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Original Article

Geospatial technique for runoff estimation based on soil conservation service curve number method in upper Cauvery Karnataka

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ABSTRACT

Accurate estimation of runoff and sediment yield amount is not only an important task in physiographic but also important for proper watershed management. Watershed is an ideal unit for planning and management of land and water resources. Direct runoff in a catchment depends on soil type, land cover, and rainfall. Of the many methods available for estimating runoff from rainfall, the curve number (CN) method (soil conservation service CN [SCS-CN]) is the most popular. The CN depends on soil and land use characteristics. This study was conducted in the upper Cauvery Karnataka using remote sensing and geographic information system (GIS). SCS-CN method has been used for surface runoff estimation for eight watersheds of upper Cauvery. The soil map and land use were created in the GIS environment because the CN method is used here as a distributed model. The major advantage of employing GIS in rainfall-runoff modeling is that more accurate sizing and catchment characterization can be achieved. Furthermore, the analysis can be performed much faster, especially when there is a complex mix of land use classes and different soil types. The results showed that the surface runoff ranged from 170.12 to 599.84 mm in the study area when rainfall rates were received from 1042.65 to 1912 mm. To find the relationship between rainfall and runoff rates, the straight-line equation was used. That was found that there was a strong correlation between runoff and precipitation rates. The value correlation coefficient between them was 86%. The average depth of runoff is more in watershed A4, the average runoff coefficient is less in watershed B2, and the correlation coefficient is high in A4 to a value of almost 89.5%.

Keywords: Antecedent moisture condition, curve number, infiltration, rainfall, runoff, Thiessen polygon

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INTRODUCTION

The conventional hydrologic data are inadequate for the purpose of design and operation of water resources system. Surface water runoff is a step in the water cycle on earth. When precipitation occurs, water only has a few locations where it can go. Water can infiltrate into the ground, evaporate, or become runoff. Runoff is the short way of saying surface water runoff. Rainfall-runoff is an important component contributing significantly to the hydrological cycle, design of hydrological structures, and morphology of the drainage system. Estimation of the same is required to determine and forecast its effects.[1] The problem of estimating runoff from a storm event is one of the key points in hydrologic modeling. Estimation of direct rainfall-runoff is always efficient but is not possible for most of the location at desired time. Classical techniques as the rational method or the soil conservation service curve number (SCS-CN) approach are still widely used in practice. Due to the complexity of the hydrological processes and the basin characteristics, physically based distributed models using geographic information system (GIS) and remote sensing techniques are becoming popular. The use of remote sensing and GIS technology can be used to overcome the problem of conventional method for estimating runoff caused due to rainfall. In this paper, modified SCS-CN model is used for rainfall-runoff estimation that considers parameter such as slope, vegetation cover, and area of watershed.

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Water resources are essential renewable resources that are the basis for existence and development of a society. Proper utilization of these resources requires assessment and management of the quantity and quality of the water resources both spatially and temporally. Water crises caused by shortages, floods, and diminishing water quality, among others, are increasing in all parts of the world. The growth of population demands for increased domestic water supplies and, at the same time, results with a higher consumption of water due to expansion in agriculture and industry. Mismanagement and lack of knowledge of existing water resources and the changing climatic conditions have consequences of an imbalance of supply and demand of water. The problem is pronounced in semi-arid and arid areas where the resources are limited. Surface water being easy, direct, and, therefore, less expensive to exploit in comparison to other sources such as groundwater or desalinization makes it the major source of water supply for irrigation, industry, and domestic uses. The surface water, in the form of lakes and river discharge (runoff), is predominately obtained from rainfall after being generated by the rainfall-runoff processes. To make decisions for planning, design, and control of water resource systems, long runoff series are required. The latter are not often available with reasonable length. On the other hand, for flood control and reservoir regulation future, flows shall be forecasted with rainfall-runoff models. A number of rainfall-runoff models exist for the generation of flow, forecasting, and other purposes.[2] Establishing a rainfall-runoff relationship is the central focus of hydrological modeling from its simple form of unit hydrograph to rather complex models based on fully dynamic flow equations. As the computing capabilities are increasing, the use of these models to simulate a catchment became a standard. Models are generally used as utility in various areas of water resource development, in assessing the available resources, in studying the impact of human interference in an area such as land-use change, deforestation, and other hydraulic structure such as dams and reservoirs.

