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Morphometric analysis of biriyakhedi micro-watershed, Jhalawar district of Rajasthan, using geospatial techniques: A case study

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Abstract
Biriyakhedi micro-watershed is part of Kalisindh, Chandrabhaga catchment covering an area of 1648.28 ha in Jhalrapatan tehsil of Jhalawar district in south eastern Rajasthan. The morphometric parameters of the basin can address linear, areal and relief aspects. The present study deals mainly with the geometry, more emphasis being placed on the evaluation of morphometric parameters such as stream order (Nu), stream length (Lu), bifurcation ratio (Rb), drainage density (Dd), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc), and form factor ratio (Rf) etc. The GIS based morphometric analysis of this drainage basin revealed that the Biriyakhedi micro-watershed is 4th order drainage basin and drainage pattern is sub-dendritic to dendritic type. It indicates the homogeneity in texture and lack of structural control. Total number of streams is 125 in which 93 are first order, 23 are second order, 8 are third order and 1 is fourth order streams. The length of stream segment is maximum for first order stream and decreases as the stream order increases. The drainage density (Dd) of study area is 3.5 km/km^2. The low value of bifurcation ratio (4.04) revealed that the drainage pattern is not affected by the geologic structures. High value of elongation ratio has flat land with low relief and low slope (0.47) compare to circulatory ratio (0.61) indicates elongated shape of the micro-watershed. Low value of drainage density (3.5 km/Sq km) shows that the region is having coarse permeable sub stratum material under vegetative cover and watershed relief is low. Relief ratio (0.052) and relative relief (0.28%) reflects that the watershed can be treated with soil and water conservation measures. This study would help the local people to utilize the resources for sustainable development of the micro watershed.

Keywords: Geospatial techniques, GIS and geomorphological and morphometric analysis

Introduction
The quantitative analysis of morphometric parameters is of immense utility in river basin evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level. Morphometric analysis represents relatively simple approaches to describe basin processes and to compare basin characteristics (Mesa 2006) [9] and enable an enhanced understanding of the geological and geomorphic history of a drainage basin (Strahler 1964) [15]. The morphometric assessment helps to elaborate a primary hydrological diagnosis in order to predict approximate behavior of a watershed if correctly coupled with geomorphology and geology (Esper 2008) [4]. The hydrological response of a river basin can be interrelated with the physiographic characteristics of the drainage basin, such as size, shape, slope, drainage density and size, and length of the streams etc. Hence, morphometric analysis of a watershed is an essential first step, toward basic understanding of watershed dynamics. Morphometric analysis could be used for prioritization of micro watersheds by studying different linear and aerial parameters of the watershed even without the availability of soil maps (Biswas *et al*., 1999) [2]. Remote sensing and GIS are the most advanced tools for studies of micro-watersheds for their development and management.

Materials and methods
Study area: The Biriyakhedi micro-watershed is located in Jhalrapatan tehsil of Jhalawar district of south eastern Rajasthan (Fig.1) and lies between 76°06′0.79” to 76°09′10.446” East longitudes and 24°28′5.383”to 24°31′24.807” North latitudes and falls in Survey of India Toposheet 54D/2 and 54D/3 (1:50000). The Biriyakhedi micro-watershed is covering an area of 1648.28 ha. The study area forms a part of Deccan traps which cover along with the rocks of Vindhyan Super Group. The Vindhyan Super Group in Malwa plateau which consist of

sandstone, shale and limestone. The Ratneshwar Mahadev Nallah flows from south west to north east joining the Gomti Sagar talab than flow in Chandrabhaga river and lastly falls into Kalisindh river. It is the main water source for Mundiyakhedi lake. It falls in Agro-climatic Zone V (Humid south eastern plain). The climate is fairly dry. The annual rainfall is 833 mm. Major kharif crops are soybean, sorghum, maize, groundnut while wheat, chickpea, coriander and mustard are major rabi crops of the area. The study area is known as "Chhota Nagpur" for orange production and having a well-known identity for garlic and coriander production.

Drainage has been generated from Advanced Land Observing Satellite (ALOS) with 12.5 meter resolution. The boundaries of micro watershed have been derived by defining pour point. The pour point is the location where water drained from whole of the micro watershed flows into the main Nallah. Based on the cumulative number of the upstream cells draining to each cell, stream network in both the micro watersheds was defined. The critical threshold is the minimum upstream drainage required to initiate a stream. Area of the micro watershed is evaluated by calculating the geometry of the derived micro watershed polygons and length of the micro watershed

