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Estimate the geomorphological parameters of the Arang watershed in Chhattisgarh region

■ **GEETA AND ANISA**

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■ **ABSTRACT :** This study was conducted for the Arang watershed of the Chhattisgarh, India. Several geomorphological parameters of the watershed were determined using standard procedure. The Arang is 3rd order watershed and comprises of 10 villages. Predominant soil of the watershed is clay loam. The watershed receives an average annual rainfall of 1400 mm, out of which the monsoon season (June to October) contributes more than 85 per cent rainfall. The number of 1st, 2nd and 3rd Order were found to be 20, 4, 1, respectively. The different geomorphometric parameters of watershed were determined and result showed that total length of stream segments were 26.14, 9.37, 8.56 km, respectively. Area of sub-basin for 1st, 2nd and 3rd order streams and of different order streams were to be 32.35, 43.94, and 54.50 km^2, respectively, for 1st, 2nd and 3rd order streams. The mean bifurcation ratio for the watershed was found to be 4.64. The length ratio, circularity ratio and elongation ratio for the Arang watershed were determined and found to be 2.724, 0.9148 and 0.973, respectively. The hypsometric integral of the watershed was calculated to be 0.998 km. The drainage density, length of over land flow and constant of channel maintenance of the watershed were found to be 0.808 km/km^2, 0.618 km and 1.237 km, respectively. The main channel slope of the watershed was 0.005 whereas compactness co-efficient of the watershed was 1.093. The stream frequency, basin shape factor, form factor, and ruggedness number of the watershed were 0.458 km^2, 2.578, 0.387, 0701 and 0.016, respectively. The values of relative relief and relative ratio of the watershed was found to be 1.452×10^{-3} and 1.687×10^{-3}, respectively. The weighted average slope of the entire watershed was found to be 1.5 per cent. This parameter which indicates that topography of watershed is flat.

■ **KEY WORDS :** Morphological parameters, Geomorphological watershed parameters, Runoff measurement parameters, Geomorphological parameters, Watershed parameters, Geomorphological features

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Development and management of natural resources in sustainable manner is possible by adopting soil and water conservation programme on watershed basis. Soil and water are very important for sustainable agriculture. The average annual rainfall of India is about 120 cm and 80 per cent of these occur only in monsoon season *i.e.* from July to October. The amount of rainfall annually through the four different types of weather phenomena southwest monsoon (74%), northeast monsoon (3%), pre-monsoon (13%), post-

monsoon (10%). The distribution of rainfall varies with time and space, the analysis of rainfall become more important for soil conservation point of view. Estimation of runoff is important for designing the soil and water conservation structures. Nag (1998) remote sensing techniques using satellite imagery is an indispensable tool in morphometric analysis and ground water studies. The base map showing drainage details were prepared from toposheets of survey of India (SOI) and satellite imagery. Morphometric analysis using remote sensing techniques was carried out in Chakra River sub-basin of Manbazar Block, Purulia district, West Bengal state, India. The parameters worked out included bifurcation ratio, stream length, form factor, circulatory ratio and drainage density. Tripathi *et al*. (2002) was conducted for the Nagwan watershed of the Damodar Valley Corporation (DVC), Hazaribagh, Bihar, India. Geographical Information System (GIS) was used to extract the hydrological parameters of the watershed from the Remote Sensing and field data. It was found that the model can predict runoff reasonably well and is well suited for the Nagwan watershed. Design of conservation structures can be done and their effects on direct runoff can be evaluated using the model.

Narendra and Rao (2006) used the GIS and image processing techniques to identify the morphological feature and water resources of the Meghadrigedda (Andhra Pradesh) watershed. The morphometric parameters such as linear aspects and aerial aspect of six sub-watersheds of the watershed were computed. Further suitable sites were selected for the water conservation structures.

Chopra *et al.* (2005) carried out morphometric analysis of two sub-watershed (Bhagra-Phungotri and Hara Maja) was carried using remote sensing and GIS techniques. Detailed drainage map prepared from aerial photographs and SOI toposheets was updated using latest IRS-ID PAN sharpened LISS-III analog data. Updated drainage maps were used for the morphometric analysis of the two sub-watersheds.

