International
Journal
Of Advanced Research in Engineering & Management (IJAREM)
ISSN: 2456-2033 || PP. 07-18

Morphometric Analysis and Runoff Estimation of Harangi Command Area

Amulya T H M[1], Rekha A M[2]
[1]Assistant Professor, Sri Venkateshwara College Of Engineering, Vidya Nagar, Bangalore, India;
[2]Assistant Professor, Jain Institute of Technology, Davanagere, India

Abstract Land and water are the two vital natural resources, the optimal management of these resources with minimum adverse environmental impact are essential not only for sustainable development but also for human survival. Satellite remote sensing with geographic information system has a pragmatic approach to map and generate spatial input layers of predicting response behavior and yield of watershed.

Hence, in the present study an attempt has been made to understand the hydrological process of the command area at the watershed level by drawing the inferences from morphometric analysis and runoff.

The study area chosen for the present study is Harangi command area situated in Mysore and Kodagu district lies geographically at a between 75°30'24.834"E and 76°2'42.365"E latitude and 12°29'34.304"N and 12°10'55.506"N longitude. It covers an area of 1141.403 Sq.km.

Morphometric analysis is carried out to estimate morphometric parameters at Micro-watershed to understand the hydrological response of the command area at the Micro-watershed level. Daily runoff is estimated using USDA SCS curve number model for a period of 15 years from 2000 to 2014. The rainfall runoff relationship of the study shows there is a positive correlation. The runoff estimation carried out by using SCS curve number method will help in proper planning and management of catchment yield for better planning of river basin.

Keywords: Morphometric analysis, runoff, remote sensing and GIS, SCS - method

1. Introduction

Watershed management is the process of formulating and carrying out a course of action involving manipulation of the natural system of watershed to achieve specified objectives. It implies the proper use of all land and water resources of a watershed for optimum production with minimum hazard to natural resources. Remote sensing and GIS techniques have emerged as powerful tools for watershed management programs.

Morphometry is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimensions of its landforms (Clarke, 1966). The term morphometry is derived from the Greek word, where "**morpho**" means earth and "**metry**" means measurement, so together it is the measurement of earth features.Morphometric analysis provides quantitative description of the basin geometry to understand initial slope or inequalities in the rock hardness, structural controls, geological and geomorphic history of drainage basin (Strahler, 1964).

Runoff is one of the most important hydrologic variables used in most of the water resources applications. Reliable prediction of quantity and rate of runoff from land surface into streams and rivers is difficult and time consuming to obtain for ungauged watersheds, however, this information is needed in dealing with many watershed development and management problems. Experience has shown that SOI topomap data can be interpreted to derive thematic informations on land use/land cover, soil, vegetation, drainage, etc. which combined with conventionally measured climatic parameters and topographic parameters such as height, contour, slope provide the necessary inputs to the rainfall- runoff models.

1.1.Objectives:

- To understand the relationship between different aspects of the drainage pattern of the same basin.
- For comparative evaluation of different drainage basins developed in various geologic and climatic regimes and
- To define certain useful parameters of drainage basins in numerical terms.
- To assess the quantity of surface runoff from SCS-CN method and

- To suggest better water management strategies.

1.2.Scope of the Study

- RS and GIS are being used as tools for planning and management of available natural resources within the watershed. Hence, in the present study an attempt has been made to use RS and GIS to estimate water balance components namely runoff along with morphometric to understand the hydrological process of the watershed at the sub watershed level.
- Morphometric analysis provides the physical characteristics of the watershed and also helps in derivation of parameters and ratios within the catchment.

The runoff estimation carried out by using SCS curve number method will help in proper planning and management of catchment yield for better planning of river basin.

2. Methodology

- Collection of data.
- Preparation of different thematic maps.
- Morphometric analysis by using different morphometric parameters.
- Estimation of surface runoff from SCS-CN method

2.1.Collection of data

- Daily rainfall data
- Survey Of India (Soi) Topomap Nos 48 P/14, 57d/3, 57d/4 On 1:50,000 Scale
- Indian Remote Sensing (Irs-1d, Liss Iii) Satellite in the form of FCC
- Soil Data-Ksrac, Bangalore according to National Bureau of Soil Survey And Land Use Planning (Nbss And Lup, 1995) Standards.

2.2.Preparation of different thematic maps:

In order to know the different natural resources, terrain conditions, etc. in the study area, different thematic maps are prepared. The preparation of different thematic maps follows the Integrated Mission for Sustainable Development (NRSA, 1995) Technical Guidelines, NRSA, Hyderabad.

