Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 5, Issue 03, March -2018

Estimation of Surface Runoff Using GIS-Based NRCS-CN Method in Upper Manimuktha Subwatershed,Tamilnadu,India

Velayudha Das M[1] and Poongothai S[2]

Research Scholar[1] and Professor[2]
Department of Civil Engineering, Annamalai University, Annamalainagar-608002

Abstract - *Spatial and temporal runoff measurements are required for planning, developing and managing a watershed sustainably. Among the methods for estimating runoff from rainfall, the SCS (NRCS)-CN method is most used practical method due to its requirement of single parameter estimation called Curve Number (CN). In the present study, the runoff from the upper Manimuktha sub-watershed (4C1A2e), an ungauged watershed in Villupuram district of Tamilnadu, India, has been assessed. IRS 1C LISS-3 satellite images (1995, 2003 and 2012) were used to obtain land use/land cover information. Hydrologic Soil Groups (HSG) map was prepared from the soil map of the study area. After integrating land use/land cover and hydrologic soil layers, weighted curve numbers were obtained and mapped by using ArcGIS 10.5 software. The daily rainfall data were collected from Gomukhi dam and Manimuktha dam raingauge stations for 25 years (1992-2017) and converted to weighted spatial distributed rainfall by Thiessen polygon method and used to calculate the daily, monthly and annual runoff. The average annual minimum and maximum rainfall were 548.23mm (in 2016-2017) and 2151.61 mm (in 2005-2006) and the corresponding runoff were 64.28mm (in 2016-2017) and 1134.02 mm (in 2005-2006). This study will be useful to estimate runoff from an ungauged watershed having same characteristics.*

Keywords: *Watershed, SCS(NRCS)-CN method, HSG,AMC and Land use/cover*

I. INTRODUCTION

A watershed is a natural physiographic or ecological unit that contributes runoff to a common point.The runoff information is necessitated for conservation and development of natural resources management in a watershed. Majority watersheds in India have no past rainfall-runoff records [1]. Among the empirical approaches used in such situation, the Soil Conservation Service Curve Number [Soil Conservation Service (1956), Hydrology, National Engineering Handbook, USA] (renamed as Natural Resources Conservation Service Curve Number (NRCS-CN)) (USDA, 1972 and 1994) technique has been mostly applied to ungauged watershed systems to establish the rainfall-runoff relations [2-4] and proved to be accurate and fast for surface runoff estimation [5]. Although the method is designed for a single rainfall event, it can be scaled to find average runoff [6]. The CN method is a globally accepted method to estimate the direct runoff depending on land use/land cover, soil type and its Antecedent-Moisture Condition (AMC). In general, among the different land use/cover types, the crop land plays the major role for the direct surface runoff [7]. Since the data related to runoff are more, Geographical Information System (GIS) a tool which stores, manipulates, retrieves and maps the data in a real world system [8]. Remote Sensing (RS) helps in providing land use/land cover information [9] which is the input to SCS model. RS and GIS play a vital role to visualize the prevailing status of water resources of the watershed [10] and has become a critical tool in hydrological modelling in view of its capacity to handle large amount of spatial and attribute data. Earlier studies carried out from various regions of India by several researchers such as [11-14] have revealed that GIS based SCS-CN method makes the runoff estimation more accurate, fast, facility to handle extensive data set and, is an efficient tool aid in better watershed management. [15] described the development and application of the ArcCN Runoff tool, an extension of ESRI ArcGIS software which can be applied to determine curve numbers and calculate runoff for a storm event within a watershed. A simple regression of rainfall and runoff provides a means for estimating storm runoff when precipitation records are available [16]. The objective of this study is to estimate the surface runoff using GIS-based NRCS-CN method in the upper Manimukta ungauged sub-watershed (4CIA2e) for development of water management sustainably.

II. STUDY AREA

The present investigation area is Muktha river sub-watershed (4CIA2e) of upper Manimuktha watershed in the Manimuktha sub-basin of Velar basin (Fig.1). Muktha river originates in the western side of the Eastern Ghats hill range (Kalrayan hills) and join in the Manimuktha dam. It is a part of Sankarapuram and Kallakurichi taluks of Villupuram district in Tamilnadu, India. The study area extends between 78°43’9.22’’-78° 59’ 21.73” E and 11° 46’ 12.80’’-11° 53’ 42.38’’ N with an area of 251.151 km^2. This rural ungauged sub watershed falls in SOI toposheets 58-I/9 and 58-I/13. It is an ephemeral river in nature and carries flood water during monsoon rainfall period. Agriculture is the main economical activity of about 80% of the population. The main sources of water are tanks and dug wells apart from rainfall. Due to over exploitation of groundwater, this area is fallen in semi-critical to critical stage (CGWB report, 2015). The western part of the study area is covered by thick forest vegetation (85.761 km^2) and the rest is almost plain terrain (165.390 km^2). The elevation ranges from 130m to 987m above MSL with a gentle gradient from west to east. The study area has dendrite and a parallel drainage pattern and first to third order streams. The average annual rainfall of the study area is 1231.09mm during 1992-2017. The major dominant hard rock in the study area is Charnockite type. The soil types are clay soil, red soil, alluvial soil and red gravelly soil.

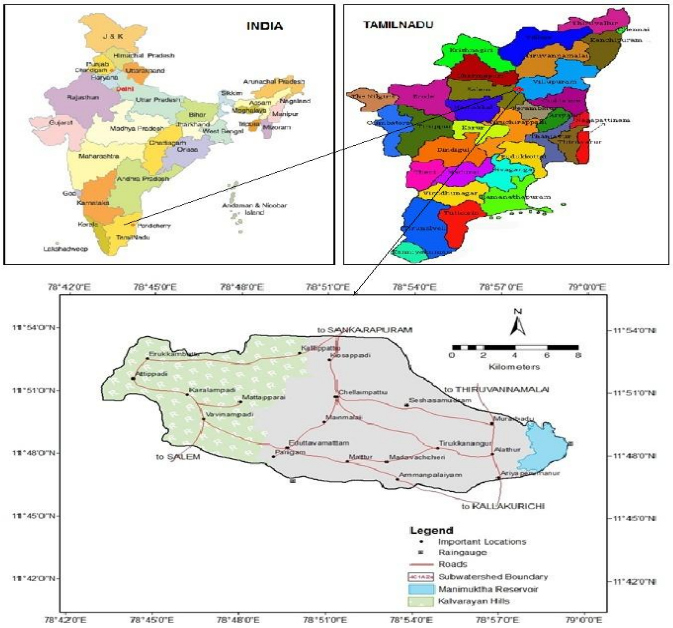

Figure 1. Index map of the study area

III. METHODOLOGY

A. NRCS-CN method

The SCS-CN method was developed by the United States of Department of Agriculture and Soil Conservation Service (USDS-SCS). Runoff is the flowing of precipitated water in the catchment area through a channel after satisfying all surface and subsurface losses [17]. It couples the water balance equation with the relationship of infiltration losses and surface storage and leads to

$$Q = \frac{(P - I_a)^2}{(P - I_a + S)} \qquad (Q \text{ is valid for } P \geq I_a) \qquad (1)$$

where Q is the direct runoff (mm), P is the rainfall depth (mm), I_a is the initial abstraction (mm) and S is the potential maximum retention (mm). In practice, S is expressed in terms of the curve number (CN),

$$S = \frac{25400}{CN} - 254 \qquad (2)$$

The non-dimensional CN (1-100) is derived from the tables, chapter 7, SCS handbook, section 4 (1972) for catchment characteristics, such as soil type, land use, hydrologic condition, and antecedent soil moisture conditions. This method has been modified by the ministry of agriculture in India (1976) as (NRCS-CN-National Resources Conservation Service Curve Number) to suite for Indian conditions $I_a = 0.3S$ and

$$Q = \frac{(P - 0.3S)^2}{(P + 0.7S)} \qquad (3)$$

Knowing the value of CN, the runoff from the watershed is computed. For large watershed, the CN values are weighted with respect to the land use / cover areas by

$$CN = \frac{\sum (CN_i \times A_i)}{A} \qquad (4)$$

where CN is the weighted CN, CN_i is the CN (1-100) from the weighted area A_i, and A is the total area of the watershed.