Nautiyal (1994). Nagwan watershed of the Damodar Valley Corporation (DVC), Hazaribagh, Bihar, India. Morphometric analysis of a drainage basin using aerial photographs in the Khairkuli Basin in Dehradun district, Uttar Pradesh, India. The morphometric parameters were measured and computed manually. It was concluded that Remote Sensing techniques using satellite image and aerial photographs are convenient tools in morphometric analysis of a drainage basin and the photo-interpretation techniques is far less time consuming.

METHODOLOGY

Study area :

Arang watershed located in the Raipur district of Chhattisgarh state has been selected for investigation. Arang watershed located at about 45 km away from Raipur city towards Mahasmund district. The watershed boundary covering various villages namely Amethi, Khamtarai, Kalai, Jarauda, Chhatauna, Sandi, Kukra etc. The watershed lies between $81^0$54' to $82^0$0'E longitude and $21^0$12' to $21^0$16'N latitude. Topographic maps number 64 G/15 and 64 G/16 of 1:50000 scale cover the entire watershed. The location map of study area is shown in Fig. A.

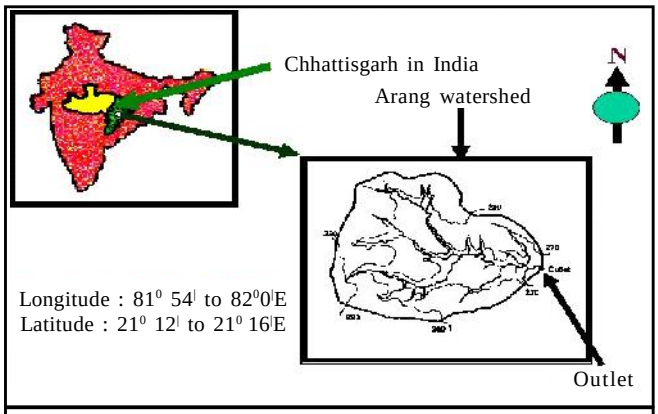

Fig. A : Location map of the Arang watershed in Chhattisgarh

Geomorphological analysis :

Morphological characterization is the systematic description of watershed's geometry. Geometry of drainage basin and its stream channel system required the following measurements: (i) linear aspects of drainage network, (ii) aerial aspect of drainage basin, (iii) relief aspect of channel network and contributing ground slopes. The methodologies adopted for computation of morphometric parameters are follows:

– Stream Length, Stream Length Ratio, Length of Over Land Flow and Drainage Texture (Horton, 1945)

– Bifurcation Ratio, Elongation Ratio and Relief Ratio (Schumann, 1956)

– Mean Bifurcation Ratio (Strahler, 1957)

– Relative Relief (Melton, 1957)

Table A : Equations used to extract various geomorphological parameters of the Arang watershed

Sr. No.	Watershed parameters	Equations used	Details of the equations
1.	Bifurcation ratio (R_b)*	$R_b = \frac{N_u}{N_{u+1}}$	N_u = Number of streams of a particular order and N_{u+1} = Number of streams of the next higher order
2.	Average bifurcation ratio (R_b)	$\log_{10} N_u = a + bU$ $R_b = \text{Antilog } b$	U = Order of stream and a and b are the regression co-efficients
3.	Circulatory ratio (R_c)	$R_c = \frac{[\sqrt{4A\pi}]}{L_P}$	L_p = Perimeter of the watershed (km) and A = Area of the watrershed (km^2)
4.	Elongation ratio (R_e)	$R_e = \left[\sqrt{4A/\pi}\right] \times [1/L_b]$	L_b= Maximum length of the watershed (km) and A = Area of the watrershed (km^2)
5.	Relief ratio (R_r)	$R_r = \frac{H}{L_b}$	H = Maximum watershed relief (km) L_b= Maximum length of the watershed (km)
6.	Relative relief (R_R)	$R_R = \frac{H}{L_P}$	L_p = Perimeter of the watershed (km) and H = Maximum watershed relief (km)
7.	Basin shape factor (S_b)	$S_b = \frac{[L_b]^2}{A}$	L_b= Maximum length of the watershed (km) and A = Area of the watrershed (km^2)
8.	Ruggedness number (R_N)	$R_N = \frac{H D_d}{1000}$	D_d = Drainage density (km^{-1}) and H = Maximum watershed relief (m)
9.	Average slope of the watershed (S_a)	$S_a = \frac{H L_{ca}}{A}$	A = Drainage area of the watershed (km^2) and L_{ca} = Average length of the contour (km)
10.	Drainage density (Dd)	$Dd = \frac{Ls}{A}$	L_s = length of stream of stream segment (km), A = Basin area in km^2
11.	Constant of channel maintenance (C)	$C = \frac{1}{Dd}$	Dd = Drainage density
12.	Length of overland flow (Lo)	$Lo = \frac{1}{2Dd}$	Dd = Drainage density
13.	Stream/drainage frequency (Sf)	$Sf = \frac{Nu}{A}$	Nu = Total number of stream segments of order 'u' A = Basin area in km^2
14.	Form factor (Ff)	$Ff = \frac{1}{Sb}$	Sb = Basin shape factor