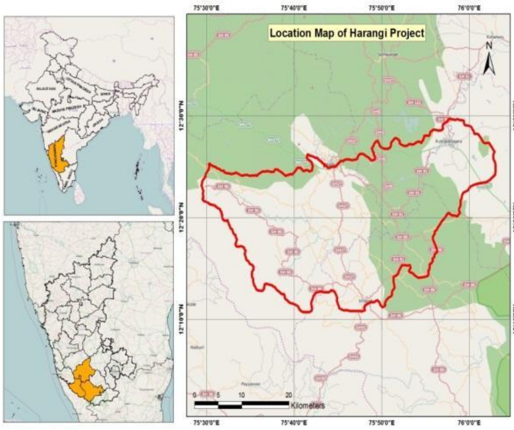


Fig 1.1: Base Map of study area

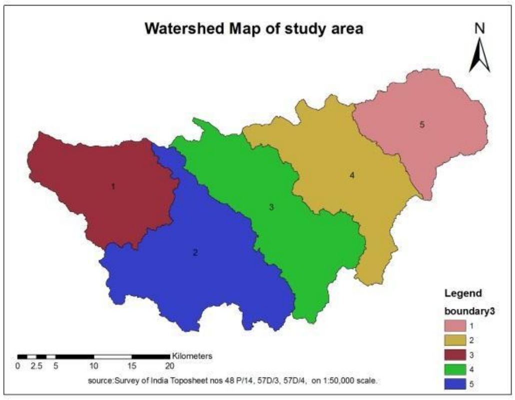


Fig 1.2: Watershed Map of study area

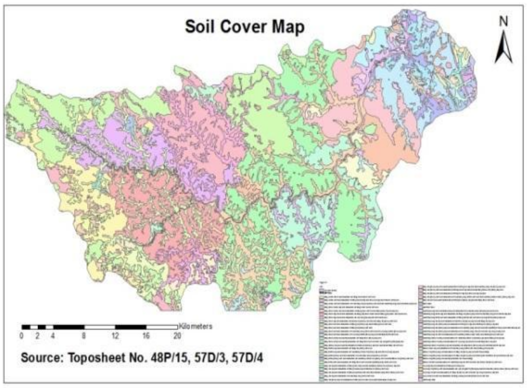


Fig 1.3: Soil cover Map of study area

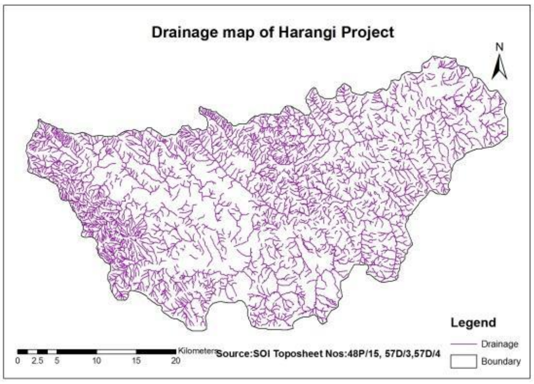


Fig 1.4: Drainage Map of study area

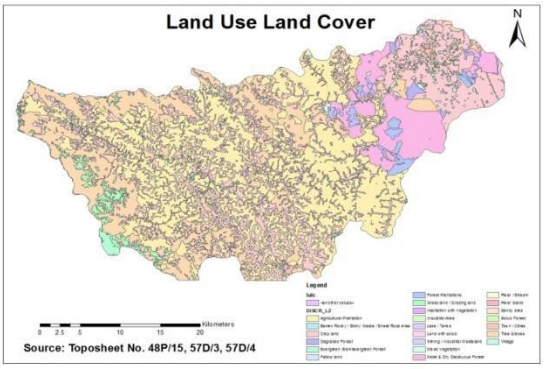


Fig 1.5 Land use Land cover Map of study area

2.3. Morphometric analysis

morphometric analysis of Harangi command area at the watershed level was carried out using GIS which is a suitable tool to study the morphological analysis. The entire watersheds is divided into 5 sub watersheds. The analysis was carried out through measurement of linear, aerial and relief aspects of watershed.Table I shows the formulae for various morphometric parameters.

Formula	**Morphometric parameters**	**Sl no**
Hierarchial rank	Stream order	1
Length of the stream	Stream length (Lu)	2
Lsm = Lu / Nu	Mean stream length	3
RL = Lu / Lu – 1	Stream length ratio	4
Rb = Nu / Nu + 1	Bifurcation ratio	5
Rbm = Average of bifurcation ratios of all orders	Mean bifurcation ratio	6
Rh = H / Lb	Relief ratio	7
D = Lu / A	Drainage density	8
Fs = Nu / A	Stream frequency	9
Rf = A / Lb	Form factor	10
$Rc = (4 * Pi * A)^{1/2} / P^2$	Circularity ratio	11
Re = 2 (A/Pi)½ / Lb	Elongation ratio	12

Table I: Formulae for various morphometric parameters.

2.4.Estimation of surface runoff from SCS-CN method

Fig.1.6 shows the methodology adopted for runoff estimation using SCS curve number method. The SCS curve number method is developed from many years of stream flow records for agricultural watersheds in several parts of the United States. The method is also called hydrologic soil cover complex number method. It is based on the recharge capacity of a watershed. The recharge capacity can be determined by the antecedent moisture contents and by the physical characteristics of the watershed. Basically the curve number is an index that represents the combination of hydrologic soil group and antecedent moisture conditions.

The SCS approach has been considered as a popular method for runoff modeling because of the following reasons:

- its use has been mandated by the United States Department of Agriculture;
- it provides reasonable and useful results for average conditions;
- there is a large user base available to assist new users and much is known about how to vary the parameters for non-standard conditions;
- It is very easy to understand and requires few resources to use.

The SCS curve number method is based on the water balance equation and developed on two fundamental hypotheses;

i. Ratio of the actual direct runoff to the potential runoff is equal to the ratio of the actual infiltration to the potential infiltration.
ii. The amount of initial abstraction is some fraction of the potential infiltration.

The first hypothesis is expressed as; $\frac{Q}{P-Ia} = \frac{F}{S}$,
Where Q is the runoff, P is the rainfall and F is the actual infiltration and it is the difference between the potential and accumulated runoff. Ia is initial abstraction, which represent all the losses before the runoff begins; S is the potential infiltration after the runoff begins (S≥F). From the Fig. 2.2 F will be as follows:
$F = (P - Ia) - Q$ ..The retention S is constant for a particular storm because it is the maximum that can occur under existing conditions if the storm continues without limit. The retention F varies because it is the difference between (P-Ia) and Q at any point on the mass curve.