MATERIALS AND METHODS

Study Area

The study area geographically lies between 75°29’ 19” E and 76°37’ 40” E longitude and 11°55’ 54” N and 13°23’ 12.8” N latitude, as shown in Figure 1, and has an area of 10,874.65 Sq km.[3] The maximum length and width of the study area are approximately equal to 143.73 km and 96.75 km, respectively. The maximum and minimum elevation of the basin is 1867 m and 714 m above mean sea level, respectively. The study area covers five districts of Karnataka state, i.e., Chikmagalur, Hassan, Kodagu, Mandya, and Mysore, as shown in Figure 2.[4,5] It is divided into eight watersheds (A1, A2, A3, A4, B1, B2, B3, and B4), as shown in Figure 3.[6] The total area (A) and perimeter (P) of eight watersheds are calculated using ArcGIS and values are tabulated in Table 1.

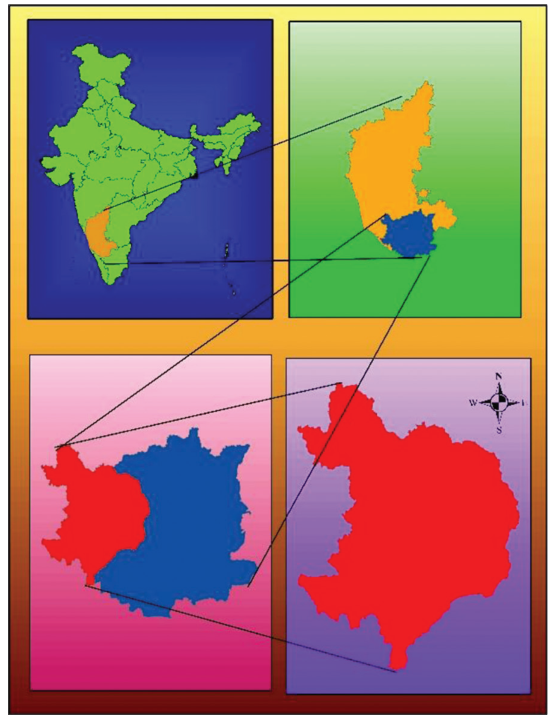

Figure 1: Location map of the study area

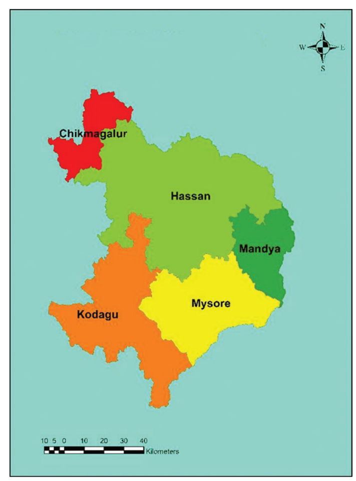

Figure 2: Districts in the study area

Table 1: Watersheds of upper Cauvery catchment

Subwatersheds	Area (km^2)	Perimeter (km)	Length (km)	Width (km)
A1	1705.50	263.13	76.20	56.52
A2	1411.28	244.53	50.02	24.30
A3	973.81	201.52	38.50	22.84
A4	1205.17	222.98	52.17	22.21
B1	1463.36	202.94	38.75	24.87
B2	1097.97	193.21	31.85	30.40
B3	1759.84	315.76	86.83	21.3
B4	1257.72	297.45	65.26	15.22

The study area which is of 10,874.65 km^2 was divided into eight watersheds as A1, A2, A3, A4, B1, B2, B3, and B4.

