yagba east, Ijumu and Mopa-Muro local government areas of Kogi state, Nigeria; Omi (Kampe) basin lies between latitude $7^o45'20''$N – $8^o29'44''$N and longitude $5^o29'24''$E – $6^o4'6''$E

III. Materials And Methods

Basically, morphometric parameters are broadly divided into three categories, i.e., linear aspect, relief aspect, and aerial aspect of the river basin (Mesa, 2006). These parameters include basin area, perimeter, basin length, stream order and stream length, mean stream length, stream length ratio, bifurcation ratio, basin relief, relief ratio, ruggedness number, drainage density, stream frequency, drainage texture, form factor, circulatory ratio, elongation ratio, length of overland flow, and constant channel maintenance.

The extraction of drainage was done from Shuttle Radar Topographic Mission (SRTM) Digital Elevation Show (DEM) (90 m) information using ArcGIS 10.2.1 software. The generation of depressionless DEM is dependably the preliminary advances for morphometric investigation of a basin. Depressions are information mistakes or result from the averaging associated with relegating rise esteems to cells (pixels) of limited zone. These fake melancholies meddle with the right directing of flow paths amid the watershed examination, particularly in zones of low elevation. The Watershed progression solves this error by first locating and filling the depressions. This DEM is used to compute the flow direction and flow accumulation raster. This facilitates recreation of these two raster delivers the standard flow paths and sub watersheds. The flow chart of detailed methodology is given in Figure 2. The methods used for analysis of the different parameters are listed in Table 1.