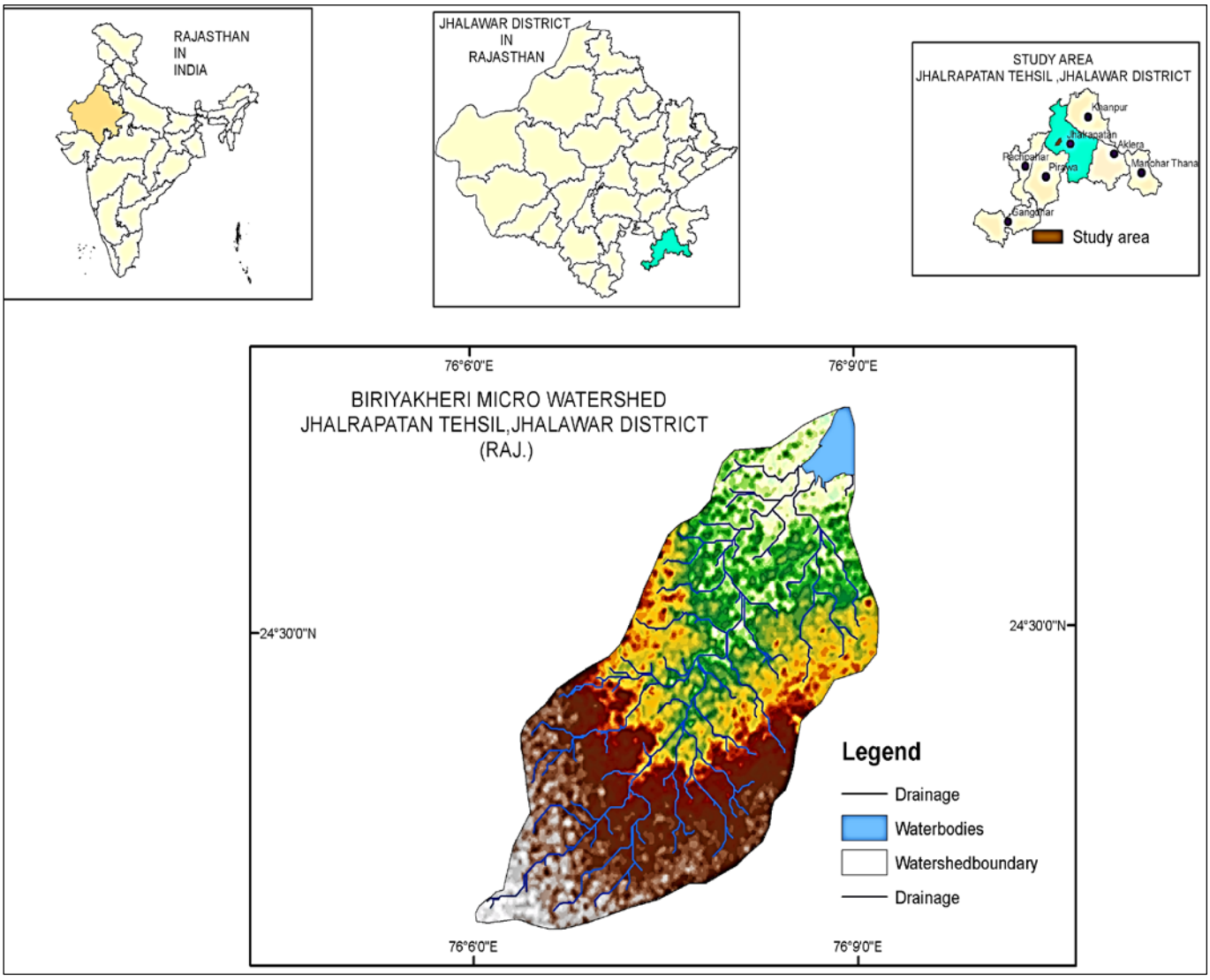

Fig 1: Location map of study area

is calculated by summing of the length of the main stream channel and the distance from the top of the main channel to the micro watershed boundary. By summing the lengths of all stream segments in micro-watershed the total stream length has been computed.

Table 1: Grouping of geomorphological parameters

Groups	Geomorphological Parameters
Linear Aspects of Drainage Network	Stream order, stream number, bifurcation ratio, stream length and stream length ratio
Areal Aspects of Watershed	Drainage density, form factor, circulatory ratio and elongation ratio,
Relief Aspects of Channel Network	Relief ratio, relative relief, ruggedness number and geometric number

The various morphometric parameters computed using standard methods and formulae have been given in table 2. The morphometric analysis, area, perimeter, maximum length, drainage map, stream length of each order, numbers of stream of each order and watershed relief values are required. These inputs were derived by using GIS software. The necessary parameters for morphometric characteristics of micro-watershed have been computed.