Methodology

SCS-CN model

In this model, runoff will be determined as a function of current soil moisture content, static soil conditions, and management practices. Runoff is deduced from the water available to enter the soil before infiltration. Figure 4 shows the methodology adopted for runoff estimation using SCS-CN method. This 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 CN is an index that represents the combination of hydrologic soil group and antecedent moisture conditions (AMCs). The SCS prepared an index, which is called as the runoff CN to represent the combined hydrologic effect of soil, land use and land cover, agriculture class, hydrologic conditions, and antecedent soil moisture conditions. These factors can be accessed from soil survey and the site investigations and land use maps, while using the hydrologic model for the design.

The specifications of AMCs are often a policy decision that suggests the average watershed conditions rather than recognitions of hydrologic conditions at a particular time and place.

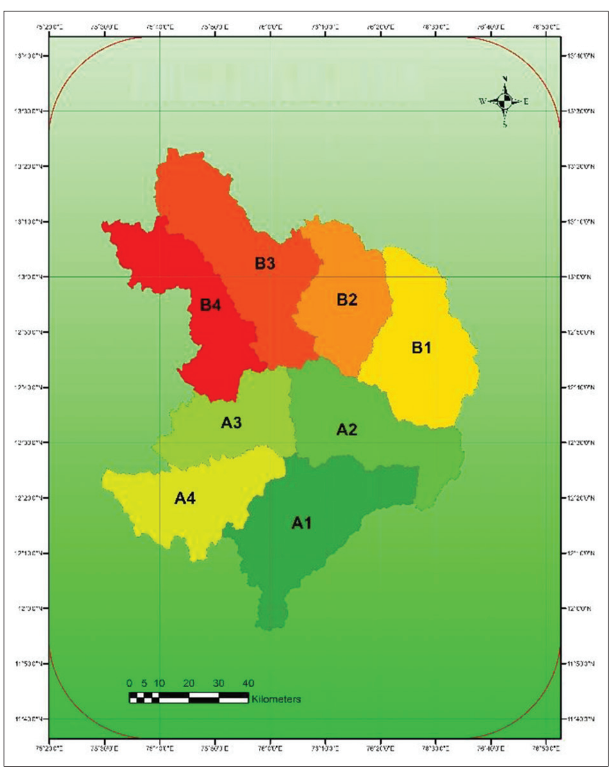

Figure 3: Watershed map

Expressed mathematically as given,

$$\frac{Q}{P-Ia} = \frac{F}{S} \tag{1}$$

Where, Q is the runoff, P is the precipitation, and F is the infiltrations and it is the difference between the potential and accumulated runoff. Ia is beginning abstraction, which represents all the losses before the runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, and initial infiltrations. This is variable but generally is correlated with soil and land cover parameter; S is the potential infiltrations after the runoff begins.

Thus, a runoff CNs is defined to relate the unknown S as spatially distributed variables are as follows:

$$S = \frac{25400}{CN} - 254 \tag{2}$$

$$Q = \frac{(P-0.2S)2}{(P+0.8S)} \tag{3}$$

Determination of 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 CN. 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

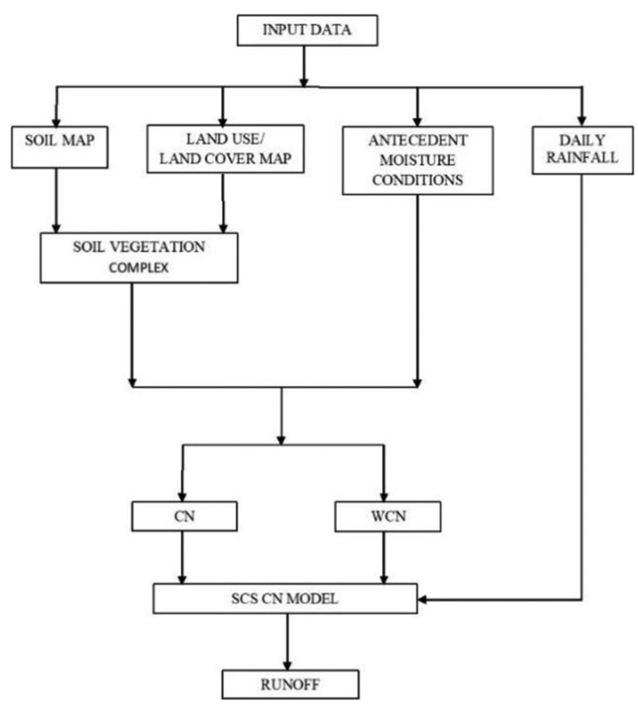

Figure 4: Methodology soil conservation service curve number

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, treatment, and hydrologic conditions were assigned based on the CN table. Runoff CNs for AMC II hydrologic soil cover complex are shown in Table 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 to 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 3 shows the minimum infiltration rates associated with each soil group.