B. Watershed Database

In this study the following data are used

- Base map of study area (sub-watershed 4CIA2e) from SOI toposheet 58-I/9 and 58I/13 (Source: IRS,Anna University,Chennai).
- Remote sensing data (IRS 1-C, LISS III) to study the soil type and land use maps of year 1995, 2003 and 2012 (Source: IRS,Anna University,Chennai)
- Daily rainfall data of Gomuki and Manimuktha dams raingauge station from 1992 to 2017 (Source: IWS,WRO (PWD),Chennai).

Thiessen polygon method is based on the arithmetic mean approach which may account for orographic effects and storm morphology, used to calculate the spatial distribution of rainfall [18]. Gomuki dam and Manimuktha dam raingauge stations are around the study area which seems to have an influence on it are considered for the study. The Study area divided into two parts by Thiessen polygon as shown in Fig.3. As per the spatial coverage, the Gomuki and Manimuktha raingauge stations have weightage of 0.78 and 0.22 respectively. Each weight is then multiplied by the station rainfall to obtain the areal average rainfall of the study area (Table 8). The area-weighting curve numbers for AMCs are calculated from the land use-soil group polygons boundaries within the sub-watershed [19].

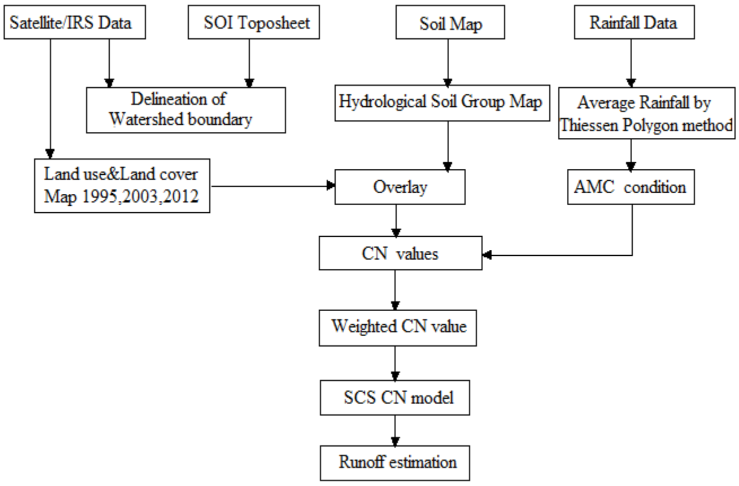

Figure 2. Flow chart showing the methodology of SCS(NRCS)-CN model

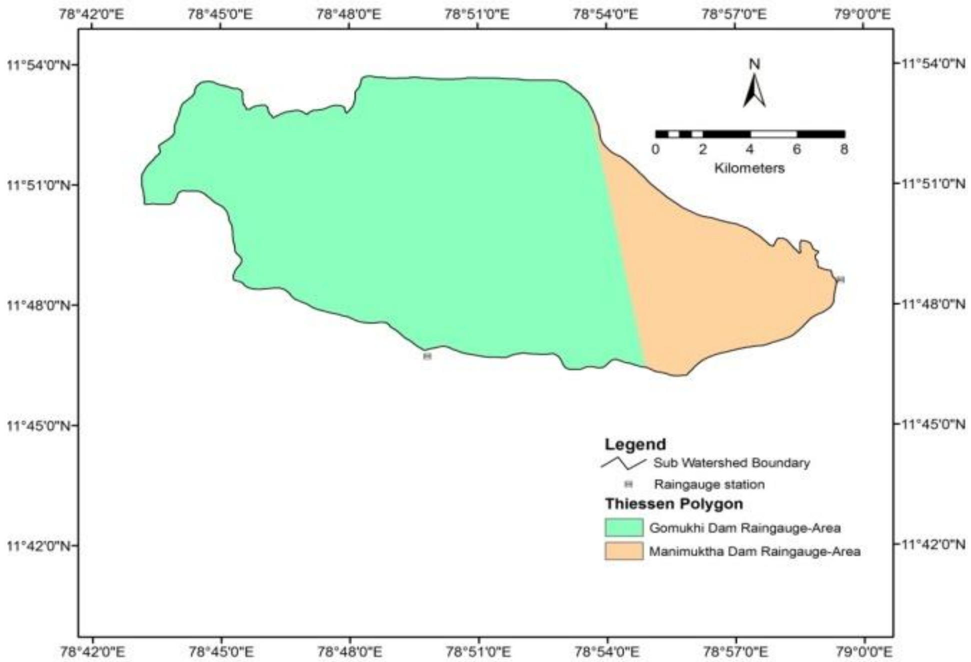

Figure 3. Spatial distribution by Thiessen polygon method

According to US soil conservation service, soil is divided into four Hydrologic Soil Groups (HSG A, B, C and D) with respect to rate of potential and minimum infiltration rate (Table 1). AMC is expressed in three levels (AMC I, II and III) according to rainfall limits for dormant and growing season (Table 2). The CN values for AMC II condition can be converted into CN values for AMC I and AMC III by interpolation method (Table 3 and 4). Base map, land use maps (Fig.4-6) and HSG map (Fig.7) of the study area is prepared using remote sensing and PC ARC/INFO (Version 10.5) GIS package. By overlaying these thematic maps, a new PAT (Polygon Attribute Table) was obtained using Arc GIS. This PAT was used to compute the spatial area and information of each unit and also total area weighted curve number of the study area to calculate the AMC II for the year 1995, 2003 and 2012 (Tables 5-7). The slope of the soil surface is not considered when assigning HSG (SCS, 1956, Handbook). The SCS-CN is a purpose of the ability of soils to allow infiltration of water with respect to land use/land cover and antecedent soil moisture condition [20]. [21] pointed out that there was not much difference between runoff depth before and after applying slope factor. It is concluded that the SCS-CN method runoff in a particular location mainly depends upon rainfall, land use, soil property, and doesn't take into account flow processes due to topographical variations [13]. A high curve number means high runoff and low infiltration, whereas a low curve number means little runoff and high infiltration [15].

Table 1. Hydrologic Soil Groups of the study area

Character of soil	***Hydrologic Soil Group***			
	A	***B***	***C***	***D***
Infiltration Rate	*High*	*Moderate*	*Slow*	*Very slow*
	7.81 to 11.43mm	*3.81 to 7.81mm*	*1.24 to 3.81mm*	*0.00 to 1.24 mm*
Texture	*Sand or Gravel*	*Moderately Coarse to Fine*	*Moderately Fine to Fine*	*Clay*
Drainage	*Well to excess*	*Moderately drained*	*Moderately slow drained*	*Slow*
Soil Group	*Entisols*	*Inceptisols*	*Alfisols*	*Vertisols*
Runoff	*Low*	*Moderate*	*Moderate*	*High*
Recharge	*High*	*Moderate*	*Moderate*	*Low*

Table 2. Antecedent soil Moisture Conditions

AMC Group	***Characteristics of soil***	***Total 5-day Antecedent Rainfall in mm***	
		Dormant Season	***Growing Season***
I	*Lowest runoff potential. The watershed soils are dry enough for satisfactory cultivation*	*Less than 12.7*	*Less than 35.6*
II	*The average conditions.*	*12.7- 27.9*	*35.6- 53.3*
III	*Highest runoff potential.*	*Over 27.9*	*Over 53.3*

Table 3. Curve Numbers for AMC II for Indian Conditions
(Source: from literature review)

Land use/cover	***Treatment / practices***	***Hydrologic Soil Group***			
		A	***B***	***C***	***D***
Agricultural land	*Plantation*	*41*	*55*	*69*	*73*
	Dry crops	*72*	*81*	*88*	*91*
	Wet crops	*95*	*95*	*95*	*95*
	Fallow	*49*	*69*	*79*	*84*
Build up land		*77*	*86*	*91*	*93*
Forest land	*Deciduous*	*28*	*44*	*60*	*64*
	Scrub	*33*	*47*	*64*	*67*
	Unnotified/Plantation	*26*	*40*	*58*	*61*
Wasteland	*Barren/stony*	*71*	*80*	*85*	*88*
	With scrub	*39*	*55*	*67*	*77*
	Without scrub	*41*	*55*	*69*	*73*
	Salt affected	*71*	*80*	*85*	*88*
	Water logged	*85*	*85*	*85*	*85*
Water bodies	*Reservoir/Tanks*	*100*	*100*	*100*	*100*
	River/Stream	*97*	*97*	*97*	*97*