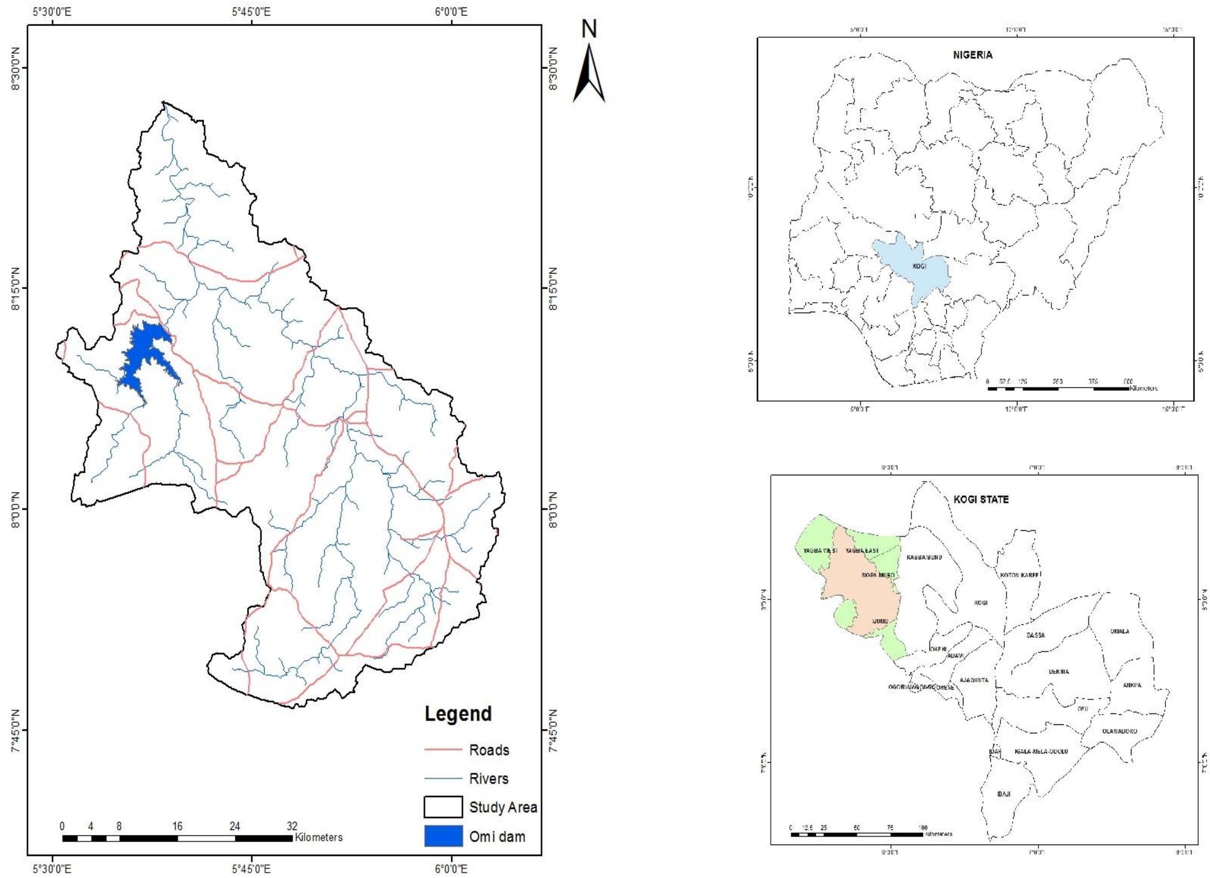

Fig. 1. Omi drainage basin in Kogi state, Nigeria

IV. Results and discussions

4.1 *Aspect, slope and relative relieve of the basin*

The aspect of topography is the direction to which it faces (Magesh, Jitheshlal, Chandrasekar, & Jini, 2013). The vegetation and precipitation is more or less affected by aspect of the topography. The aspect of the Omi Dam is shown in Figure 2. These major slopes reflect the higher moisture content and low evaporation that the other parts of the basin which plays an important role to conserve vegetation, forests, and bio-diversity in the study area. The slope of the basin is dependent of rock type of its watershed area having varying resistance (Magesh *et al*., 2011). The slope elements are highly related to run-off of the water, so that affecting the required time for rain water to enter in the river beds that make up the network of the river basin (Villela & Mattos, 1975).

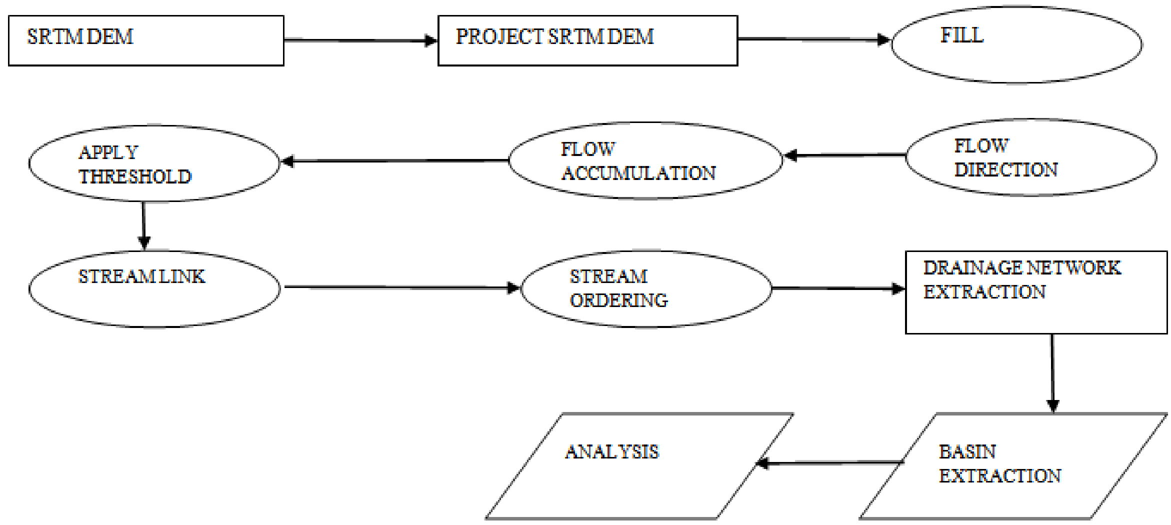

Fig. 2. Flow chart of the methodology

Table 1. Methods of calculations of morphometric parameters and their observed values

Morphometric Parameters	Methods	References
Stream Order (U)	Hierarchical order	Strahler, 1964
Stream Length (Lu)	Length of the stream	Horton, 1945
Mean Stream Length (Lsm)	Lsm = Lu/Nu, where Lu = Stream length of order "U" Nu = Total number of stream segments of order "U"	Horton, 1945
Stream Length Ratio (Rl)	Rl = Lu/Lu-1, where Lu = total Stream length of order "U;" Lu-1 = Stream length of next lower order	Horton, 1945
Bifurcation Ratio (Rb)	Rb = Nu/Nu + 1, where Nu = Total number of stream Segments of order "U;" Nu + 1 = Number of stream segments of next higher order	Schumm, 1956
Drainage Density (Dd)	Dd = L/A, where L = Total length of streams; A = Area of watershed	Horton, 1945
Stream Frequency (Fs)	Fs = N/A, where N = Total number of streams; A = Area of watershed	Horton, 1945
Form Factor (Rf)	Rf = A/(Lb)^2, where A = Area of watershed; Lb = Basin Length	Horton, 1945
Circulation Ratio (Rc)	Rc = 4πA/P^2, where A = Area of watershed; P = Perimeter of watershed; π = 3.14	Miller, 1953
Elongation Ratio (Re)	Re = 2√(A/π)/Lb, where A = Area of watershed; Lb = Basin Length; π = 3.14	Schumm, 1956