AMCs

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, and III.[7-14]

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 [Table 4]. The CN 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:

Table 2: Runoff curve numbers for AMC II hydrologic soil cover complex

Land use	Hydrologic soil group			
	A	B	C	D
Agricultural land without conservation (Kharif)	72	81	88	91
Double crop	62	71	88	91
Agriculture plantation	45	53	67	72
Land with scrub	36	60	73	79
Land without scrub (stony waste/rock outcrops)	45	66	77	83
Forest (degraded)	45	66	77	83
Forest plantation	25	55	70	77
Grass land/pasture	39	61	74	80
Settlement	57	72	81	86
Road/railway line	98	98	98	98
River/Stream	97	97	97	97
Tanks without water	96	96	96	96
Tank with water	100	100	100	100

Table 3: Minimum infiltration rates associated with each soil group

Soil group	Minimum infiltration rate (mm/h)
A	7.62–11.43
B	3.81–7.62
C	1.27–3.81
D	0–1.27

Table 4: AMCs

AMcs	Five days antecedent rainfall (mm)	
	Dormant season	Growing season
I	<12.7	<35.56
II	12.7–27.94	35.56–53.34
III	>27.94	53.34

AMC: Antecedent moisture condition

Table 5: Runoff for watershed A1

Year	Precipitation (mm)	Runoff (mm)	Runoff volume (×10^6 m^3)
1991	1249.30	266.73	454.8551046
1992	1063.50	155.41	265.0284378
1993	1775.29	260.54	444.3053687
1994	956.96	160.46	273.6304411
1995	654.29	76.82	130.9996262
1996	823.77	111.92	190.8664807
1997	1012.35	132.91	226.6632402
1998	768.55	134.62	229.576311
1999	941.40	155.41	265.0237727
2000	945.31	265.72	453.1455233
2001	1191.59	258.86	441.4417238
2002	1011.32	159.14	271.3862162
2003	995.92	113.28	193.1797824
2004	1217.19	209.29	356.9085157
2005	1741.97	400.80	683.496264
2006	1402.97	259.13	441.9021629
2007	1803.85	519.15	885.3220695
2008	1206.21	186.28	317.6688724
2009	1477.18	335.52	572.1723216
2010	1285.60	174.35	297.3242855
2011	1410.17	196.34	334.8244922
2012	1035.03	164.08	279.8105464
2013	1427.89	310.84	530.0847772
2014	1357.17	260.69	444.5624777
2015	1058.20	199.92	340.9295736

Table 6: Runoff for watershed A2

Year	Precipitation (mm)	Runoff (mm)	Runoff volume (×10⁶ m³)
1991	1079.238	318.3105	449.2315583
1992	831.8756	135.0322	190.5708813
1993	973.8835	319.0637	450.2946524
1994	837.2658	209.3959	295.520456
1995	697.2699	147.0037	207.4663848
1996	806.5247	165.6314	233.7556224
1997	787.8882	126.7231	178.8442789
1998	671.9876	85.2907	120.3707706
1999	1047.133	326.8451	461.2765252
2000	933.4563	275.6445	389.017062
2001	753.37	172.01	242.7567695
2002	599.81	135.66	191.461236
2003	558.72	83.78	118.2412828
2004	913.84	193.75	273.4435929
2005	1058.56	251.16	354.4621611
2006	573.64	75.21	106.1419294
2007	831.42	153.51	216.6513618
2008	838.18	127.55	180.0142987
2009	801.10	157.85	222.778385
2010	907.81	152.77	215.6104961
2011	691.24	105.76	149.2646623
2012	466.92	64.56	91.1087415
2013	710.72	100.94	142.4600626
2014	873.56	190.04	268.2003552
2015	889.22	156.86	221.3824721