Table 4. Corrections for Curve Numbers for different AMCs

CN values for conditions					
II	***I***	***III***	***II***	***I***	***III***
100	*100*	*100*	*65*	*45*	*82*
95	*87*	*98*	*60*	*40*	*78*
90	*78*	*96*	*55*	*35*	*74*
85	*70*	*94*	*50*	*31*	*70*
50	*63*	*92*	*45*	*26*	*65*
75	*57*	*88*	*40*	*22*	*60*
70	*51*	*85*			

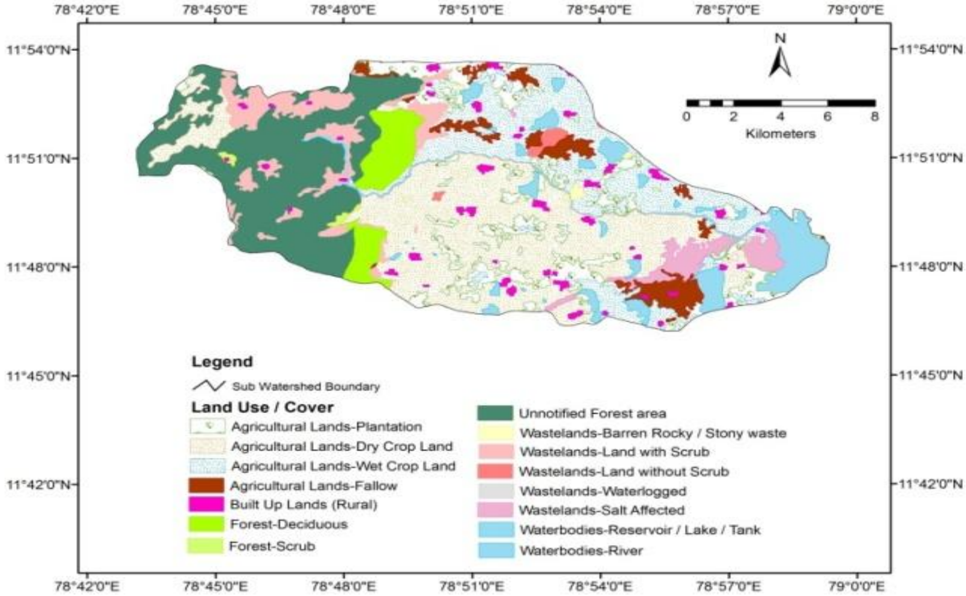

Figure 4. Land use and Land cover map of the study area in 1995

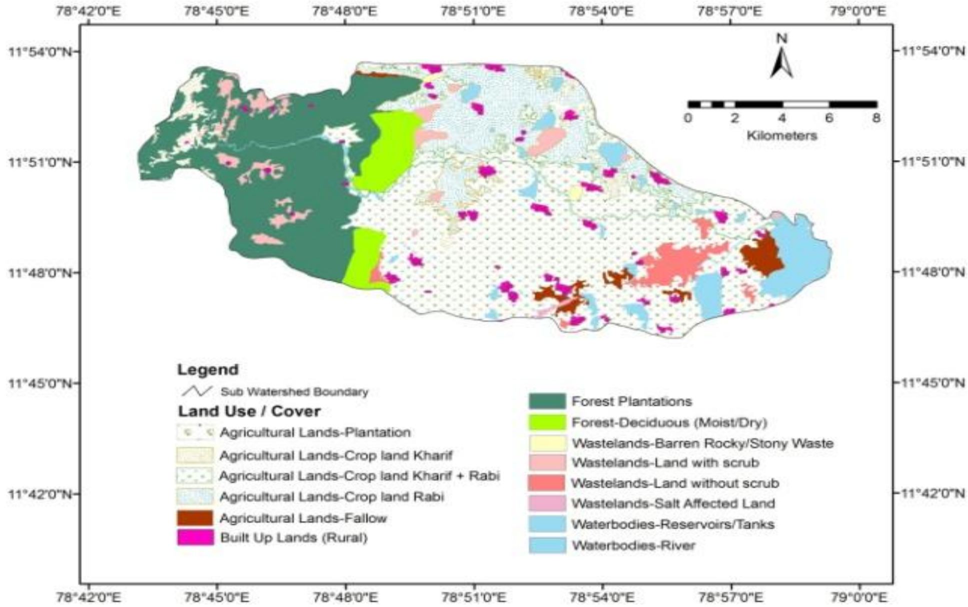

Figure 5. Land use and Land cover map of the study area in 2003

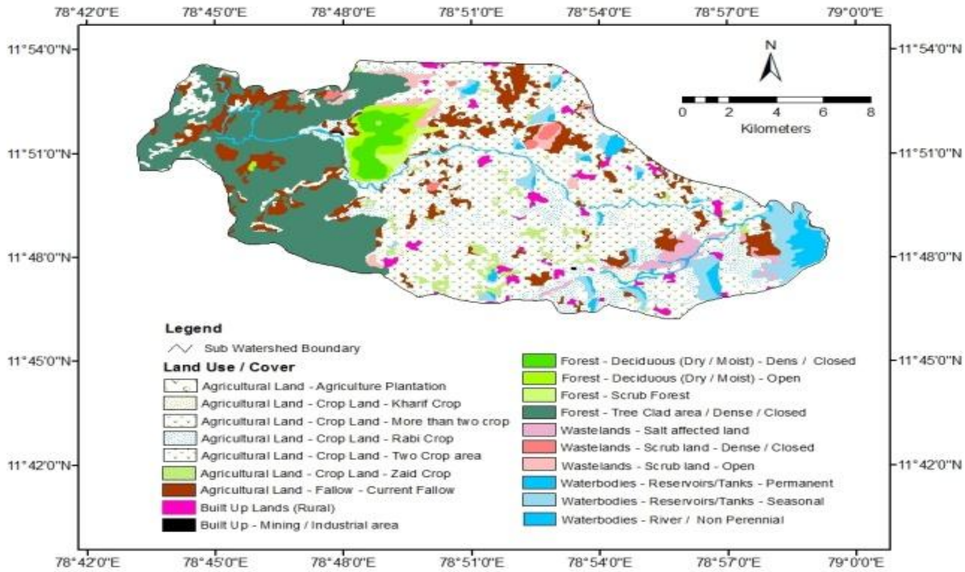

Figure 6. Land use and Land cover map of the study area in 2012

IV. RESULTS AND DISCUSSION

The area of HSG A, B, C, and D of the sub-watershed were obtained through GIS as 26.383, 29.698, 83.631 and 111.439 km^2 respectively. The computed monthly and annual rainfall and runoff values are presented in table 10. The maximum and the minimum annual rainfall of the study area for the past 25 water years (1992-2017) range from 2151.61mm (in 2005-2006) to 548.23mm (in 2016-2017). Usually a heavy rainfall is noticed during the northeast monsoon season (52.85%) during October to December months compared to other monsoon seasons (Table 10). Monthly maximum runoff of 477.67mm is noted during November 2005 and minimum of 1mm (0.96mm) in May 2001 and (0.98mm) in July 2008. The annual runoff is more during 2005-2006 (1134.02mm) and less during 2016-2017 (64.28mm). A rainfall-runoff regression model is developed using the sub-watershed database as shown in Fig.8. A straight line equation $y=0.598x-303.6$, where x represents rainfall (mm) and y represents runoff (mm) is obtained. The correlation coefficient r^2 is found to be 0.89, which is highly satisfactory. Compare the land use/land cover maps of 1995 and 2012, the agricultural land area has increased 10.19 % and forest area has reduced 3.09 % resulting in increased CN values in 2012.