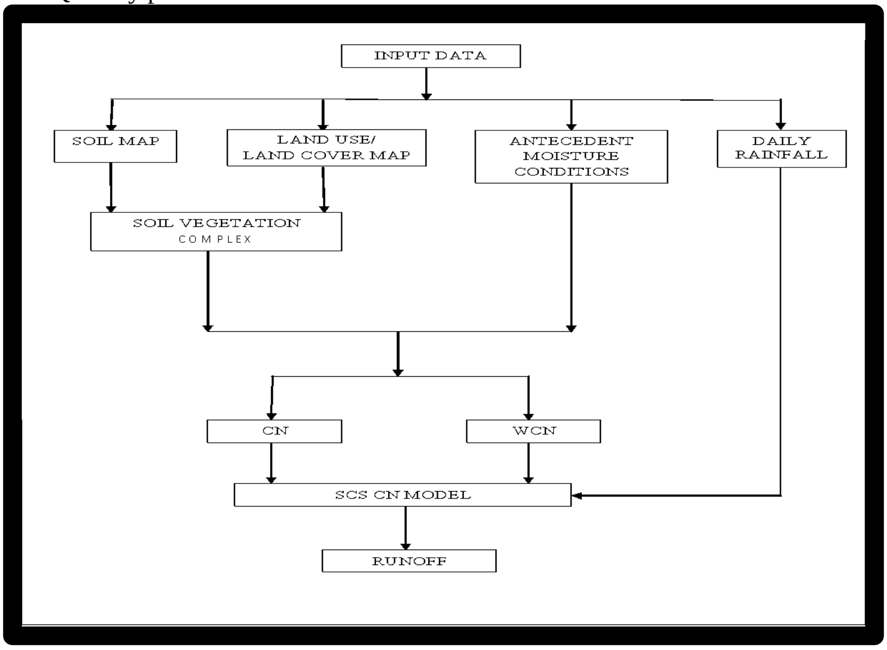


Fig. 2.1 Methodology to estimate surface runoff by SCS Curve number model

An empirical analysis was performed for development of SCS rainfall runoff relation and the following formulas were arrived for estimating Ia…. Ia = 0.2S. Eq shows that the factors affecting Ia would affect S,then becomes; $Q = \frac{(P-0.2S)2}{(P+0.8S)}$

The SCS developed an index, which is called runoff curve number (CN) to represent the combined hydrologic effects of soil, land use, agricultural land treatment class, hydrologic condition and antecedent soil moisture. Thus, a runoff curve number is defined to relate the unknown S as spatially distributed variable as,

$$CN = \frac{25400}{S + 254} \qquad S = \frac{25400}{CN} - 254$$

Where S is in mm. Thus, the rainfall-rainfall relationship has one unknown, and has been replaced with another relationship with one unknown as, CN. The CN is a relative measure of retention of water by a given soil vegetation complex and takes on values from 0 to 100. This number is derived from the character of soil; vegetation, including crops; and the land use of that soil, as well as intensity of use. When the CN equals to 100, S becomes zero, this leads to Q = P. when $S = \infty$, $CN = \infty$ this yields Q = 0 for all P when $S = \infty$ and C=0

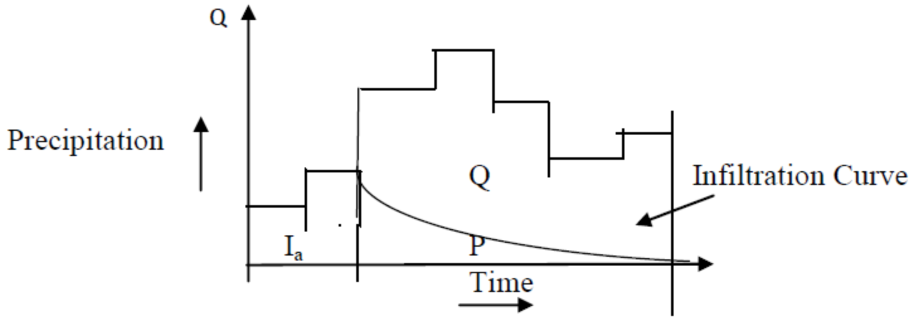


Fig. 2.2 Relationship between precipitation, runoff and retention (Mc Cuen)

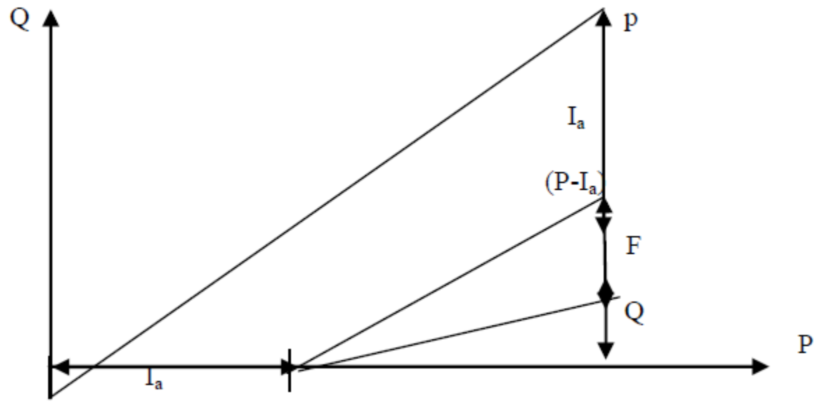


Fig. 2.3 Mass curve representation of the SCS rainfall runoff relationship.