Table 7: Runoff for watershed A3

Year	Precipitation (mm)	Runoff (mm)	Runoff volume (×10⁶ m³)
1991	2154.5102	369.3993	359.584393
1992	2338.1808	390.4288	380.055128
1993	2160.7990	507.5535	494.067810
1994	2329.9708	444.1791	432.377221
1995	1935.8946	357.3768	347.881345
1996	2095.3924	342.7029	333.597293
1997	2441.4797	518.4870	504.710779
1998	2085.4218	365.2931	355.587230
1999	1993.4384	305.1998	297.090659
2000	2087.6794	354.8509	345.422541
2001	1474.2592	175.8424	171.170267
2002	1313.5518	196.3142	191.098086
2003	1501.0252	214.2358	208.543553
2004	1797.7194	317.0055	308.582655
2005	2224.8687	424.1388	412.869438
2006	1942.4453	330.4714	321.690749
2007	2097.8077	477.9737	465.273973
2008	1706.0792	276.7440	269.390953
2009	1765.0453	299.2862	291.334150
2010	1674.0848	177.3204	172.609027
2011	1893.6137	249.3415	242.716535
2012	1142.1750	153.9015	149.812315
2013	2329.2629	459.4696	447.261503
2014	1771.5376	331.7718	322.956640
2015	1587.7551	230.6284	224.500576

Table 8: Runoff for watershed A4

Year	Precipitation (mm)	Runoff (mm)	Runoff volume (×10⁶ m³)
1991	3073.9666	862.4353	1010.179063
1992	2954.3484	758.4316	888.358510
1993	3086.5209	1068.1747	1251.163654
1994	3459.9810	1117.1005	1308.470946
1995	2857.4361	842.7651	987.139144
1996	2947.2302	846.7903	991.853971
1997	3433.2208	1174.2738	1375.438700
1998	3103.6553	894.1021	1047.270747
1999	2686.2422	666.2689	780.407387
2000	2762.0267	712.6912	834.782289
2001	2657.3683	741.2566	868.241322
2002	2354.0192	681.5756	798.336282
2003	2290.6827	590.0753	691.161070
2004	2776.7827	844.7599	989.475705
2005	3646.1924	1377.9178	1613.968901
2006	3770.6536	1505.1959	1763.051026
2007	4237.5225	1917.6484	2246.160796
2008	2796.7170	865.9510	1014.297088
2009	3243.6842	1232.6357	1443.798574
2010	2825.8352	746.7225	874.643492
2011	3248.4447	1051.8255	1232.013737
2012	2401.4336	731.9800	857.375519
2013	3458.8132	1253.1982	1467.883545
2014	3373.8519	1338.1872	1567.432007
2015	2714.0473	826.7243	968.350476

Table 9: Runoff for watershed B1

Year	Precipitation (mm)	Runoff (mm)	Runoff volume (×10⁶ m³)
1991	1019.2074	197.4925	288.990796
1992	842.5873	144.9634	212.124929
1993	696.8212	104.3230	152.655853
1994	779.9273	159.2105	232.972735
1995	693.8713	131.8019	192.865777
1996	811.9827	171.4599	250.897338
1997	731.3317	134.7727	197.212874
1998	739.0310	109.5882	160.360421
1999	1058.1186	254.9084	373.007433
2000	987.3320	216.7717	317.202017
2001	858.4920	128.9491	188.691180
2002	757.8522	108.3444	158.540405
2003	616.7539	90.8529	132.945105
2004	1047.4533	142.8753	209.069357
2005	1205.1043	243.3481	356.091316
2006	740.1969	95.3040	139.458315
2007	1049.2340	217.6334	318.462976
2008	1073.2332	176.9690	258.958705
2009	1132.5484	234.9874	343.857028
2010	1122.8356	166.3110	243.362905
2011	859.3664	105.5207	154.408494
2012	548.4158	61.7702	90.388354
2013	836.2059	93.7555	137.192481
2014	927.6891	146.5934	214.510057
2015	743.3538	103.6308	151.642983