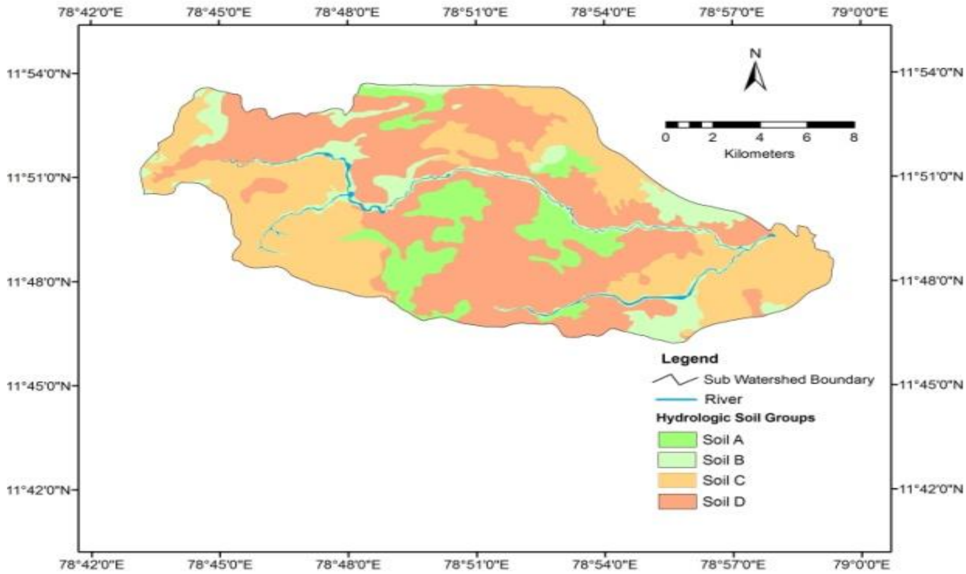

Figure 7. Hydrologic Soil Groups map of the study area

V. CONCLUSION

As the input parameters of NRCS-CN method is based on ground truth data, this method is used to estimate the direct runoff of this ungauged Muktha sub-watershed (4C1A2e). The estimated runoff showed that the semi-arid watershed has a very good surface runoff potential and is very important in various activities of water resource planning and management in the hard rock regions. The correlation between rainfall and runoff can be estimated by obtaining a linear regression line between these two variables. From the monthly values of runoff, the irrigation scheduling and crop rotation can be carried out successfully and also develop the water management of the watershed sustainably.

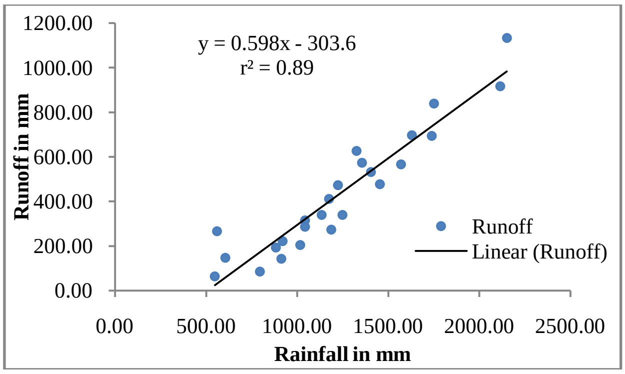

Figure 8. Correlation of Rainfall and Runoff

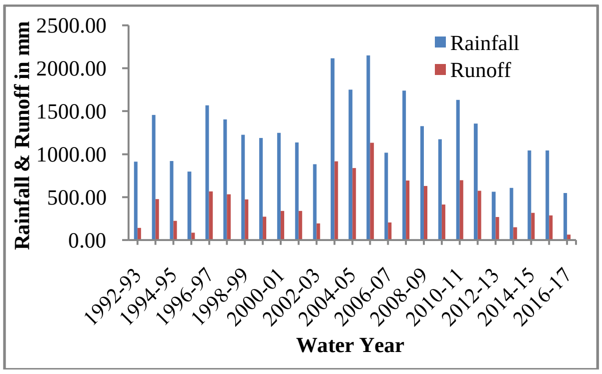

Figure 9. Rainfall and Runoff vs.Water year

Table 5. Weighted CN of the study area (for AMC II) in 1995

Land use/cover 1995		HSG	Area (sq.km)	CN	Area (%)	Area X CN	Weighted CN
Agricultural Land	Dry crop	Soil A	0.442	72	0.176	31.824	AMC I=62.52 AMC II=79.60 AMC III=91.68
		Soil B	2.153	81	0.857	174.393	
		Soil C	4.585	88	1.826	403.480	
		Soil D	6.341	91	2.525	577.031	
	Fallow	Soil A	1.611	49	0.641	78.939	
		Soil B	2.805	69	1.117	193.545	
		Soil C	3.120	79	1.242	246.480	
		Soil D	2.155	84	0.858	181.020	
	Plantation	Soil A	2.756	41	1.097	112.996	
		Soil B	1.945	55	0.774	106.975	
		Soil C	3.813	69	1.518	263.097	
		Soil D	14.372	73	5.722	1049.156	
	wet crop	Soil A	18.277	95	7.277	1736.315	
		Soil B	8.707	95	3.467	827.165	
		Soil C	15.721	95	6.260	1493.495	
		Soil D	53.939	95	21.477	5124.205	
Built-up Land	Rural settlements villages	Soil A	0.730	77	0.291	56.210	
		Soil B	0.568	86	0.226	48.848	
		Soil C	0.934	91	0.372	84.994	
		Soil D	1.239	93	0.493	115.227	
Forest Land	Deciduous	Soil A	0.100	28	0.040	2.800	
		Soil B	2.038	44	0.811	89.672	
		Soil C	3.164	60	1.260	189.840	
		Soil D	5.442	64	2.167	348.288	
	Scrub forest	Soil A	0.060	33	0.024	1.973	
		Soil C	0.493	64	0.196	31.552	
		Soil D	0.022	67	0.009	1.501	
	Unnotified forest area	Soil A	0.398	26	0.159	10.360	
		Soil B	5.225	40	2.080	209.000	
		Soil C	31.953	58	12.723	1853.274	
		Soil D	13.455	61	5.357	820.755	
Wasteland	Barren rocky / Stony waste	Soil A	0.029	71	0.012	2.059	
		Soil B	0.062	80	0.025	4.960	
		Soil C	0.104	85	0.041	8.840	
		Soil D	0.526	88	0.209	46.288	
	Land with scrub	Soil A	0.810	39	0.323	31.590	
		Soil B	2.689	55	1.071	147.895	
		Soil C	2.870	67	1.143	192.290	
		Soil D	8.524	71	3.394	605.204	
	Land without scrub	Soil A	0.523	41	0.208	21.443	
		Soil B	0.715	55	0.285	39.325	
		Soil C	0.039	69	0.016	2.718	
		Soil D	0.039	73	0.016	2.847	
	Salt affected land	Soil A	0.232	71	0.092	16.478	
		Soil B	0.641	80	0.255	51.280	
		Soil C	6.081	85	2.421	516.885	
		Soil D	0.223	88	0.089	19.624	
	Waterlogged	Soil C	0.105	85	0.042	8.943	
Water bodies	Reservoir / Tank	Soil A	0.481	100	0.192	48.100	
		Soil B	0.904	100	0.360	90.400	
		Soil C	4.485	100	1.786	448.500	
		Soil D	3.038	100	1.210	303.800	
	River	Soil A	0.029	97	0.012	2.813	
		Soil B	1.293	97	0.515	125.421	
		Soil C	7.490	97	2.982	726.530	
		Soil D	0.655	97	0.261	63.535	
		Total	**251.151**		**100**	**19992.177**	