2.4.1. Determination of Curve Number (CN)

The SCS cover complex classification consists of three factors: land use, treatment of practice and hydrologic condition. There are approximately eight different land use classes that are identified in the tables for estimating curve number. Cultivated land uses are often subdivided by treatment or practices such as contoured or straight row. This separation reflects the different hydrologic runoff potential that is associated with variation in land treatment. The hydrologic condition reflects the level of land management; it is separated with three classes as poor, fair and good. Not all of the land use classes are separated by treatment or condition.

CN values for different land uses, soil treatment and hydrologic conditions were assigned based on the curve number table. Runoff Curve Numbers for (AMC II) hydrologic soil cover complex is shown in Table II.

Hydrologic Soil Group				**Land use**	**Sl No**
D	C	B	A		
91	88	81	72	Agricultural land without conservation (Kharif)	1
91	88	71	62	Double crop	2
72	67	53	45	Agriculture Plantation	3
79	73	60	36	Land with scrub	4
83	77	66	45	Land without scrub (Stony waste/rock outcrops)	5
83	77	66	45	Forest (degraded)	6
77	70	55	25	Forest Plantation	7
80	74	61	39	Grass land/pasture	8
86	81	72	57	Settlement	9
98	98	98	98	Road/railway line	10
97	97	97	97	River/Stream	11
96	96	96	96	Tanks without water	12
100	100	100	100	Tank with water	13

Table II: Runoff Curve Numbers for (AMC II) hydrologic soil cover complex.

2.4.2. Hydrological Soil Group Classification

SCS developed a soil classification system that consists of four groups, which are identified as A, B, C, and D according their minimum infiltration rate. The identification of the particular SCS soil group at a site can be done by one of the following three ways (i).soil characteristics (ii).county soil surveys and (iii).minimum infiltration rates. Table III shows the minimum infiltration rates associated with each soil group.

Minimum Infiltration Rate (cm/ltr)	**Soil Group**
0.76	A
0.38 - 0.76	B
0.13 - 0.38	C
0 - 0.13	D

FIVE DAYS ANTECEDENT RAINFALL (mm)		**AMCs**
Growing season	Dormant season	
<35.56 mm	< 12.7 mm	I
35.56-53.34 mm	12.7-27.94 mm	II
53.34 mm	> 27.94 mm	III

Table III:Minimum infiltration rates
Table IV: Antecedent Moisture Condition (AMCs) associated with each soil group

2.4.3.Antecedent Moisture Condition (AMCs)

Antecedent Moisture Condition (AMC) refers to the water content present in the soil at a given time. The AMC value is intended to reflect the effect of infiltration on both the volume and rate of runoff according to the infiltration curve. The SCS developed three antecedent soil-moisture conditions and labeled them as I, II, III. These AMC's correspond to the following soil conditions. Table IV shows the AMC's classification.
The value of CN is shown for AMC II and for a variety of land uses, soil treatment, or farming practices. The

hydrologic condition refers to the state of the vegetation growth. The Curve Number values for AMC-I and AMC-III can be obtained from AMC-II by the method of conservation. The empirical CN_1 and CN_3 equations for conservation methods are as follows:

$$CN_1 = \frac{CN_2}{2.281 - 0.01281 CN_2}$$

$$CN_3 = \frac{CN_2}{0.427 + 0.00573 CN_2}$$

A weighted runoff was estimated for the watershed as

$$Weighted Q = \frac{(A_1 * q_1 + A_2 * q_2 + \dots\dots\dots + A_n * q_n)}{(A_1 + A_2 + \dots\dots\dots + A_n)}$$

Where A_1, A_2…A_n are the areas of the watersheds having respective runoff q_1, q_2….q_n. The weighted runoff approach was again extended to quantify the total amount of runoff from the entire watershed.

3. Results and Discussions

In the present study, the morphometric analysis has been carried out about parameters as stream order, stream length, bifurcation ratio, stream length ratio, basin length, drainage density, stream frequency, elongation ratio, circularity ratio, form factor, basin relief, relief ratio, channel gradient using mathematical formulae as given in TableI1. Table V shows subwatershed wise morphometric parameters of Harangi Command area and Table VI shows the subwatershed wise morphometric characteristics of Harangi Command area.

					Units	**Watershed Parameters**	**Sl No.**
5	**4**	**3**	**2**	**1**			
166.73	233.20	256.17	294.53	190.76	km^2	Watershed area	**1**
83.75	138.22	144.22	156.58	93.64	km	Perimeter of the watershed	**2**
23.87	29.878	39.841	31.018	27.59	km	Maximum length of the watershed	**3**
27.78	33.98	35.95	39.09	30.12	km	Maximum width of the watershed	**4**
6	6	6	6	6	No.	Watershed highest stream order	**5**
309.00	608.00	740	740.00	676.00	No.	Cumulative stream segments	**6**
297.37	485.11	655.26	655.26	504.01	km	Cumulative stream length	**7**
0.28	0.24	0.20	0.22	0.19	km	Length of overland flow	**8**
1.78	2.08	2.56	2.22	2.64	km/km^2	Drainage density	**9**
0.56	0.48	0.39	0.45	0.38	km^2/km	Constant of channel maintenance	**10**
1.85	2.61	2.89	2.51	3.54	No/ km^2	Stream frequency	**11**
4.97	3.92	4.38	3.68	3.608		Bifurcation ratio	**12**
3.44	3.23	18.02	2.03	1.33		Length ratio	**13**
0.29	0.26	0.16	0.31	0.25		Form factor	**14**
3.24	3.83	6.2	3.27	3.99		Shape factor	**15**
0.3	0.15	0.15	0.15	0.27		Circularity ratio	**16**
0.34	0.33	0.26	0.35	0.32		Elongation ratio	**17**
1.83	2.55	2.54	2.57	1.91		Compactness coefficient	**18**
1.006	1.150	1.195	1.263	1.062	km	Total watershed relief	**19**
0.042	0.039	0.030	0.041	0.038		Relief ratio	**20**
0.012	0.008	0.008	0.008	0.011		Relative relief	**21**
0.018	0.024	0.031	0.028	0.028		Ruggedness number	**22**