– Drainage Density, Stream Frequency and Form Factor (Horton, 1932)

– Circulatory Ratio (Miller, 1953)

The basin geomorphology plays an important role in the transition of water from the overland region to channels (streams) and also from the channels of one order to the other, the basin has to be ordered to determine the geomorphological features.

Drainage area :

The drainage area 'A' is the probably the single most important watershed characteristic for hydrologic design. It reflects the volume of water that can be generated from rainfall. It is common in hydrologic design to assume a constant depth of rainfall occurring uniformly over the watershed. Under this assumption, the volume of water available for runoff would be the product of rainfall depth and the drainage area.

Perimeter :

Total length of boundary of a watershed is known as the perimeter of the watershed and it is denoted by 'P' the factors that are dependent on the basin parameter are elongation ratio and circulatory ratio. Earlier, the perimeter was measured with chartometer (*i.e.*, a map measurer) all segments within the specified drainage network were used to measure successively without pause or recorded the cumulative length appeared on the dial of the chartometer.

■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Geomorphological analysis :

Geomorphological is a science that attempts to

quantify the shape of drainage basin. Various parameters were extracted from the thematic maps including watershed boundary, drainage map and Digital Elevation Model (Plate 1 and 2). The geomorphological analysis parameters of the watershed were given in Table 1 and 2.

Stream order :

The designation of stream orders was the first step in drainage basin analysis. It is the dimensionless term. After analysis of the drainage map, it was found that Arang watershed was third order stream and drainage pattern was dendrite. The number of 1st order stream were found 20, 2nd order streams was found 4 and 3rd order stream was found 1.

Hypsometric integral :

The hypsometric Integral was entreated by measuring the area under graph plotted between relative height and relative area (Table 2).

Other watershed parameters :

Various perimeter of the watershed, length of all stream, total length of all contours, maximum relief of the watershed, area ratio, main channel slope, compactness co-efficient, basin shape factor, drainage factor, relative relief and ruggedness number watershed are given in Table 3.

Conclusion :

The geo-morphometric analysis was done in order to study overall morphology of the watershed and to carry out further hydrological analysis. It was found that the geo-morphometric parameters like stream order, stream length, area perimeter, basin length, hypsometric integral, bifurcation ratio, circulatory ratio, elongation ratio, relief ratio, relative relief, basin shape factor, ruggedness number, main stream channel slope, average slope of