Table 10: Runoff for watershed B2

Year	Precipitation (mm)	Runoff (mm)	Runoff volume (×10⁶ m³)
1991	866.0056	144.9797	159.180515
1992	917.5032	161.7460	177.589048
1993	612.2102	84.1117	92.350450
1994	791.9234	137.9095	151.417742
1995	522.8862	71.3086	78.293244
1996	563.9623	71.0987	78.062772
1997	962.2941	167.7906	184.225643
1998	662.6345	116.5299	127.943962
1999	909.4994	177.7742	195.187214
2000	501.9354	79.8128	87.630444
2001	687.4660	90.9753	99.886329
2002	603.9395	81.2430	89.200779
2003	432.1601	14.0912	15.471417
2004	798.9935	84.7668	93.069746
2005	999.4346	154.8822	170.052859
2006	728.1843	53.1904	58.400414
2007	800.5145	92.9043	102.004319
2008	1011.2350	152.6332	167.583607
2009	746.9902	68.3684	75.065091
2010	1048.1491	133.1956	146.242105
2011	711.8691	47.6230	52.287650
2012	448.8039	47.6843	52.354968
2013	1031.6900	179.9621	197.589435
2014	955.8102	127.8927	140.419761
2015	786.8077	112.8354	123.887648

Table 11: Runoff for watershed B3

Year	Precipitation (mm)	Runoff (mm)	Runoff volume (×10⁶ m³)
1991	1433.4174	516.6466	909.292794
1992	1259.2009	403.2245	709.671024
1993	894.3712	205.4942	361.667682
1994	1150.7905	390.9697	688.102680
1995	791.5547	176.4301	310.515254
1996	835.9902	218.3669	384.323578
1997	1117.4799	339.0832	596.782971
1998	960.2136	189.2769	333.125380
1999	991.6294	262.9674	462.820050
2000	1052.9776	324.4289	570.991633
2001	878.2994	124.0365	218.303049
2002	792.2978	112.1445	197.373252
2003	622.3318	69.5983	122.492385
2004	1083.3301	171.2514	301.400805
2005	1410.4914	289.2459	509.069844
2006	1180.2386	179.6660	316.210370
2007	1334.5533	307.0147	540.342761
2008	1272.8014	261.3772	460.021247
2009	1324.8584	256.8468	452.047842
2010	1485.5820	289.6312	509.747982
2011	1214.4203	157.7785	277.688496
2012	769.3122	84.8106	149.265835
2013	1243.4165	217.5712	382.923076
2014	1238.2078	198.2882	348.985226
2015	853.3896	126.6312	222.869634

Table 12: Runoff for watershed B4

Year	Precipitation (mm)	Runoff (mm)	Runoff volume (×10⁶ m³)
1991	2802.4290	659.2157	811.290129
1992	3838.7832	1197.4066	1473.636370
1993	2568.9060	520.0108	639.972152
1994	3399.3569	871.1248	1072.084580
1995	2305.5662	534.4764	657.774726
1996	2353.6678	528.8168	650.809555
1997	2874.1429	734.4160	903.838470
1998	2888.7052	663.2465	816.250814
1999	2886.7160	700.3633	861.930078
2000	2505.0213	611.2734	752.288060
2001	2330.0111	486.0960	598.233451
2002	1937.1071	368.7947	453.871957
2003	1714.8078	276.5903	340.396951
2004	2670.3528	698.0119	859.036315
2005	3119.0208	882.2360	1085.758995
2006	3115.1992	843.6801	1038.308637
2007	3687.3560	1338.6928	1647.515815
2008	2704.3718	686.8805	845.336946
2009	3160.0772	911.3583	1121.599500
2010	2369.6522	377.6406	464.758571
2011	2681.0367	516.9668	636.225930
2012	2218.8633	504.5169	620.903947
2013	3090.0011	871.2388	1072.224934
2014	2827.3600	785.0015	966.093538
2015	2148.4567	499.8711	615.186355