Constant of channel Maintenance (C)	C = 1/Dd, where Dd = Drainage density	Horton, 1945
Length of Overland Flow (Lof)	Lof = 1/2Dd, where Dd = Drainage density	Horton, 1945
Drainage Texture (T)	T = Fs*Dd, where Fs = Stream frequency; Dd = Drainage density	Horton, 1945
Relief Basin Relief (Bh)	Vertical distance between the lowest and highest points of watershed	Schumm, 1956
Relief Ratio (Rh)	Rh = Bh/Lb, where Bh = Basin Relief; Lb = Basin Length	Schumm, 1956
Ruggedness number (Rn)	Rn = Bh × Dd, where Bh = Basin Relief; Dd = Drainage density	Schumm, 1956

source: Singh *etal*, 2019 and modified by the authors

The slope map is very useful to delineate watershed planning, agriculture, deforestation/afforestation, water harvesting, civil engineering purpose, and morpho-conservation practices (Sreedevi *et al*., 2005). The topographical characteristic of a basin is determined using the relative relief of its watershed area (Gayen, Bhunia, & Shi, 2013). The Omi watershed is having highest relief as 502 m (Figure 4). The low relief designated in the SW side suggests that this area of the basin is flat to gentle slope type (Figure 4). So the SW area is more prone to water accessibility and also suitable for agriculture activities.

4.2 *Linear aspect*

The linear aspects include the stream order (U), stream length (Lu), mean stream length (Lsm), stream length ratio (RL), and bifurcation ratio (Rbm), which are determined and results have been presented in Table 2.

Stream order (U), stream length (Lu), and mean stream length (Lsm)

The designated stream order (Nu) is the first step in the drainage basin analysis. In this study, ranking of the stream was carried out following Strahler (1964). The watershed has 121 first-order streams, 59 second-order streams, 31 third-order streams and 44 fourth-order streams (Figure 5). The mean stream length of the basin is 5 km. In general, there is a decrease in stream frequency as the stream order increases in the present study.

Stream length ratio (RI)

The stream length ratio (Rl) is the resultant of mean stream length of a given order (Lu) to the mean stream length of next higher order (Lu + 1). It is somehow controlled by the slop and regional topography, and thus controls the discharge and erosional activity of the particular watershed or basin (Sreedevi *et al*., 2004; Thomas *et al*., 2010). The stream length ratio values are calculated following Horton (1945). The mean values of stream length ratio for the Omi watershed is 1.4 Increase in the stream length ratio from lower to higher orders successively reveals geomorphic maturity of the basin (Kanhaiya *et al*., 2018; Rai *et al.*, 2018; Thomas *et al*., 2010).

Bifurcation ratio (Rb)

Bifurcation ratio (Rb) is the ratio between the numbers of stream segments of any given order (Nu) to the number of stream segments of next higher order (Nu + 1). The bifurcation ratio for fourth to third order is 0.70; third to second order is 1.90 and second to first order is 2.05 with a mean value of 1.60 which shows very small structural control and elongated shape of the basin. The medium Rb ratio of the basin shows the structural and lithological control. The calculated values are listed in Table 2.