TableV:Subwatershed wise morphometric parameters of Harangi Command area

Stream Length (Km)						**Stream Order**						**Highest stream order**	**Perimeter (km)**	**Area (Sq.km)**	**WS No**
6	**5**	**4**	**3**	**2**	**1**	**6**	**5**	**4**	**3**	**2**	**1**				
1.15	6.55	26.22	53.94	94.65	321.50	1	2	9	31	125	508	6	93.64	190.76	1
15.69	36.02	53.56	53.25	137.63	359.12	1	3	9	30	194	503	6	156.57	294.53	2
14.08	0.16	53.55	60.14	75.19	430.43	1	1	9	22	114	485	6	144.21	256.17	3
10.86	3.83	37.38	40.90	86.68	305.46	1	1	5	24	114	463	6	138.21	233.20	4
13.32	-	11.19	36.49	56.27	180.10	1	-	2	12	56	238	6	83.74	166.72	5

Table VI: the subwatershed wise morphometric characteristics of Harangi Command area.

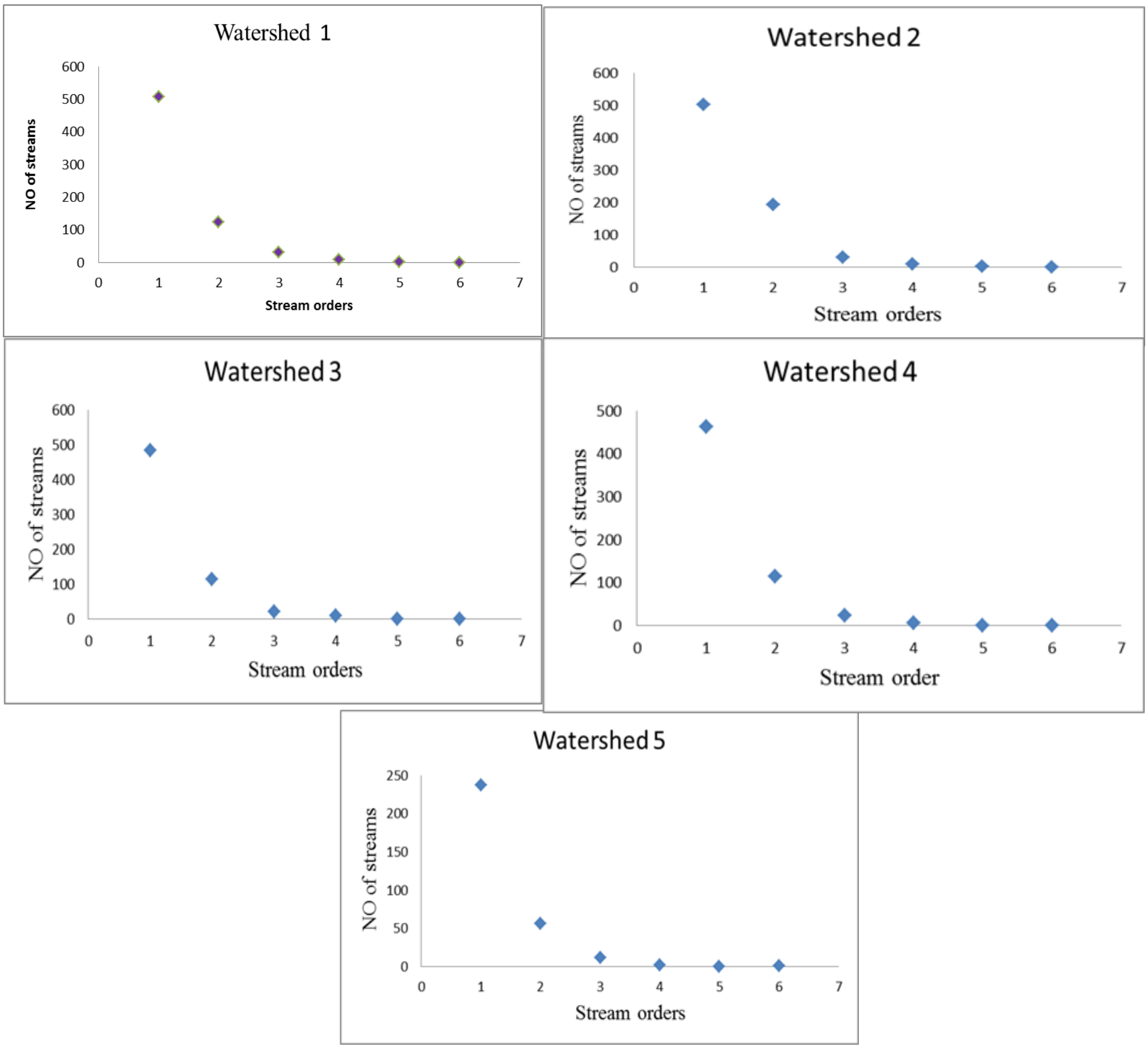


Fig. 2.4 Regression of stream order on number of streams of watersheds 1,2, 3, 4,5