Table 13: Runoff of upper Cauvery

Year	Precipitation (mm)	Runoff (mm)	Precipitation (MCM)	Runoff (MCM)
1991	1650.2694	412.8631	17,946.1022	4489.741612
1992	1665.3184	400.4914	18,109.7544	4355.204256
1993	1537.7947	362.0263	16,722.9791	3936.909807
1994	1615.1313	415.2864	17,563.9879	4516.093869
1995	1224.0478	271.8292	13,311.0914	2956.047213
1996	1321.8349	290.3319	14,374.4919	3157.257746
1997	1568.9576	388.7488	17,061.8652	4227.506800
1998	1394.2881	297.8328	15,162.3946	3238.827992
1999	1488.3028	343.7673	16,184.7724	3738.349066
2000	1406.1073	348.6342	15,290.9250	3791.274454
2001	1307.7169	263.6462	14,220.9641	2867.060553
2002	1130.1719	219.2627	12,290.2241	2384.405129
2003	1042.6461	170.1188	11,338.4118	1849.982017
2004	1483.9886	316.2028	16,137.8569	3438.594271
2005	1865.9618	483.3693	20,291.6815	5256.471509
2006	1610.7152	391.6523	17,515.9637	4259.082169
2007	1912.7282	599.8433	20,800.2496	6523.086192
2008	1525.9443	327.4835	16,594.1097	3561.267942
2009	1660.8757	422.0061	18,061.4422	4589.168500
2010	1553.9178	272.1792	16,898.3127	2959.853678
2011	1534.5670	287.7452	16,687.8789	3129.128052
2012	1091.5727	214.2156	11,870.4711	2329.519185
2013	1683.3663	408.6389	18,306.0191	4443.804701
2014	1607.4791	399.0784	17,480.7721	4339.837870
2015	1290.3798	267.6281	14,032.4282	2910.362087