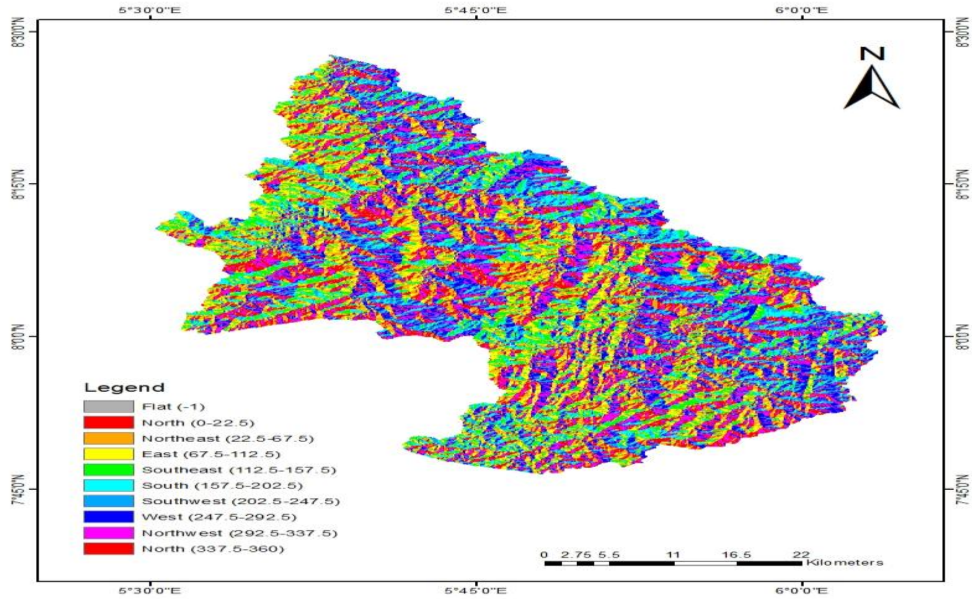

Fig. 2. Aspect map of Omi basin

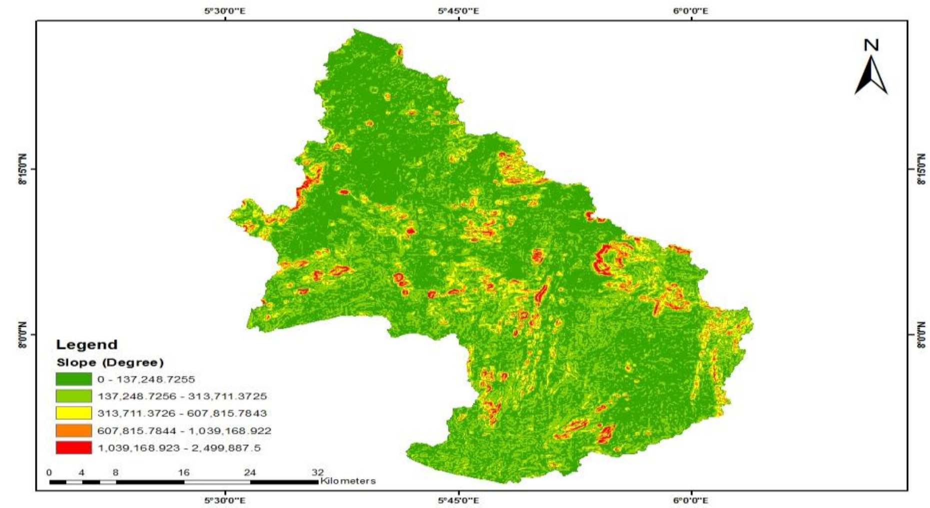

Fig. 3. Slope map of Omi basin

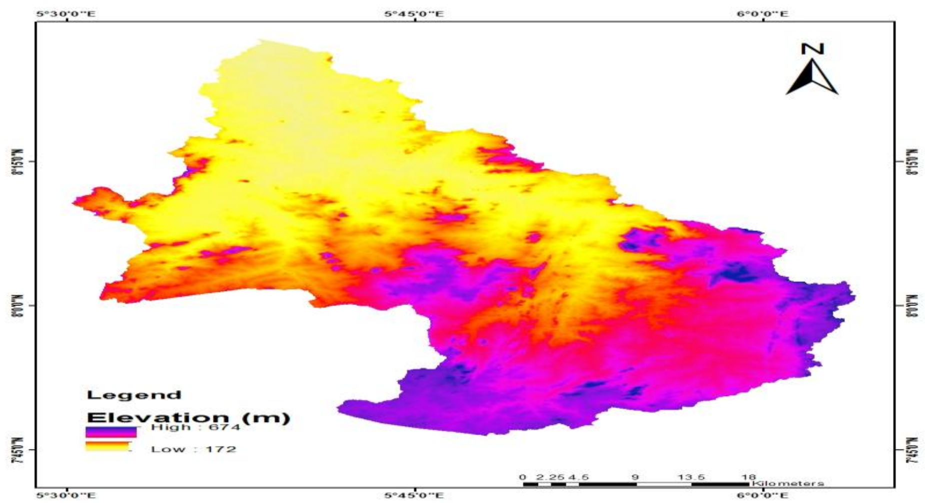

Fig. 4. Elevation map of Omi basin

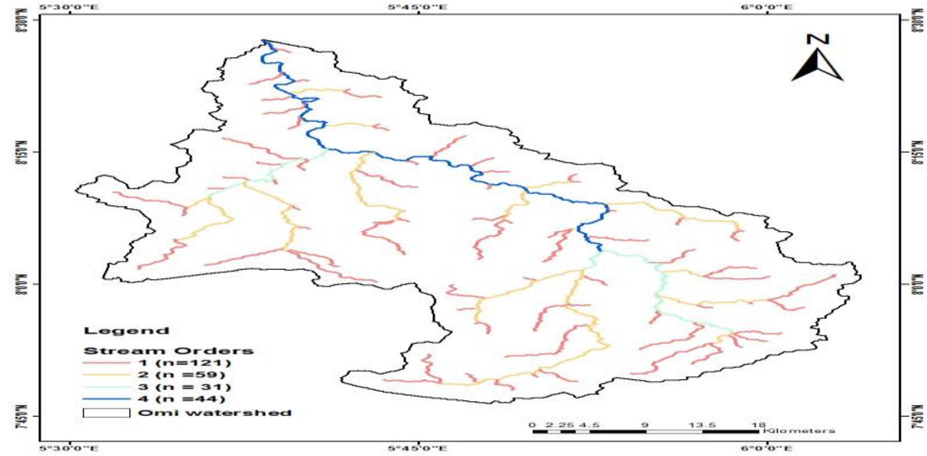

Fig. 5. Different orders of the Omi basin

Relief aspects

The relief aspect includes the study of basin relief (Bh), relief ratio (Rh), and Ruggedness number (Rn), respectively. The formulae with references and calculated values are listed in Table 2

Basin relief (Bh)

The height of the mouth of the watershed is 502 m from the sea level. The relief of watershed varies in between 502 m from the height of the watershed mouth. The calculated relief of the Omi watershed is 502 m as given in Table 2. The generalized relief map of the basin is given in Figure 4c.

Relief ratio (Rh)

Relief ratio (Rh) is the response of horizontal distance between two points (H) to the vertical difference between the same two points (Lb). The calculated value of relief ratio for the Omi watershed is 3.08 m/km as in Table 2.

Ruggedness number (Rn)

Strahler (1958) expressed ruggedness number (Rn) as the product of basin relief and drainage density. The Rn reflects the slop and relief variation in the basin. The low value of Rn (= 0.15) implies that the basin area is less prone to soil erosion and having lack of intrinsic structural complexity in association with the basin relief and drainage density (Vijith and Satheesh, 2006; Thomas et al., 2010) (Table 2)

4.3 ***Aerial aspect***

Drainage density (Dn