Table 6. Weighted CN of the study area (for AMC II) in 2003

Land use/cover 2003		HSG	Area (sq.km)	CN	Area (%)	Area X CN	Weighted CN
Agricultural Land	Fallow	Soil A	0.795	49	0.32	38.955	AMC I=64.71 AMC II=81.22 AMC III=92.49
		Soil B	0.623	69	0.25	42.987	
		Soil C	3.074	79	1.22	242.846	
		Soil D	2.736	84	1.09	229.824	
	Crop land Kharif	Soil A	0.323	72	0.13	23.254	
		Soil B	0.337	81	0.13	27.297	
		Soil C	3.014	88	1.20	265.232	
		Soil D	1.383	91	0.55	125.853	
	Crop land double cropped	Soil A	15.750	84	6.27	1323.000	
		Soil B	13.006	88	5.18	1144.528	
		Soil C	9.477	92	3.77	871.884	
		Soil D	62.182	93	24.76	5782.926	
	Plantations	Soil A	0.132	41	0.05	5.412	
		Soil B	0.546	55	0.22	30.030	
		Soil C	0.075	69	0.03	5.180	
		Soil D	0.056	73	0.02	4.113	
	Crop land Rabi	Soil A	7.238	95	2.88	687.610	
		Soil B	2.471	95	0.98	234.745	
		Soil C	11.505	95	4.58	1092.975	
		Soil D	12.515	95	4.98	1188.925	
Built-up Land	Villages and Town	Soil A	0.686	77	0.27	52.822	
		Soil B	0.649	86	0.26	55.814	
		Soil C	0.681	91	0.27	61.971	
		Soil D	2.351	93	0.94	218.643	
Forest Land	Deciduous (Moist/Dry) closed	Soil A	0.018	28	0.01	0.504	
		Soil C	3.461	60	1.38	207.663	
		Soil D	0.245	64	0.10	15.665	
	Forest Plantations	Soil A	0.244	26	0.10	6.344	
		Soil B	5.573	40	2.22	222.920	
		Soil C	33.431	58	13.31	1938.998	
		Soil D	15.977	61	6.36	974.597	
	Deciduous (Moist/Dry) scrub	Soil A	0.005	33	0.00	0.150	
		Soil B	1.601	47	0.64	75.247	
		Soil C	1.550	64	0.62	99.200	
		Soil D	4.691	67	1.87	314.297	
Wasteland	Barren Rocky/Stony waste	Soil A	0.186	71	0.07	13.211	
		Soil B	0.010	80	0.00	0.800	
		Soil C	0.011	85	0.00	0.965	
		Soil D	0.353	88	0.14	31.064	
	Land with scrub	Soil A	0.396	39	0.16	15.444	
		Soil B	1.446	55	0.58	79.530	
		Soil C	1.873	67	0.75	125.491	
		Soil D	4.264	71	1.70	302.744	
	Land without scrub	Soil A	0.012	41	0.00	0.473	
		Soil B	0.331	55	0.13	18.205	
		Soil C	4.012	69	1.60	276.828	
		Soil D	1.767	73	0.70	128.991	
	Salt affected Land	Soil A	0.309	71	0.12	21.913	
		Soil B	0.042	80	0.02	3.360	
		Soil D	0.169	88	0.07	14.872	
Water bodies	Reservoirs/Tanks	Soil A	0.290	100	0.12	29.000	
		Soil B	1.575	100	0.63	157.500	
		Soil C	11.333	100	4.51	1133.300	
		Soil D	2.724	100	1.08	272.400	
	River	Soil A	0.000	97	0.00	0.000	
		Soil B	1.488	97	0.59	144.336	
		Soil C	0.134	97	0.05	12.998	
		Soil D	0.025	97	0.01	2.425	
			251.151		**100**	**20398.262**	

Table 7. Weighted CN of the study area (for AMC II) in 2012

Land use/cover 2003		HSG	Area (sq.km)	CN	Area (%)	Area X CN	Weighted CN
Agricultural Land	Plantation	Soil B	0.032	55	0.013	1.752	AMC I=65.41 AMC II=81.72 AMC III=92.69
		Soil C	0.232	69	0.092	16.008	
		Soil D	0.172	73	0.068	12.556	
	Kharif Crop	Soil A	0.761	72	0.303	54.792	
		Soil B	0.480	81	0.191	38.880	
		Soil C	0.668	88	0.266	58.784	
		Soil D	2.507	91	0.998	228.137	
	More than two crop/Zaid	Soil A	14.612	84	5.818	1227.408	
		Soil B	12.061	88	4.802	1061.368	
		Soil C	17.930	92	7.139	1649.560	
		Soil D	62.024	93	24.696	5768.232	
	Rabi Crop	Soil A	5.123	95	2.040	486.685	
		Soil B	3.463	95	1.379	328.985	
		Soil C	4.569	95	1.819	434.055	
		Soil D	8.252	95	3.286	783.940	
	Fallow	Soil A	2.787	49	1.110	136.563	
		Soil B	2.350	69	0.936	162.150	
		Soil C	10.190	79	4.057	805.010	
		Soil D	9.082	84	3.616	762.888	
Built Up Land		Soil A	1.007	77	0.401	77.539	
		Soil B	0.901	86	0.359	77.460	
		Soil C	0.721	91	0.287	65.611	
		Soil D	2.054	93	0.818	190.997	
Forest Land	Deciduous (Dry / Moist / Thorn) - Dens / Closed	Soil A	0.023	28	0.009	0.644	
		Soil B	0.740	44	0.295	32.560	
		Soil C	0.053	60	0.021	3.180	
		Soil D	7.896	64	3.144	505.344	
	Scrub	Soil B	1.012	47	0.403	47.564	
		Soil C	0.023	64	0.009	1.472	
		Soil D	0.790	67	0.315	52.930	
	Tree Clad area / Dense / Closed	Soil A	0.196	26	0.078	5.096	
		Soil B	3.958	40	1.576	158.320	
		Soil C	33.738	58	13.433	1956.804	
		Soil D	11.992	61	4.775	731.512	
Wastelands	Salt affected land	Soil A	0.266	71	0.106	18.890	
		Soil B	0.154	80	0.061	12.320	
		Soil C	3.499	85	1.393	297.415	
		Soil D	0.013	88	0.005	1.144	
	Scrub land - Dense / Closed	Soil A	0.214	39	0.085	8.346	
		Soil B	1.043	55	0.415	57.365	
		Soil C	0.005	67	0.002	0.326	
		Soil D	0.057	71	0.023	4.047	
	Scrub land - Open	Soil A	1.073	41	0.427	43.993	
		Soil B	0.484	55	0.193	26.620	
		Soil C	0.535	69	0.213	36.915	
		Soil D	1.451	73	0.578	105.923	
Water bodies	Reservoirs/Tanks	Soil A	0.321	100	0.128	32.100	
		Soil B	0.712	100	0.283	71.200	
		Soil C	10.882	100	4.333	1088.200	
		Soil D	4.355	100	1.734	435.500	
	River	Soil B	2.309	97	0.919	223.973	
		Soil C	0.586	97	0.233	56.842	
		Soil D	0.794	97	0.316	77.018	
			251.151		**100**	**20522.924**	