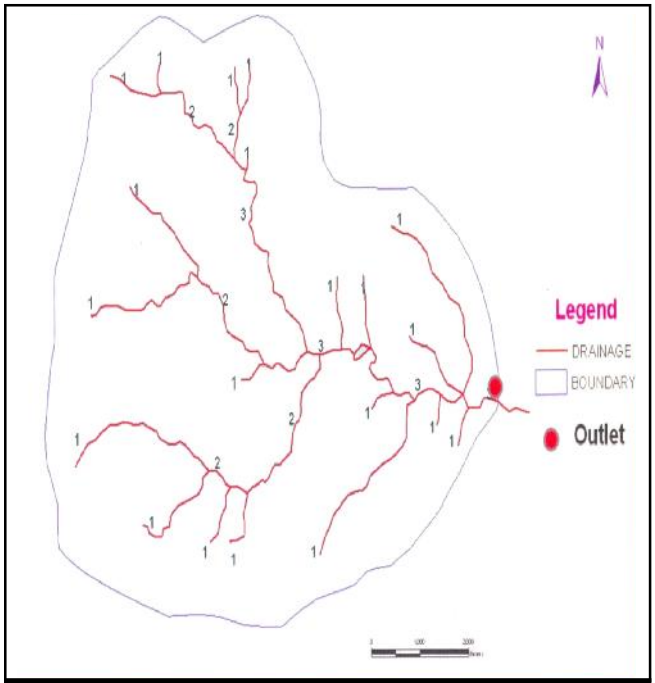

Plate 1 : Drainage map of the w/s

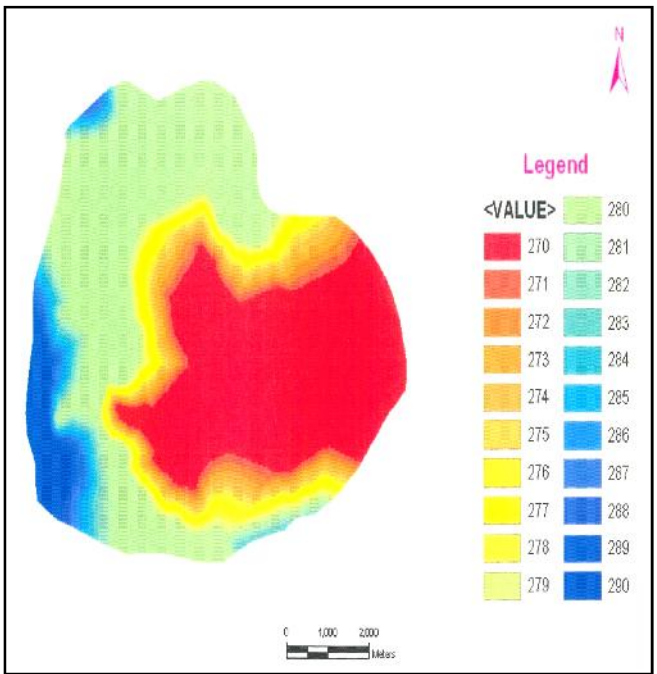

Plate 2 : Digital elevation model of the w/s

Table 1 : Area between different contour elevations for the Arang watershed

Sr. No.	Contour elevation, m	Area between contours, km^2	% of total area	% of total area over given lower limit
1.	<270	10.875	19.954	100
2.	270-280	23.687	43.462	80.04
3.	280-290	18.125	33.256	36.584
4.	>290	1.812	3.324	3.324

Table 2 : Values of geomorphological parameters of the Arang watershed

Sr. No.	Watershed parameters	Value
1.	Watershed area (A,) km^2	54.50
2.	Perimeter of the watershed,(Lp) km	28.60
3.	Total length of Drainage, km	44.07
4.	Length of all the streams, km	44.08
5.	Length of main stream, (Lms) km	8.56
6.	Maximum length of watershed (Lb), km	11.85
7.	Total length of all contours, (Lca) km	59.75
8.	Average contour length, km	19.91
9.	Maximum relief of the watershed, (H) m	20
10.	Area ratio (R_A)	3.5481
11.	Hypsometric integral (Hsi) km	0.998
12.	Drainage density (Dd) km/km^2	0.808
13.	Length of over land flow (Lo) km	0.618
14.	Constant of channel maintenance (C) km	1.237
15.	Average slope of the watershed (Sa)	0.015
16.	Main channel slope (Sc)	0.005
17.	Compactness co-efficient (C_c)	1.093
18.	Circularity ratio (R_c)	0.9148
19.	Elongation ratio (R_e)	0.973
20.	Length ratio	2.724
21.	Bifurcation ratio (R_b)	4.461
22.	Stream frequency (Sf) km^{-2}	0.458
23.	Basin shape factor (Sb)	2.578
24.	Form factor (Ff)	0.387
25.	Drainage factor (Df)	0.701
26.	Relative relief (RR)	$1.452*10^{-3}$
27.	Relative ratio (Rr)	$1.687 *10^{-3}$
28.	Ruggedness number (RN)	0.016

the watershed and length of overland flow of the watershed is flat, estimating the runoff and evaluating its effect on various structures of the considering in the Arang watershed safe.

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