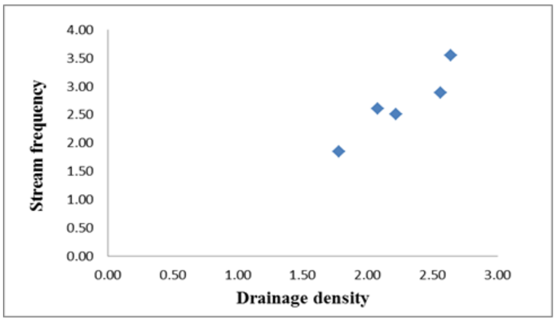


Fig. 2.5 Regression of stream order on mean stream length

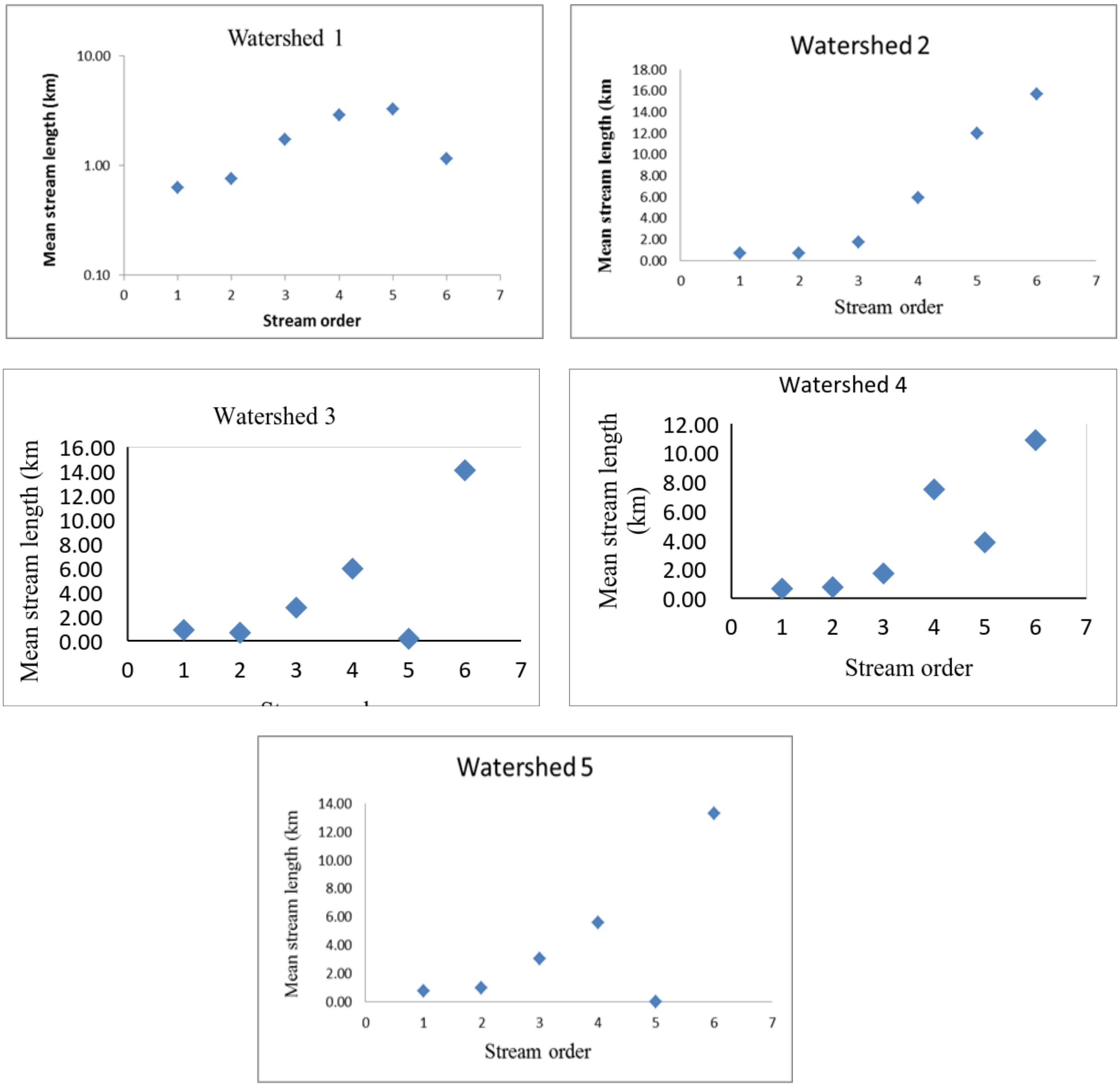


Fig. 2.6 Regression of Drainage density on Stream frequency of watersheds 1,2, 3, 4&5

CN3	**WCN**	**CN1**	**Area (Sq.km)**	**Watershed No**
165.92	70.67	30.08	1385.92	1
171.44	73.02	31.08	1153.12	2
169.89	72.36	30.79	1056.82	3
167.09	71.17	30.29	1730.95	4
177.41	75.57	32.16	1448.76	5