Table 2: Morphometric characteristics of Biriyakhedi micro-watershed

Area (Km^2)	16.48			
Constant channel maintenance (c)	0.68			
Perimeter (Km)	18.48			
Stream order	I	II	III	IV
Number of Streams (Nu)	93	23	8	1
Stream length (Lu) Km	28.06	16.68	7.60	5.36
Average stream length (Km)	0.30	0.72	0.95	5.36
Bifurcation ratio (rb)	4.04	2.88	8	
Drainage density (Dd) Km^2	3.5			
Stream frequency (Fs)	3.12			
Drainage texture (Rt)	6.24			
Form factor (Rf)	0.17			
Circulatory Ratio (Rc)	0.61			
Elongation Ratio (Te)	0.27			
Relief Ratio (Rh)	0.005			
Time of Concentration (Tc) Minute	51.37			

Results and Discussion

The geomorphological analysis is the measurements has been made from the digitized drainage pattern and micro-watershed boundary. Micro-watershed boundary and digitized drainage pattern is shown in Fig. 2.

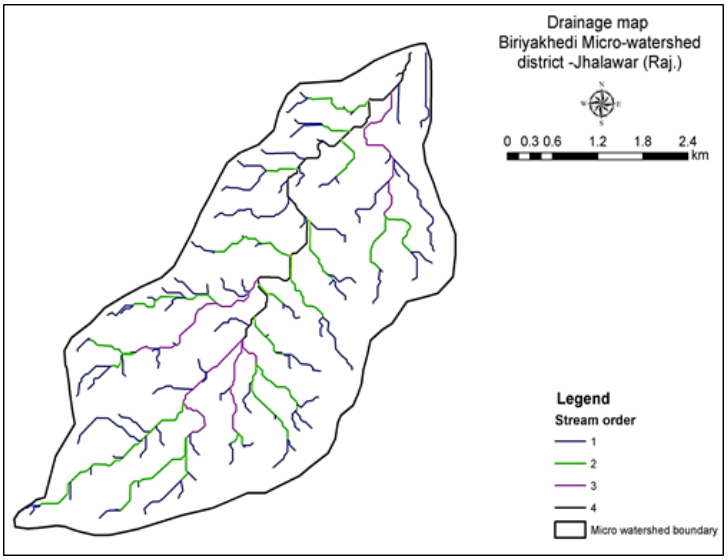

Fig 2: Drainage Map of Watershed

Stream analysis: Stream analysis consisted of grouping of stream segment in different orders, measuring stream length, calculating cumulative stream length and mean stream length.

i) Relation between stream number and stream order

According to the Horton's law, the plot of logarithm of stream number (ordinate) as a function of stream order should yield a set of points lying along a straight line. For the present study, this graph was plotted for the watershed which shows a straight line, satisfying the Horton's law (Kumar *et al*., 2001) [8]. It is evident that the correlation coefficient for the straight line fit for the watershed is 0.9809 which is quite satisfactory (Fig. 3).

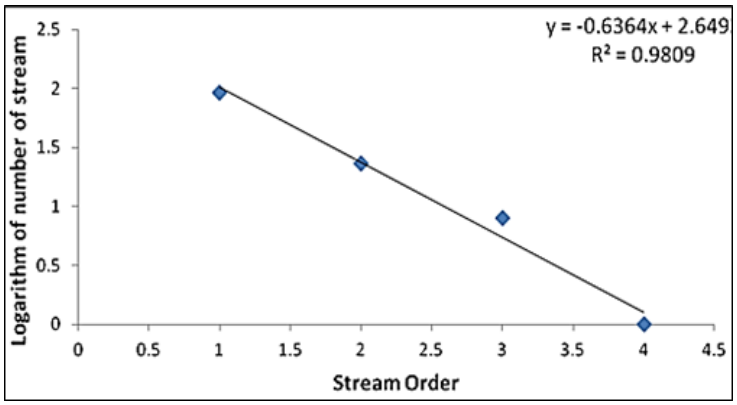

Fig 3: Regression of logarithm of number of stream and stream order

ii) Relation between cumulative stream length and stream order

In the present study, an attempt has been made to establish the relation between the stream order and the cumulative stream length. The plot of logarithm of cumulative stream length along ordinate and stream order along abscissa for the watershed is a straight line fit as shown in Fig. 4. The straight-line fit indicates that the ratio between cumulative stream lengths is constant throughout the successive order of a basin and suggests that geometrical similarity is preserved in basins of increasing order (Kumar *et al*., 2001, Gupta, 2003, Tailor *et al*., 2008) [8, 5, 3]. It is evident that the correlation coefficient for the straight line fit for the watershed is 0.7159 which is substantial quite satisfactory.