Table 8. Average Rainfall of the study area by Thiessen polygon method

Year	Raingauge station	June	July	Augu	Septe	Octo	Nove	Dece	Janu	Febr	Marc	April	May
1992-1993	Gomuki Dam	109.50	71.00	43.60	175.10	44.40	473.00	2.60	0.00	6.70	0.00	0.00	2.60
	Manimuktha Dam	36.00	0.00	94.00	250.50	140.50	305.00	17.00	0.00	6.50	0.00	0.00	8.00
	Study Area Rainfall	**93.70**	**55.74**	**54.44**	**191.31**	**65.06**	**436.88**	**5.70**	**0.00**	**6.46**	**0.00**	**0.00**	**3.76**
1993-1994	Gomuki Dam	104.20	39.80	230.20	250.00	364.80	288.20	211.60	0.00	0.00	0.00	0.00	74.00
	Manimuktha Dam	12.00	5.00	151.50	165.50	114.00	254.00	182.00	0.00	0.00	0.00	0.00	178.00
	Study Area Rainfall	**84.38**	**32.32**	**213.28**	**231.73**	**310.88**	**280.85**	**205.24**	**0.00**	**0.00**	**0.00**	**0.00**	**96.36**
1994-1995	Gomuki Dam	0.00	86.20	51.20	45.40	219.70	385.60	52.40	39.40	0.00	0.00	36.00	44.40
	Manimuktha Dam	35.00	57.00	151.50	96.50	108.50	214.70	35.00	0.00	0.00	0.00	0.00	79.50
	Study Area Rainfall	7.53	79.92	72.76	56.39	195.79	348.86	48.66	30.93	0.00	0.00	28.26	51.95
1995-1996	Gomuki Dam	128.90	88.40	46.50	135.10	111.10	127.20	0.00	0.00	0.00	0.00	84.40	74.80
	Manimuktha Dam	73.50	75.50	168.00	188.00	102.00	144.00	0.00	0.00	0.00	0.00	25.00	19.50
	Study Area Rainfall	**116.99**	**85.63**	**72.62**	**146.47**	**109.14**	**130.81**	**0.00**	**0.00**	**0.00**	**0.00**	**71.63**	**62.91**
1996-1997	Gomuki Dam	83.40	11.60	228.80	335.40	140.00	144.60	487.30	15.40	0.00	0.00	39.40	15.00
	Manimuktha Dam	191.50	52.50	198.40	394.50	211.00	71.70	629.00	5.50	0.00	0.00	48.50	19.50
	Study Area Rainfall	**106.64**	**20.39**	**222.26**	**348.11**	**155.27**	**128.93**	**517.77**	**13.27**	**0.00**	**0.00**	**41.36**	**15.97**
1997-1998	Gomuki Dam	27.60	36.20	72.00	280.60	379.60	506.40	100.70	0.00	0.00	0.00	0.00	74.60
	Manimuktha Dam	109.00	28.50	131.00	232.00	150.50	305.50	163.00	0.00	0.00	0.00	0.00	20.00
	Study Area Rainfall	**45.10**	**34.54**	**84.69**	**270.15**	**330.34**	**463.21**	**114.09**	**0.00**	**0.00**	**0.00**	**0.00**	**62.86**
1998-1999	Gomuki Dam	19.00	75.80	273.80	93.90	274.10	276.20	321.00	0.00	0.00	0.00	8.80	36.60
	Manimuktha Dam	13.30	52.00	107.50	37.50	145.00	145.50	115.00	0.00	0.00	0.00	0.00	43.50
	Study Area Rainfall	**17.77**	**70.68**	**238.05**	**81.77**	**246.34**	**248.10**	**276.71**	**0.00**	**0.00**	**0.00**	**6.91**	**38.08**
1999-2000	Gomuki Dam	30.20	27.40	118.10	63.40	233.60	381.90	130.40	3.70	194.60	0.00	31.20	77.00
	Manimuktha Dam	28.50	13.00	91.00	88.00	72.90	192.30	166.50	0.00	39.00	0.00	23.00	92.00
	Study Area Rainfall	**29.83**	**24.30**	**112.27**	**68.69**	**199.05**	**341.14**	**138.16**	**2.90**	**161.15**	**0.00**	**29.44**	**80.23**
2000-2001	Gomuki Dam	28.20	17.00	148.30	249.70	341.40	159.30	116.40	9.50	0.00	0.00	204.60	64.60
	Manimuktha Dam	80.00	9.50	134.00	197.50	178.00	89.30	60.20	0.00	0.00	0.00	95.00	79.00
	Study Area Rainfall	**39.34**	**15.39**	**145.23**	**238.48**	**306.27**	**144.25**	**104.32**	**7.46**	**0.00**	**0.00**	**181.04**	**67.70**
2001-2002	Gomuki Dam	59.90	236.60	83.20	209.50	254.00	116.30	71.20	11.20	20.40	0.00	0.00	107.00
	Manimuktha Dam	17.00	262.50	21.50	202.50	142.50	78.50	133.50	8.00	30.00	0.00	0.00	111.50
	Study Area Rainfall	**50.68**	**242.17**	**69.93**	**208.00**	**230.03**	**108.17**	**84.59**	**10.51**	**22.46**	**0.00**	**0.00**	**107.97**
2002-2003	Gomuki Dam	78.40	44.80	146.80	131.00	178.00	146.80	13.00	0.00	0.00	65.00	62.20	54.70
	Manimuktha Dam	69.00	57.00	54.00	107.00	190.50	184.00	43.50	0.00	0.00	0.00	44.00	0.00
	Study Area Rainfall	**76.38**	**47.42**	**126.85**	**125.84**	**180.69**	**154.17**	**19.56**	**0.00**	**0.00**	**51.03**	**58.29**	**42.94**
2003-2004	Gomuki Dam	74.00	166.60	464.20	144.00	324.00	293.00	122.00	0.00	0.00	0.00	22.00	686.00
	Manimuktha Dam	48.50	209.50	267.00	64.00	137.50	225.80	12.50	0.00	0.00	0.00	9.00	481.00
	Study Area Rainfall	**68.52**	**175.82**	**421.80**	**126.80**	**283.90**	**278.55**	**98.46**	**0.00**	**0.00**	**0.00**	**19.21**	**641.93**
2004-2005	Gomuki Dam	43.00	224.00	20.00	643.00	590.00	208.00	0.00	0.00	0.00	4.30	74.70	90.00
	Manimuktha Dam	43.50	45.50	14.50	253.00	421.00	127.50	0.00	0.00	0.00	38.15	32.00	112.00
	Study Area Rainfall	**43.11**	**185.64**	**18.82**	**559.15**	**553.67**	**190.69**	**0.00**	**0.00**	**0.00**	**11.58**	**65.52**	**94.73**
2005-2006	Gomuki Dam	9.00	183.00	183.00	257.00	432.00	702.00	235.00	10.00	0.00	100.00	85.00	82.00
	Manimuktha Dam	11.50	110.50	193.50	256.50	267.00	497.00	196.00	5.00	0.00	15.00	57.00	81.00
	Study Area Rainfall	**9.54**	**167.41**	**185.26**	**256.89**	**396.53**	**657.93**	**226.62**	**8.93**	**0.00**	**81.73**	**78.98**	**81.79**
2006-2007	Gomuki Dam	40.00	40.00	55.00	105.00	295.00	220.00	40.00	0.00	20.00	0.00	100.00	82.00
	Manimuktha Dam	81.00	63.00	80.00	130.00	380.00	215.00	20.00	0.00	0.00	0.00	105.00	15.00
	Study Area Rainfall	**48.82**	**44.95**	**60.38**	**110.38**	**313.28**	**218.93**	**35.70**	**0.00**	**15.70**	**0.00**	**101.08**	**67.60**
2007-2008	Gomuki Dam	20.00	295.00	285.00	52.00	250.00	170.00	435.00	25.00	10.00	150.00	10.00	162.00
	Manimuktha Dam	45.00	95.00	130.00	60.00	255.00	180.00	267.00	15.00	10.00	115.00	20.00	93.00
	Study Area Rainfall	**25.38**	**252.00**	**251.68**	**53.72**	**251.08**	**172.15**	**398.88**	**22.85**	**10.00**	**142.48**	**12.15**	**147.17**
2008-2009	Gomuki Dam	60.00	30.00	55.00	110.00	338.00	660.00	55.00	0.00	0.00	35.00	0.00	30.00
	Manimuktha Dam	70.00	133.00	50.00	45.00	261.00	490.00	60.00	0.00	0.00	45.00	0.00	5.00
	Study Area Rainfall	**62.15**	**52.15**	**53.93**	**96.03**	**321.45**	**623.45**	**56.08**	**0.00**	**0.00**	**37.15**	**0.00**	**24.63**
2009-2010	Gomuki Dam	42.00	50.00	87.00	170.00	79.00	475.00	153.00	0.00	0.00	0.00	0.00	155.00
	Manimuktha Dam	30.00	35.00	90.00	165.00	55.00	380.00	105.00	15.00	0.00	0.00	0.00	170.00
	Study Area Rainfall	**39.42**	**46.78**	**87.65**	**168.93**	**73.84**	**454.58**	**142.68**	**3.23**	**0.00**	**0.00**	**0.00**	**158.23**
2010-2011	Gomuki Dam	45.00	18.00	208.00	196.00	96.00	616.00	323.00	0.00	12.00	0.00	105.00	68.00
	Manimuktha Dam	140.00	95.00	92.00	125.00	40.00	505.00	175.00	5.00	0.00	0.00	240.00	6.00
	Study Area Rainfall	**65.43**	**34.56**	**183.06**	**180.74**	**83.96**	**592.14**	**291.18**	**1.08**	**9.42**	**0.00**	**134.03**	**54.64**
2011-2012	Gomuki Dam	15.00	109.00	171.00	123.00	171.00	546.00	273.00	0.00	0.00	0.00	25.00	12.00
	Manimuktha Dam	60.00	140.00	140.00	90.00	141.20	303.20	117.60	0.00	0.00	0.00	21.40	20.20
	Study Area Rainfall	**24.68**	**115.67**	**164.34**	**115.91**	**164.59**	**493.80**	**239.59**	**0.00**	**0.00**	**0.00**	**24.23**	**13.76**
2012-2013	Gomuki Dam	0.00	123.00	0.00	14.00	412.00	69.00	0.00	0.00	0.00	0.00	0.00	0.00
	Manimuktha Dam	0.00	43.30	0.00	17.20	224.10	65.40	3.20	0.00	0.00	0.00	0.00	0.00
	Study Area Rainfall	**0.00**	**105.86**	**0.00**	**14.69**	**371.60**	**68.23**	**0.69**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
2013-2014	Gomuki Dam	0.00	0.00	0.00	127.00	83.00	185.10	103.00	0.00	0.00	0.00	0.00	86.00
	Manimuktha Dam	0.00	0.00	0.00	150.20	129.50	138.80	65.10	0.00	0.00	0.00	0.00	201.30
	Study Area Rainfall	**0.00**	**0.00**	**0.00**	**131.99**	**93.00**	**175.15**	**94.85**	**0.00**	**0.00**	**0.00**	**0.00**	**110.79**
2014-2015	Gomuki Dam	55.20	41.10	148.60	135.80	276.20	102.40	81.10	17.50	0.00	0.00	147.40	67.10
	Manimuktha Dam	108.60	46.20	176.90	51.20	172.00	89.00	74.90	18.00	0.00	0.00	48.30	155.80
	Study Area Rainfall	**66.68**	**42.20**	**154.68**	**117.61**	**253.80**	**99.52**	**79.77**	**17.61**	**0.00**	**0.00**	**126.09**	**86.17**
2015-2016	Gomuki Dam	35.10	100.50	107.40	191.70	74.60	354.70	112.60	17.50	0.00	0.00	0.00	81.00
	Manimuktha Dam	11.80	35.50	87.00	40.80	152.60	377.60	115.80	0.00	0.00	0.00	0.00	109.00
	Study Area Rainfall	**30.09**	**86.53**	**103.01**	**159.26**	**91.37**	**359.62**	**113.29**	**13.74**	**0.00**	**0.00**	**0.00**	**87.02**
2016-2017	Gomuki Dam	40.80	113.00	5.00	34.60	119.60	34.00	61.60	75.20	0.00	3.60	0.00	58.00
	Manimuktha Dam	42.00	61.00	59.40	13.20	121.50	81.40	48.80	79.20	0.00	0.00	0.00	52.00
	Study Area Rainfall	**41.06**	**101.82**	**16.70**	**30.00**	**120.01**	**44.19**	**58.85**	**76.06**	**0.00**	**2.83**	**0.00**	**56.71**