Table VII: Watershed wise weighted curve numbers

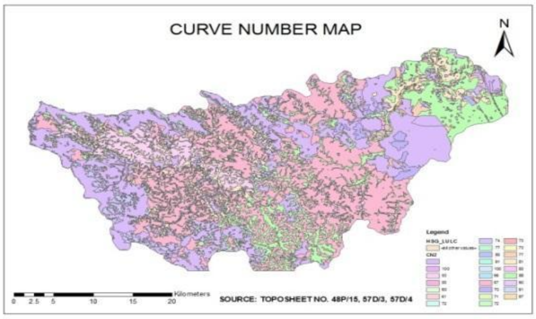
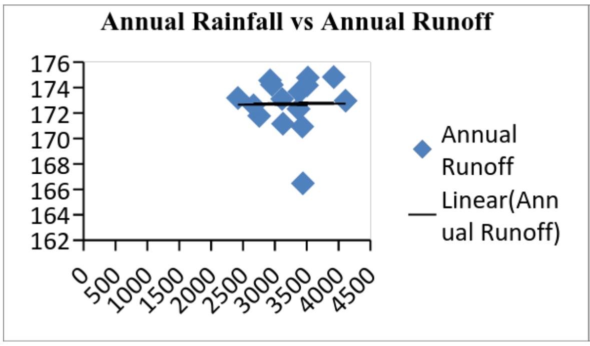
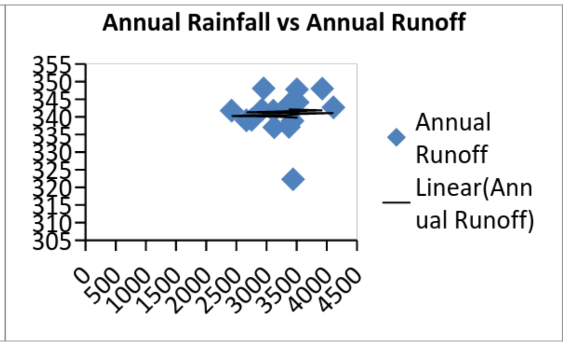


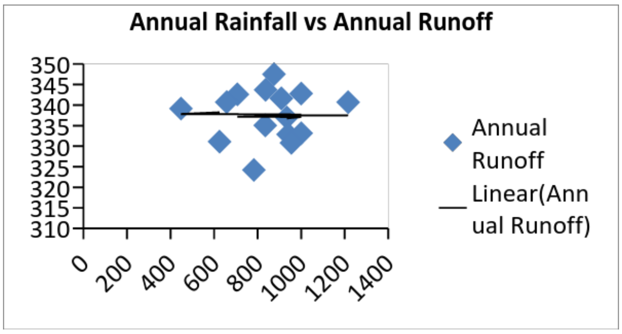
Fig. 2.7 curve number map

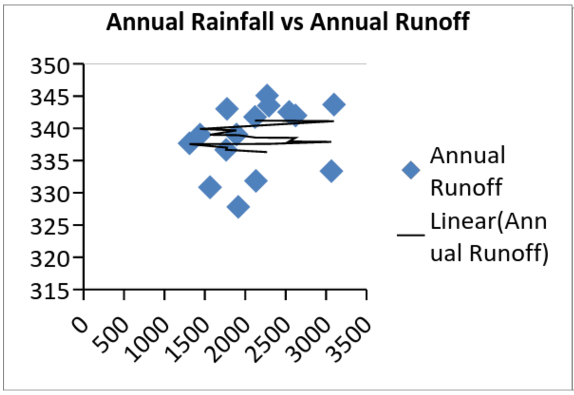
2014	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**	**Year/WS No**
172.31	174.81	172.60	174.21	171.15	166.47	174.56	172.96	170.93	174.16	173.65	171.77	173.18	173.16	174.77	1
337.17	348.02	339.01	348.07	337.07	322.30	342.02	342.7	338.87	347.8	343.72	339.21	341.76	341.72	344.13	2
341.75	343.67	339.02	339.03	330.85	327.81	331.85	341.91	342.53	33.36	343.52	337.66	343.01	336.66	345.09	3
342.57	345.63	339.48	340.55	330.21	328.80	332.97	343.25	343.94	333.89	344.60	338.89	344.58	339.55	346.87	4
340.73	331.09	339.14	341.63	330.8	333.15	335.04	332.89	347.49	340.69	343.70	324.22	342.61	342.80	336.96	5

Table VIII Watershed wise runoff (mm) estimated for watersheds.









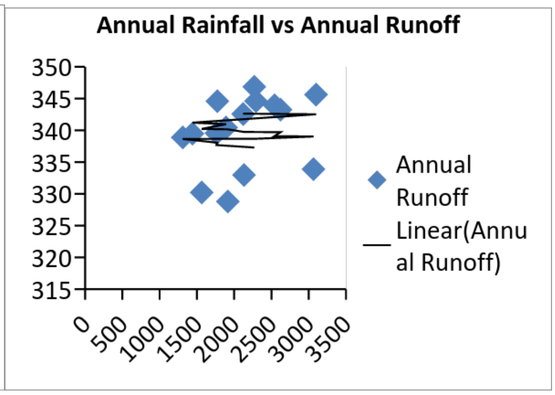


Fig 2.8 the values of correlation coefficients, the values of slope in the regression equation for various watersheds are obtained for further classifications.