Drainage density (Dn) is defined as the length of streams (L) per unit of drainage area (A) and measured by dividing the total length of stream by the area of a drainage basin (Horton, 1945). It reflects the interaction between climate and the geological setup. There is a high correlation among drainage density, precipitation, and evaporation (Horton, 1932). Drainage density describes the spacing of the drainage ways. Higher this number means closer together are the channels. Coarse drainage density occurs in regions of highly permeable subsoil material, under dense vegetative cover, and where relief is low. The low drainage density values (0.30 km/km^2) of the Omi watershed reveal coarse drainage texture, permeable subsurface/subsoil, and dense vegetation in the study area.

Stream frequency (Fs)

The ratio between total number of streams (N) and area of a basin (A) is known as stream frequency (Fs) as given by Horton (1945). It is dimensionless and is a measure of texture of the drainage basin in geomorphologic terms (Thomas *et al*., 2010). The ratio >3 shows the very rough texture and high run-off on medium-to-high relief of low permeability (Reddy, 2002).The calculated value of stream frequency (Fs) is $0.11km^{-2}$ (<3) showing smooth texture and low run-off on low-to-medium relief of high permeability. The low value of stream frequency (Fs) indicates permeable subsoil and gentler gradient of the watershed area (Kanhaiya *et al*., 2018; Rai *et al*., 2018; Thomas *et al*., 2010)

Drainage texture (T)

The drainage texture is defined as the total number of stream segments of all order in a basin per perimeter of the basin (Horton, 1945). In general, the drainage texture is a measure of relative channel spacing in a fluvial-dissected terrain, which is greatly influenced by the climate, vegetation, lithology, soil type, relief, and stage of development of a watershed (Smith, 1950). In case of the Omi Dam, the calculated value of the drainage texture is 0.03 showing all drainage are texturally very coarse in nature.

