Morphometeric Analysis of KR-25Watershed with the Help of Remote Sensing (RS) and Geographical Information System (GIS) - Scope in Planning of Water Resources

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Abstract

To study scope for watershed development and management morphometeric features of Krishna River (KR) 25 watershed have been selected. Analysis reveals that, KR 25 watershed area of Basin (Km^2) is 320.031and have Vth stream order.Stream length for the watershed KR- 25 is 715.021 km comprised of 1168 streams of Ist toVth order. Mean stream length of the watershed is (Lsm) 0.61.Bifurcation ratio (Rb) value is stand for 5.57. The Circulatory ratio (Rc)value 0.47 reveals that, KR 25 watershed is elongated in shape where infiltration rate is very high. Drainage density (Dd) is 2.23 and Stream frequency (Fs) is 3.65.After analyzing morphometeric features results reveals that, watershed development in KR 25will give effective results on the occurrence of the ground water. This type of scientific study is need to carry forward while scientific planning of watershed development, which will generate strong base for natural resources such as soil and water.

KEYWORDS: Geographical Information System (GIS), Morphometeric analysis, watershed, Krishna River Basin.

Introduction: Systematic description of the geometry of a drainage basin and its stream-channel system requires measurement of linear aspects of the drainage network, aerial aspects of the drainage basin, and relief aspects of channel network and contributing ground slopes.(Nageswara Rao, 2010)Geographical Information System (GIS) based morphometeric analysis has been carried out to evaluate linear, relief and aerial morphometeric parameters of the KR 25 watershed using software's Geo media Professional 5.0, ERDAS Imagine 9.1, and ArcGIS 9.2.with objective such as, to analyze linear, relief and aerial morphometeric parameters of the KR 25 watershed, to study co relevance of morphometeric parameters and watershed development in KR 125 watershed, to analyze potential of Geographical Information System (GIS) in planning of watershed development and management.

Materials and Methods: Study was carried out in the year 2012 and 2013. In this study the morphometeric analysis of KR 25 watershed were done by following a systematic method, comprising the software packages of Geomedia Professional 5.0 and ArcGIS 9.2

Primary Data: -Satellite Digital data acquired by Landsat ETMP (Enhanced Thematic Mapper Plus) sensor acquired for January 2006 has been used as primary data source. From this 30 m spatial resolution imagery all types of spatial information such as land use/land cover, water bodies, morphological features, drainage network etc.

Secondary Data:-Survey of India (SOI) Toposheets of KR 25 watershed of Sangli district which stretches between latitudes of 17^0, 17'-22' N and 74°,19'-45' E with the scale of 1:50000 published during 1973 to 1979 are used to extract contours, drainages and base maps.

Results and Discussion

Morphometric analysis of KR 25 watershed: Morphometric analysis is carried out for the shape of the basin, area of the basin and the length of the stream. On the basis of projection of the system to horizontal plane, the linear properties such as length, area, arrangement etc. are calculated. The plan metric' measurements were carried out in a single plane.

Linear Aspects: The linear aspects Stream order, stream length, mean stream length, stream length ratio and bifurcation ratio etc. are linear aspects that were determined and results have been given in tabulated form Table 1.

Table 1: Linear aspects of the KR-25, watershed is as follows.

Sr.No	Morphometeric parameters	Watershed No. KR-25
1.	Stream order	5^{th}
2.	Total Stream length (Lu)	715.021
3.	Average of Mean stream length (Lsm)	0.61
4.	Mean Stream length ratio (RL)	0.38
5.	Bifurcation ratio (Rb)	5.57
5.	Relief Ratio (Rl)	9.34
6.	Drainage density (D)	2.23
7.	Stream frequency (Fs)	3.65
8.	Drainage Texture (RE)	12.57
9.	Form Factor (RF)	0.26
10.	Circulatory ratio (Rc)	0.47
11	Elongation ratio (Re)	0.57
12.	Length of overland flow (Lg)	0.90

Stream Order (Nu): The first step of drainage basin analysis to draw the drainage divide and trace all the streams occurring within it. The smallest fingertip tributaries are designated as order 1. Where two first order channels join, a channel segment of order 2 is formed; where two of order 2 join, a segment of order 3 is formed; and so on. The stream through which all discharge of water and sediments passes is the stream of the highest order by using Strahler's Method. (Strahle, A.N.1964).