Table 9. Computed Rainfall and Runoff of the study area

Year/ Month		June	July	Augu	Sept	Octo	Nove	Dece	Janu	Febru	Marc	April	May	Annual
1992-1993	Rainfall	93.70	55.74	54.44	191.31	65.06	436.88	5.70	0.00	6.46	0.00	0.00	3.76	913.05
	Runoff	44.43	0.86	0.00	28.13	0.00	69.90	0.00	0.00	0.00	0.00	0.00	0.00	143.32
1993-1994	Rainfall	84.38	32.32	213.28	231.73	310.88	280.85	205.24	0.00	0.00	0.00	0.00	96.36	1455.04
	Runoff	0.00	0.00	89.01	96.03	97.40	85.14	87.63	0.00	0.00	0.00	0.00	22.66	477.87
1994-1995	Rainfall	7.53	79.92	72.76	56.39	195.79	348.86	48.66	30.93	0.00	0.00	28.26	51.95	921.05
	Runoff	0.00	30.85	0.00	0.90	24.72	166.22	0.00	0.00	0.00	0.00	0.00	0.00	222.69
1995-1996	Rainfall	116.99	85.63	72.62	146.47	109.14	130.81	0.00	0.00	0.00	0.00	71.63	62.91	796.20
	Runoff	23.96	1.50	0.00	9.07	8.58	32.87	0.00	0.00	0.00	0.00	4.72	4.60	85.30
1996-1997	Rainfall	106.64	20.39	222.26	348.11	155.27	128.93	517.77	13.27	0.00	0.00	41.36	15.97	1569.97
	Runoff	12.08	0.00	82.84	112.73	32.47	28.36	298.78	0.00	0.00	0.00	0.00	0.00	567.26
1997-1998	Rainfall	45.10	34.54	84.69	270.15	330.34	463.21	114.09	0.00	0.00	0.00	0.00	62.86	1404.98
	Runoff	0.00	0.00	27.45	134.23	161.87	194.92	4.01	0.00	0.00	0.00	0.00	10.55	533.03
1998-1999	Rainfall	17.77	70.68	238.05	81.77	246.34	248.10	276.71	0.00	0.00	0.00	6.91	38.08	1224.41
	Runoff	0.00	0.00	96.94	4.27	116.53	98.12	157.66	0.00	0.00	0.00	0.00	0.00	473.52
1999-2000	Rainfall	29.83	24.30	112.27	68.69	199.05	341.14	138.16	2.90	161.15	0.00	29.44	80.23	1187.16
	Runoff	0.00	0.00	3.66	1.03	13.68	188.99	14.11	0.00	48.39	0.00	0.00	3.83	273.69
2000-2001	Rainfall	39.34	15.39	145.23	238.48	306.27	144.25	104.32	7.46	0.00	0.00	181.04	67.70	1249.48
	Runoff	0.00	0.00	41.42	55.99	114.56	31.68	17.91	0.01	0.00	0.00	77.23	0.96	339.76
2001-2002	Rainfall	50.68	242.17	69.93	208.00	230.03	108.17	84.59	10.51	22.46	0.00	0.00	107.97	1134.51
	Runoff	0.00	141.48	4.28	61.08	60.90	32.35	0.15	0.00	0.00	0.00	0.00	39.68	339.92
2002-2003	Rainfall	76.38	47.42	126.85	125.84	180.69	154.17	19.56	0.00	0.00	51.03	58.29	42.94	883.17
	Runoff	0.85	6.69	57.87	9.55	52.99	53.44	0.00	0.00	0.00	11.65	0.00	0.00	193.04
2003-2004	Rainfall	68.52	175.82	421.80	126.80	283.90	278.55	98.46	0.00	0.00	0.00	19.21	641.93	2114.99
	Runoff	0.00	61.02	195.44	30.09	84.79	136.64	48.40	0.00	0.00	0.00	0.00	361.05	917.43
2004-2005	Rainfall	43.11	185.64	18.82	559.15	553.67	190.69	0.00	0.00	27.94	11.58	65.52	94.73	1750.85
	Runoff	6.32	102.34	0.00	308.86	357.86	43.07	0.00	0.00	0.00	0.00	6.57	15.02	840.04
2005-2006	Rainfall	9.54	167.41	185.26	256.89	396.53	657.93	226.62	8.93	0.00	81.73	78.98	81.79	2151.61
	Runoff	0.00	95.53	69.30	104.15	191.75	477.67	130.56	0.00	0.00	19.52	19.34	26.20	1134.02
2006-2007	Rainfall	48.82	44.95	60.38	110.38	313.28	218.93	35.70	0.00	15.70	0.00	101.08	67.60	1016.82
	Runoff	6.69	4.71	4.71	1.30	98.22	54.20	0.00	0.00	0.00	0.00	35.54	0.00	205.37
2007-2008	Rainfall	25.38	252.00	251.68	53.72	251.08	172.15	398.88	22.85	10.00	142.48	12.15	147.17	1739.54
	Runoff	0.00	112.61	107.92	0.00	92.81	47.74	299.54	0.00	0.00	10.40	1.34	22.34	694.70
2008-2009	Rainfall	62.15	52.15	53.93	96.03	321.45	623.45	56.08	0.00	0.00	37.15	0.00	24.63	1327.02
	Runoff	12.06	0.98	8.70	50.86	127.07	427.96	0.13	0.00	0.00	0.09	0.00	0.00	627.85
2009-2010	Rainfall	39.42	46.78	87.65	168.93	73.84	454.58	142.68	3.23	0.00	0.00	0.00	158.23	1175.34
	Runoff	0.00	0.00	16.38	83.69	0.54	194.80	47.91	0.00	0.00	0.00	0.00	68.41	411.73
2010-2011	Rainfall	65.43	34.56	183.06	180.74	83.96	592.14	291.18	1.08	9.42	0.00	134.03	54.64	1630.24
	Runoff	0.00	0.00	59.21	84.47	0.00	341.32	141.86	0.00	0.00	0.00	60.37	10.58	697.81
2011-2012	Rainfall	24.68	115.67	164.34	115.91	164.59	493.80	239.59	0.00	0.00	0.00	24.23	13.76	1356.57
	Runoff	0.00	40.65	36.10	0.00	26.15	277.07	193.99	0.00	0.00	0.00	0.00	0.00	573.96
2012-2013	Rainfall	0.00	105.86	0.00	14.69	371.60	68.23	0.69	0.00	0.00	0.00	0.00	0.00	561.07
	Runoff	0.00	39.88	0.00	0.00	180.52	46.54	0.00	0.00	0.00	0.00	0.00	0.00	266.94
2013-2014	Rainfall	0.00	0.00	0.00	131.99	93.00	175.15	94.85	0.00	0.00	0.00	0.00	110.79	605.78
	Runoff	0.00	0.00	0.00	40.17	0.00	80.08	14.08	0.00	0.00	0.00	0.00	13.39	147.72
2014-2015	Rainfall	66.68	42.20	154.68	117.61	253.80	99.52	79.77	17.61	0.00	0.00	126.09	86.17	1044.13
	Runoff	0.00	15.82	46.11	54.34	106.73	35.44	16.47	0.00	0.00	0.00	33.00	7.55	315.46
2015-2016	Rainfall	30.09	86.53	103.01	159.26	91.37	359.62	113.29	13.74	0.00	0.00	0.00	87.02	1043.93
	Runoff	0.00	0.82	3.48	68.35	1.16	145.33	39.09	0.00	0.00	0.00	0.00	28.09	286.32
2016-2017	Rainfall	41.06	101.82	16.70	30.00	120.01	44.19	58.85	76.06	0.00	2.83	0.00	56.71	548.23
	Runoff	0.00	0.30	0.00	0.00	24.06	0.00	4.94	34.98	0.00	0.00	0.00	0.00	64.28