Form factor (Rf)

Horton (1945) defined the form factor (Rf) as the ratio between basin area (A) and the square of basin length (Lb^2). Using this method, the calculated value for the study area is 0.09 which confirms flatter peak flow for longer duration in moderately elongated shape. Low form factor ratio indicates basins of flatter peak flow for longer duration (Biswas, 1999) with less side flow for shorter duration and main flow for longer duration (Reddy *et al*., 2002; Reddy, Maji, & Gajbhiye, 2004), and vice versa for high ratio.

Circulation ratio (Rc)

It is the ratio of area of basin (A) to the area of the circle having the same perimeter of the same basin (Miller, 1953). Similar to form factor, value nearer to one means more circular shape (Strahler, 1964). Runoff in circular shape basins gets more time to stay. Therefore, circular-to-elongate basin is inversely related to their character of movement (rapid or slow) of run-off to outlet and infiltration. These are further subjected to lithology, slope, and land cover of the basins or sub watersheds. The calculated value of the circulatory ratio is 0.31, which indicates elongated shape of the studied river basin.

Elongation ratio (Re)

According to Schumn (1956), the ratio between diameters of the circle having same area as of the basin and the length of the same basin is defined as elongation ratio (Re) of a river basin. The higher value of the Re indicates high infiltration capacity and low run-off conditions and vice versa (Reddy *et al*., 2002, 2004). The observed value of the elongation ratio for the Omi Dam is 0.33 which indicates high run-off and elongated shape of the basin.

Length of overland flow (Lof)

As per Horton (1945), the length of overland flow (Lof) is the length of water over the ground before it gets concentrated into definite stream channels which affect both the hydrological and physiographic characteristics of the basin. In the present studied basin, the Lof value is 1.9 showing relatively mature stage of the drainage development.

Constant of channel maintenance (C)

It is the inverse of drainage density and expressed with dimension of square per unit (Horton, 1945). It is also defined as the area of the basin needed to develop and sustain a unit length of stream channel (Schumm, 1956). Permeability, rock type, relief, vegetation, and duration of rainfall are the affecting factors of the constant of channel maintenance (C). The high value (= 3.9) of constant of channel maintenance for the studied basin indicates high permeability of subsoil, gentle-to-moderate slope, and high surface run-off.

Table 2. Morphometric parameters of Omi (Kampe) Basin

Morphometric Parameters	Result
Drainage area (km^2), A	2285
Perimeter (km), P	304
Basin order, U	4.0
Basin length (km), Lb	163
Bifurcation ratio, Rb	1.60
Drainage density (km/km^2), D	0.30
Stream frequency (km^2), Fs	0.11
Form factor, Rf	0.09
Circularity ratio, Rc	0.31
Elongation ratio, Re	0.33
Constant of channel maintenance (km^2/km), C	3.9
Length of overland flow (km), Lof	1.9
Drainage texture (T)	0.03
Relief (m), Bh	502
Relief ratio, Rh	3.08
Ruggedness number, Rn	0.15

V. Conclusion

Based on detailed investigation of the Omi watershed using remote sensing and GIS, and field survey, the following conclusions are made:

The Omi Dam is fourth-order basing, elongated in nature, which is usually associated with high relief and steep ground slope and moderately high peak flow of slightly shorter duration having basin area 2,285 km^2, and maximum length of the basin is 14 km. The basin have low drainage density and coarse drainage texture suggests permeable subsurface/subsoil, dense vegetation cover in the study area. The low value of stream frequency indicates permeable subsoil and gradual slope of the watershed area, while the form factor value confirms flatter peak flow for longer duration in moderately elongated shape of the basin. The high value of constant of channel maintenance of the basin indicates high permeability of subsoil, gentle-to-moderate slope, and high surface run-off showing relatively mature stage of the drainage development confirmed by length of overland flow.

The study also reveals that geographic information system (GIS) provides an ideal and convenient approach in the quantitative evaluation of drainage basin parameters and their influence on landform characteristics of the Omi watershed.

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