Drainage pattern of the study area: In the following table stream orders and length of streams of the study watershed KR 25, have been given as Table 2.It is observed in the present study, the maximum number of streams is in lower order i.e. 5^{th} order for watershed KR25.

Table 2: Stream order of KR 25 watershed.

SN	Stream order	No of streams	Length of Stream (Km)
1	I^{st} order	901	383.962
2	II^{nd} order	219	178.466
3	III^{rd} order	41	108.717
4	IV^{th} order	06	41.308
5	V^{th} order	01	2.568
	Total	1168	715.021

1.Total no of stream order-1168   2.Total stream length of all order - 715.021 km.

Stream length (Lu): The numbers of streams of various orders in a watershed are counted and their lengths from mouth to drainage divide are measured with the help of GIS software's. The stream length (Lu) has been computed based on the law proposed by Horton (1945) for the all study watersheds. Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. Total length of all streams of all order (I to V) is calculated for this watershed. Total stream length of watershed KR-25 is 715.023 km comprised of 1168 streams of $I^{st}$to V^{th}order. Sometimes there may be changes in the computation of streams.This change may indicate the streams of high altitude, lithological variation and moderately steep slopes (Singh and Singh, 1997).

Mean stream length (Lsm): According to Strahler (1964), the mean stream length is a characteristic property related to the drainage network and its associated surfaces. The mean stream length (Lsm) has been calculated by dividing the total stream length of order 'u' and number of streams of segment of order 'u', given in Table No.2. Mean stream length (Lsm) of any given order is greater than that of the lower order and less than that of its next higher order in both the sub-watersheds which might be due variations in slope and topography. Lsm of the KR 25 watershed is 0.61 km.

Stream Length Ratio(RL): Stream length ratio (RL) may be defined as the ratio of the mean length of the one order to the next lower order of stream segment.

Stream Length Ratio RL = Lu / (Lu – 1)

Where, RL = Stream Length Ratio, Lu = Total stream length of the order 'u'

Lu – 1 = Total stream length of its next lower order.

Horton's law (1945) of stream length stated that mean stream length segments of each of the successive orders of a basin tends to approximate a direct geometric series with stream length increasing towards higher order of streams. The RL values of the KR 25 watershed is 0.38 km, The RL values differ from watersheds to watersheds. Generally, a variation in slope and topography affects the stream length ratio. (Horton,1945)

Relief Ratio (Rh): Relief ratio, (Rh) is ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line (Schumm, 1956).

Relief Ratio   Rh = H / Lb

Where, Rh = Relief Ratio,   H = Total relief (Relative relief) of the basin in Kilometers

Lb = Basin length

The Rh normally increases with decreasing drainage area and size of sub-watersheds of a given drainage basin (Gottschalk, 1964). Rh value of KR 25 watershed is 9.34.

Digital Elevation Model (DEM): In this study the values of Rh for the watersheds KR 25 watershed is 9.34. It is noticed that, the high values of Rh indicate steep slope and high relief (m). These values may indicate the presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope. (Gottschalk,1964)

Bifurcation Ratio (Rb): The ratio of number of segments of a given order N_u to the number of segments of the higher order. (N_u + 1) is termed the bifurcation ratio R_b. The term bifurcation ratio (Rb) is the ratio of number of the stream segments of given order to the number of segments of the next higher order (Schumm, 1956).

Bifurcation Ratio Rb = Nu / (Nu + 1)

Where, Rb = Bifurcation Ratio, Nu = Total no. of stream segments of order 'u'

Nu + 1 = Number of segments of the next higher order

Strahler (1957)demonstrated that, bifurcation ratio shows a small range of variation for different regions or for different environment except where the powerful geological control dominates. In this study the mean bifurcation ratio of study KR 25 watershed is 5.57. Bifurcation ratio characteristically ranges between 3 and 5 for drainage in which the geologic structure does not distort the drainage pattern. This pattern is observed in the KR 25watershed. Bifurcation ratio above 5 indicates structural control of drainage. In such cases, the development of higher order streams is normally facilitated by head ward erosion and guided by linear zones of structural weakness. Such streams are significant because they enhance the recharge and thereby the potential of groundwater and this type of stream pattern is recorded in the KR 25 watershed. Abnormally high bifurcation ratios might be expected towards dip direction. Thus, bifurcation ratio is a significant parameter throwing light on groundwater regime.