4. Conclusion

In the present study Harangi command area is often selected as a unit of morphometric investigation because of its topographic and hydrological unity. GIS software have resulted to be of immense utility in the quantitative analysis of the geo-morphometric aspects of the drainage basins. The study reveals that GIS based approach in evaluation of drainage morphometric parameters at river basin level is more appropriate than the conventional methods. The stream length has been computed based on the Horton's law for all the five watersheds the obtained parameters are as follows.

- In the present case the values of R_b varies from 3.608 to 4.97 (less than 5) for the watersheds and hence these have not suffered any structural disturbances.
- The drainage density of the area varies from 1.78 to 2.64 km/km^2 indicating that the area is coarse texture.
- Stream frequency value for the watershed varies from 1.85 to 3.54 this indicates that the stream frequency is low.
- The circularity ratio varies from 0.15 to 0.3 for the watersheds, which indicates the nature of topography.
- The elongation ratio ranges from 0.26 to 0.35 which indicates that the watershed is more elongated.
- The values of relief vary from 1.263 km to 1.006 km indicates that the watershed has enough slope for the runoff to occur from the remote point of the watershed to mouth.
- The relative relief ratios are ranging from 0.008 to 0.012. The high relative relief indicates that it is composed of resistant rock patches and low relief ratio indicates less resistant patch of rock.
- From Runoff estimation method it is observed that during the year 2011 maximum runoff of 348.072 mm has occurred in the watershed 2.
- It was also observed that the minimum runoff of 166.47 mm has occurred in the year 2009 for watershed 1.
- The values of correlation coefficients are very high for all the watersheds and it varies from 0.079 to 0.0007.
- Hence, it can be said that there is a strong positive linear dependence between the annual rainfall and annual runoff and it can be observed that in the regression equation as the values of slope increases the runoff generated also increases.

- In this context, the highest slope value of 0.003 was obtained in the watershed 4 and hence it has produced more runoff in all the years.

Similarly for the watershed 1 the slope value was 0.0001 and the runoff generated from this watershed is minimum for all the years.

5. Future Scope

- The runoff estimation by SCS curve number method can be compared with the observed runoff to check the accuracy in runoff estimation.
- Land use /land cover information were assumed to be same for all the 15 years. Recent land use/land cover information can be used for the accurate estimation of the runoff for the corresponding years.
- Since the thematic maps were prepared by remotely sensed data and digital database was created by using ArcGIS software this database can be used for better management of natural resources within the catchment by proposing suitable land and water conservation practices.
- Runoff was estimated on polygon wise within the watershed, this can be checked with the pixel wise runoff estimation.
- The runoff estimated by SCS curve number model and observed data can be used to derive the CN as per the site condition of Harangi. Since there is soil erosion in the entire area, conservation methods can be proposed on the priority basis.

References

[1]. **Ajoy Das, Milan Mondal, Bhaskar Das, Asim Ratan Ghosh**,(2012), Analysis of drainage morphometry and watershed prioritization.

[2]. **Dawod, G., and Koshak, N.** (2011), Developing GIS-Based Unit Hydrographs for Flood Management in Makkah Metropolitan Area, Saudi Arabia, Journal of Geographic Information System, 3(2), pp 153-159.

[3]. **Koshak.N, Dawod.G,(**2011), A GIS morphometric analysis of hydrological catchments within Makkah Metropolitan area, Saudi Arabia.

[4]. **Mesa LM** (2006) Morphometric analysis of a subtropical Andean basin (Tucumam, Argentina). Environmental Geology 50: 1235-1242.

[5]. **Obi Reddy GP, Maji AK, Gajbhiye KS** (2002) GIS for morphometric analysis of drainage basins. Geological Survey of India 11: 9-14.

[6]. **Pareta K, Pareta U** (2011) Quantitative Morphometric Analysis of a Watershed of Yamuna Basin, India using ASTER (DEM) Data and GIS. International Journal of Geomatics and Geosciences 2: 251-265.

[7]. **Rafiq Ahmad Hajam, Aadil Hamid and SamiUllah Bhat**-A Case Study of Vishav Drainage Basin.

[8]. **Rao, N., Latha, S., Kumar, A., and. Krishna, H**. (2010), Morphometric Analysis of Gostani river basin in Andhra Pradesh state, India using spatial information technology, International Journal of Geomatics and Geosciences, 1(2), pp 179-187.

[9]. **Rudraiah, Govinaiah, Vittala**., (2008), Morphometry Using Remote Sensing and GIS Techniques In The Sub-Basins of Kagna River Basin, Gulburga District, Karnataka, India, Journal of Indian society of Remote Sensing 36, 351-360.

[10]. **Singh S, Singh MC** (1997) Morphometric analysis of Kanhar river basin. National Geographical Journal of India 43:31-43.

[11]. **Sethupathi. A.S , Lakshmi Narasimhan C , Vasanthamohan V , MohanS.P**, (2011), Prioritization of mini watersheds based on Morphometric analysis using Remote Sensing and GIS techniques in a draught prone Bargur Mathur sub water sheds, Ponnaiyar river basin, India, International Journal of Geomatics and Geosciences, 2(2), pp 403-414.

[12]. **Surendranath.G,** 2000, Runoff Estimation And Identification of Water Harvesting Structures using Remote Sensing Techniques.

[13]. **Thakkar, A.K. and Dhiman, S.D.,** (2007), Morphometric Analysis and Prioritization of mini watersheds in Mohr Watershed, Gujarat Using Remote Sensing and GIS technique, Journal of the Indian society of Remote Sensing, 35(4), 313-321.