Table 10. Mean seasonal rainfall of the study area (1992 - 2017)

Description	***Monsoon***		***Winter***	***Summer***	***Annual***
	Southwest	***Northeast***			
Rainfall (mm)	*420.63*	*650.67*	*17.35*	*142.44*	*1231.09*
% components of Rainfall	*34.17*	*52.85*	*1.41*	*11.57*	*100*

REFERENCES

[1] A.Sarangi and A.K.Bhattachary,"Comparison of Artificial Neural Network & Regression models for sediment loss prediction from Banha watershed,India", Agricultural Water Management,vol:78,pp.195-208, 2005.
[2] V.T.Chow, D.K.Maidment and L.W.Mays, Applied hydrology, McGraw-Hill Book Company,New York,USA,1988.
[3] R.E.Schulze, E.J.Schmidt and J.C.Smither, SCS-SA User Manual PC Based SCS Design Flood Estimates for Small Catchments in Southern Africa, Pietermaritzburg,Department of Agri. Engineering,University of Natal,1992.
[4] V.Hariprasad and A.K.Chakraborti,"Management of small watersheds using hydrologic modeling and GIS", International Conference on Remote Sensing and GIS/GPS,pp.16-19.1997.
[5] S.K.Mishra, V.P.Singh, J.J.Sansalone and V.Aravamuthan,"A modified SCS-CN method: Characterization and testing",Water Resources Management (WARM),vol.17, no.1,pp.37-68,2003.
[6] D.Amstutz, R.Bahadur, C.Ziemniak and W.Samuel,"Global River Basin Modeling and Contaminant Transport",American Journal of Climate Change,vol.2,no.2,pp.138-146,2013, doi: 10.4236/ajcc.2013.22014.
[7] G.Shwetha, B.Maheshwara Babu, S.Polisgowdar, G.V.Srinivas Reddy and U.K.Shanwad,"Estimation of surface runoff in Timmapur watershed using SCS-CN method", International Journal of Agricultural Science and Research, vol. 5,no.6,pp.1-8,2015.
[8] P.A.Burrough, Principles of Geographical Information Systems for Land Use, Oxford University Press, New York, USA,1986.
[9] B.S.Bisht and B.P.Kotyam,"Land Cover Change Analysis of Garur Ganga Watershed Using RS & GIS Technique", Journal of ISRS,vol.29,no.3,pp.137-149,2001.
[10] S.Poongothai and S.Thayumanavan,"Estimation of Runoff from a Watershed Using GIS Based SCS Method", Proceedings of National Seminar on Water Resources Systems Planning and Management, Department of Civil Engineering. Annamalai University, Annamalai Nagar,pp.27-37,2002.
[11] N.Nagarajan and S.Poongothai,"Spatial Mapping of Runoff from a Watershed Using SCS-CN Method with Remote Sensing and GIS",Journal of Hydrology and Engineering, special issue: Soil Conservation Service Curve Number (SCS-CN) Methodology,vol.17,pp.1268-1277,2012.
[12] A.Manoharan and A.Muragappan, "Estimation of Runoff in ungauged rural watershed, Tamilnadu,India", International Journal of Engineering Science and Technology,vol.4,no.2,pp.449-456,2012.
[13] R.Vinithra and L.Yeshodha,"Rainfall-Runoff Modelling Using SCS-CN Method: A Case Study of Krishnagiri District, Tamilnadu",International Journal of Science and Research,vol.5,no.3,pp.2080-2084,2016.
[14] S.Satheeshkumar, R.Venkateswaran and R.Kannan,"Rainfall–runoff estimation using SCS–CN and GIS approach in the Pappiredipatti watershed of the Vaniyar sub basin, SouthIndia", Model. Earth System Environment,vol.3,pp.24, doi 10.1007/s40808-017-0301-4,Springerlink.com,2017.
[15] X.Zhan and M.L.Huang,"ArcCN-Runoff: an ArcGIS tool for generating curve number and runoff maps",Environ. Model. Softw.,vol.19,no.10,pp.75-79,2004.
[16] M.Askar,"Rainfall-runoff model using the SCS-CN method and geographic information systems: A case study of Gomal river watershed",WIT Transactions on Ecology and the Environment,vol.178,pp.1-12,2014.
[17] R.Dubayah and D.Lerrenmaier,"Combing Remote Sensing and Hydrological Modeling for Applied Water and Energy Balance Studies",NASA EOS Interdisciplinary Working Group Meeting, San Diego,CA,1997.
[18] D. Kumar and R.Bhattacharya,"Distributed Rainfall Runoff Modeling",International Journal of Earth Sciences and Engineering,vol.4,no.6,pp.270-275,2011.
[19] A.B.Kudoli and R.A.Oak,"Runoff estimation by using GIS based technique and its comparison with different methods-a case study on Sangli micro watershed",International Journal of Emergency Rescue Management Technology,vol.4,no.5,pp.2278-2289,2015.
[20] R.Amutha and P.Porchelvan,"Estimation of Surface Runoff in Malattar Sub-watershed using SCS CN method", Journal of Indian Society of Remote Sensing,vol.37,pp.291-304,2009.
[21] S.Akhondi,"An investigation of curve number model in flood estimation using, Geographical information System (GIS)", MSc thesis,Tarbiat Modares University,Tehran,2001.
[22] CGWB (2015), Groundwater year book of Tamil nadu and Puducherry, Government of India, Ministry of Water Resources, Central Ground Water Board, South Eastern Coastal Region,Chennai.
[23] Ministry of Agriculture (1972), Handbook of Hydrology, Govt. of India, New Delhi.
[24] SCS (1956 and 1972), National Engineering Handbook Section-4, Hydrology, Soil Conservation Service, USDA, Washington, D.C,USA.
[25] USDA (1972 and 1994),Soil Conservation Service, National Engineering Handbook. Hydrology Section 4. Chapters 4-10, USDA, Washington, D.C,USA.