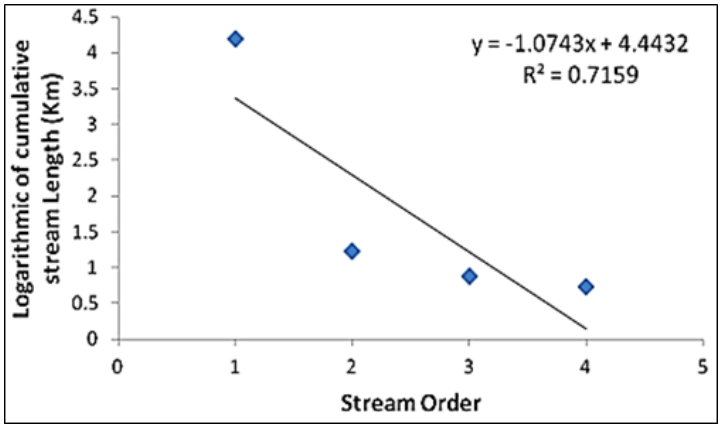

Fig 4: Regression of logarithm of cumulative stream length and stream order

Linear aspects of drainage network: It refers to the analysis of stream order, stream number, bifurcation ratio and stream length ratio. After analysis, it was found that the watershed is of 4th order type and drainage pattern is dendrite (Naitam *et al*., 2016 and Mittal, 2002) [13, 10]. The numbers of stream of 1st, 2nd, 3rd and 4th order is 93, 23, 8 and 1 respectively and their corresponding lengths are 28.06 km, 16.68 km, 7.60 km, and 5.36 km respectively. However, in general, the mean length of the stream of the particular order increases with the increase in the order of stream which means that the mean length of a stream of a given order is greater than the immediate lower order but less than that of the next higher order. This confirms the property of the stream order number and their corresponding length. The other important property bifurcation ratio (R_b) reflecting geological and tectonic characteristics of the watershed estimated as 4.04 for the watershed which confirms the research of Horton (1945) [6]. The value indicates that the watershed has suffered less structural disturbance and the drainage pattern has not been distorted by structural disturbance (Nag and Chakroborty, 2003) [11]. The average stream length ratio estimated is 1.83 and RL_2, RL_3 and RL_4 are not close to each other which confirms the property that length ratio tends to be vary throughout the successive orders of steam segments in the watershed.

Areal aspects of watershed: Under this aspect, the study gives the description of arrangement of area element mainly watershed shape which affects the stream flow hydrographs and peak flow. The important parameters that describe the shape of the watershed viz. form factor, circulatory ratio and elongation ratio were computed. Referring Table 2. It shows that the value of form factor (R_f), circulatory ratio (R_c) and elongation ratio (T_e) are 0.17, 0.61 and 0.27 respectively. Therefore, greater is the elongation ratio than circulatory ratio indicates that watershed is approaching towards the elongated shape (Singh *et al*., 2003) [14]. In this case elongated watershed with low R_f indicates that the watershed will have a flatter peak of flow for longer duration. Flood flow of such elongated watershed is easier to manage than from the circular watershed (Pandey *et al*., 2004) [12].

The drainage density of watershed is 3.5 km/km^2 indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole watershed. Further, it gives an idea about the physiographical properties of the underlying soils. High value of D_d indicated that the region is having impermeable sub-soil material under poor vegetative cover and watershed relief is low (Strahler, 1964) [15]. The value of stream frequency is 3.12 per km^2 indicating the increase in stream population with respect to increase in drainage density. Further, related to D_d another morphological characteristic property of drainage basin is constant of channel maintenance which was found to be 0.68 km/ km^2 for the study area. It indicates the number of square meters of basin surface required to maintain one linear meter of channel.

Relief aspects of channel network: This refers to the analysis of relief aspects of drainage basin and channel networks. Estimated value of relief is 51meter, based on which relief ratio (R_r) and relative relief (Rr) were found to be 0.0052 and 0.28 respectively and also time of concentration for watershed was computed and value is 51.37 min.

Conclusion

The present study demonstrates the utility of RS and GIS technique in studying morphometric analysis of micro watershed. The satellite remote sensing has the ability to provide synoptic view of large area and is very useful in analyzing drainage morphometry. It served as an efficient tool in drainage delineation and updating. In the present study these updated drainage have been used for morphometric analysis. The morphometric analysis was carried out through measurement of linear, aerial and relief aspects of the basin. Biriyakhedi micro-watershed is elongated in shape with sub-dendritic to dendritic drainage pattern that mean dendritic with fine texture. The straight-line plot of the stream order versus stream number satisfied Horton's first law of stream numbers which states that the number of streams of different orders in a given drainage basin tends to be a reverse

geometric series in which the first term is unity and the bifurcation ratio. The bifurcation ratio of Biriyakhedi micro-watershed indicates homogeneity in texture and lack of structural control. Low stream frequency 3.12 (1 to 3.5). The longitudinal profile shows that the upstream has gentle slope and gradually the gradient is very gentle to plain land towards the mouth of the micro watershed. According to Strahler these relief measures may be indicative of the potential energy of the drainage system because of its elevation above the mean sea level.

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