Drainage Density (Dd): Horton (1932) has introduced drainage density (D) into American hydrologic literature as an expression to indicate the closeness of spacing of streams. It is the total length of streams of all orders per drainage area. In other words drainage density (Dd) is the total length (L) of the stream in the basin divided by the area (A) of the whole basin, or Lu / A. It is thus average length of streams for each unit area.

Drainage Density D = Lu / A

Where, D = Drainage Density, Lu = Total stream length of all orders

A = Area of the Basin (Sq.Km.)

The drainage density value of KR 25watersheds is 2.23 km/ Sq.Km. The low drainage density indicated that the region has highly permeable subsoil and dense vegetative cover whereas high drainage density is attributed toimpermeable subsurface materials and mountainous relief.

Stream Frequency (Fs): Stream frequency is the ratio of the number of streams of all orders within a watershed. This helps to measure the topographic texture. Horton (1932) introduced stream frequency (Fs) which is the total number of stream segments of all orders per unit area.

Stream Frequency (Fs) = Nu / A

Where, Fs = Stream Frequency, Nu = Total no. of streams of all orders

A = Area of the Basin (Sq.Km.)

Stream frequency value of watersheds KR 25is 3.65. It is noted that, the Fs exhibits positive correlation with the drainage density value of the watershed indicating the increase in stream population with respect to increase in drainage density, thus runoff is also high with increasing stream population.

Drainage Texture Ratio (Rt): Drainage texture ratio (Rt) is one of the important concepts of geomorphology which means the relative spacing of drainage lines. Drainage lines are numerous over impermeable areas than permeable areas. According to Horton (1945), Rt is the total number of stream segments of all orders per perimeter of that area.

Drainage Texture (Rt) = Nu / P

Where, Rt = Drainage Texture, Nu = Total no. of streams of all orders, P= Perimeter (km)

In the study the drainage textures value of watershed KR 25watersheds is12.57.

Form Factor (Rf): According to Horton (1932), form factor (Rf) may be defined, as the ratio of basin area to square of the basin length.

Form Factor (Rf) = A / Lb²

Where, Rf = Form Factor, A = Area of the Basin (Sq.Km.), Lb^2 = Square of Basin length

In the study areas values of RF for study watershed KR 25is0.26, given in (Table No.2) Thus, a result indicates that all the watersheds are elongated in shape.

Circularity Ratio (Rc): It is the ratio of the area of the basin to the area of a circle having the same circumference as the perimeter of the basin (Miller 1953)

Circularity Ratio (Rc) = 4 x Pi x A / P²

Where, Rc = Circularity Ratio, Pi = 'Pi' value i.e., 3.14

A = Area of the Basin (Sq.Km.), P^2 = Square of the Perimeter (Km)

In the study, the Rc (Table 2) values of KR 25 is 0.47.Rc values indicated that, all the watersheds were not much circular.

Elongation Ratio (Re): According to Schumm (1956) elongation ratio (Re) is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin.

Elongation Ratio (Re) = 2 v (A / Pi) / Lb

Where, Re = Elongation Ratio, A = Area of the Basin (Sq.Km.)

Pi = 'Pi' value i.e., 3.14, Lb = Basin length

In the study areas the Re values of KR 25 is 0.57 given in Table No 2. The highest values of Re indicates high elongated watersheds with less relief and steep slope.

Length of Overland flows (Lg): The length of overland flow (Lg) approximately equals to half of the reciprocal of drainage density (Horton, 1945).

Length of Overland flow Lg = 1 / D x 2

Where, Lg = Length of Overland flow, D = Drainage Density

The computed values of watersheds KR 25 is 0.90given in (Table No.2)

Discussion

The morphometric analysis of different KR 25watersheds showed their relative characteristics with respect to hydrologic response of the watershed. Morphometric parameters coupled with integrated thematic maps, viz. land use / land cover, soil and drainage density and soil information can help in decision making process for water resources management. In poorly managed land, contour bunds can be constructed to increase the groundwater recharge which would eventually help in cultivation of kharif and rabbi crop instead of cash crop. These measures are expected to bring down the soil erosion rates as well as improvement in water resources regime. Land development activity, area treatments and percolation tanks are recommended based on the land use and drainage pattern to increase the irrigated area and recharge of the study area.

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