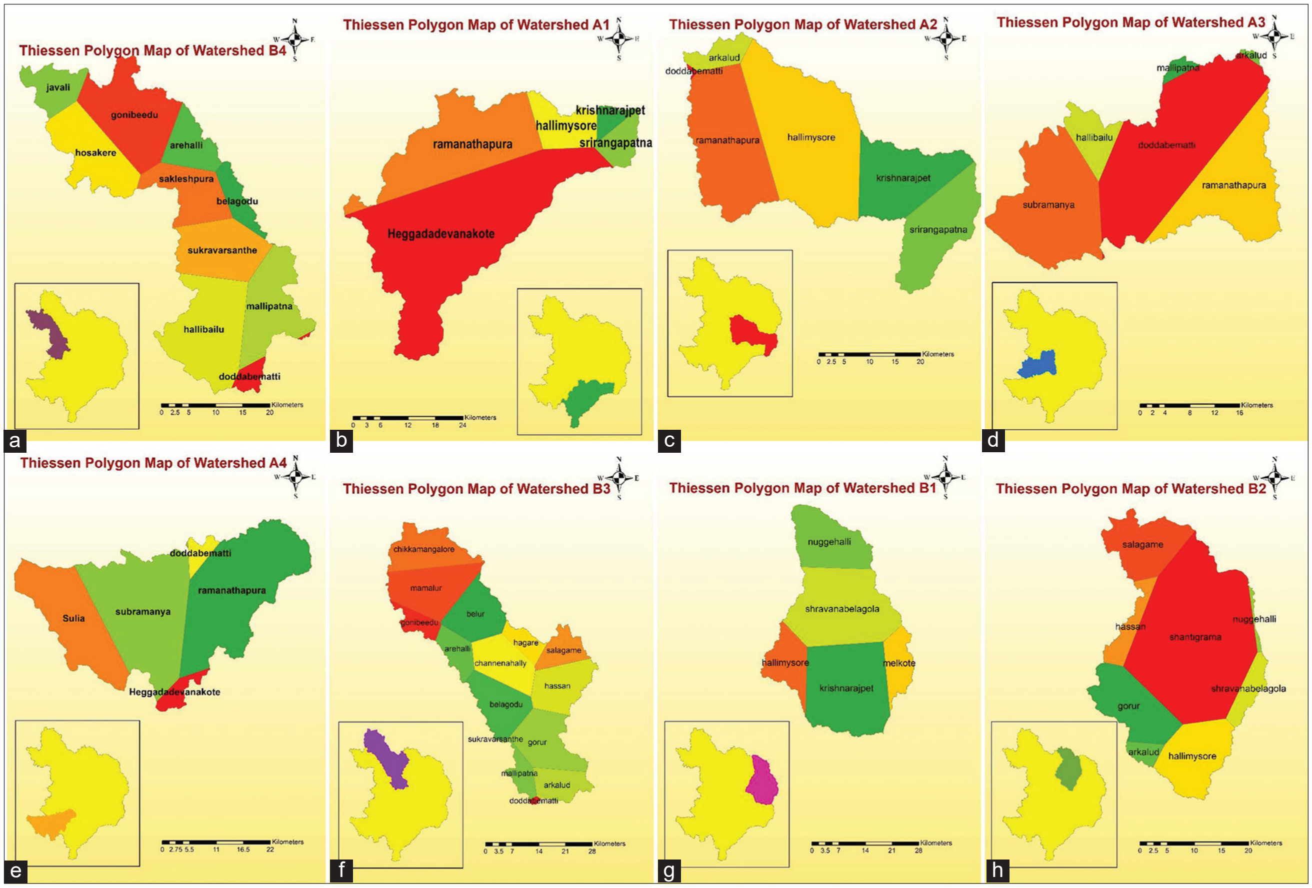

Figure 5: (a-h) Thiessen polygon map

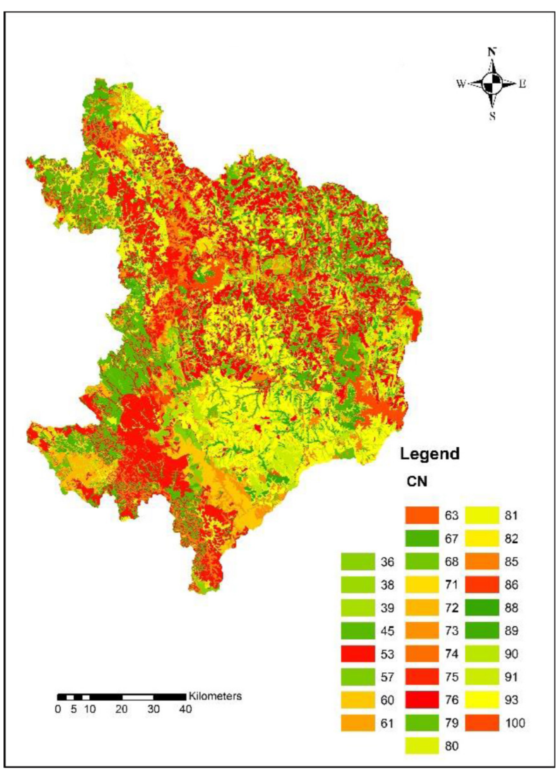

Figure 6: Curve number map

$$CN_1 = \frac{CN_2}{2.281 - 0.01281 CN_2} \quad (4)$$

$$CN_3 = \frac{CN_2}{0.427 + 0.00573 CN_2} \quad (5)$$

A weighted runoff was estimated for the watershed as

$$WeightedQ = \frac{(A_1 * q_1 + A_2 * q_2 + ... + A_n * q_n)}{(A_1 + A_2 + ... + A_n)}$$

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 area.

RESULTS AND DISCUSSION

Thiessen polygon maps were generated for all the watersheds, as shown in Figure 5. Watershed B1 was influenced by less station and watershed B3 was influenced by more raingauge stations.[15-19] CN map for whole area was generated, as shown in Figure 6. It was observed that in case of watershed A1, the average runoff coefficient was about 0.19 with correlation

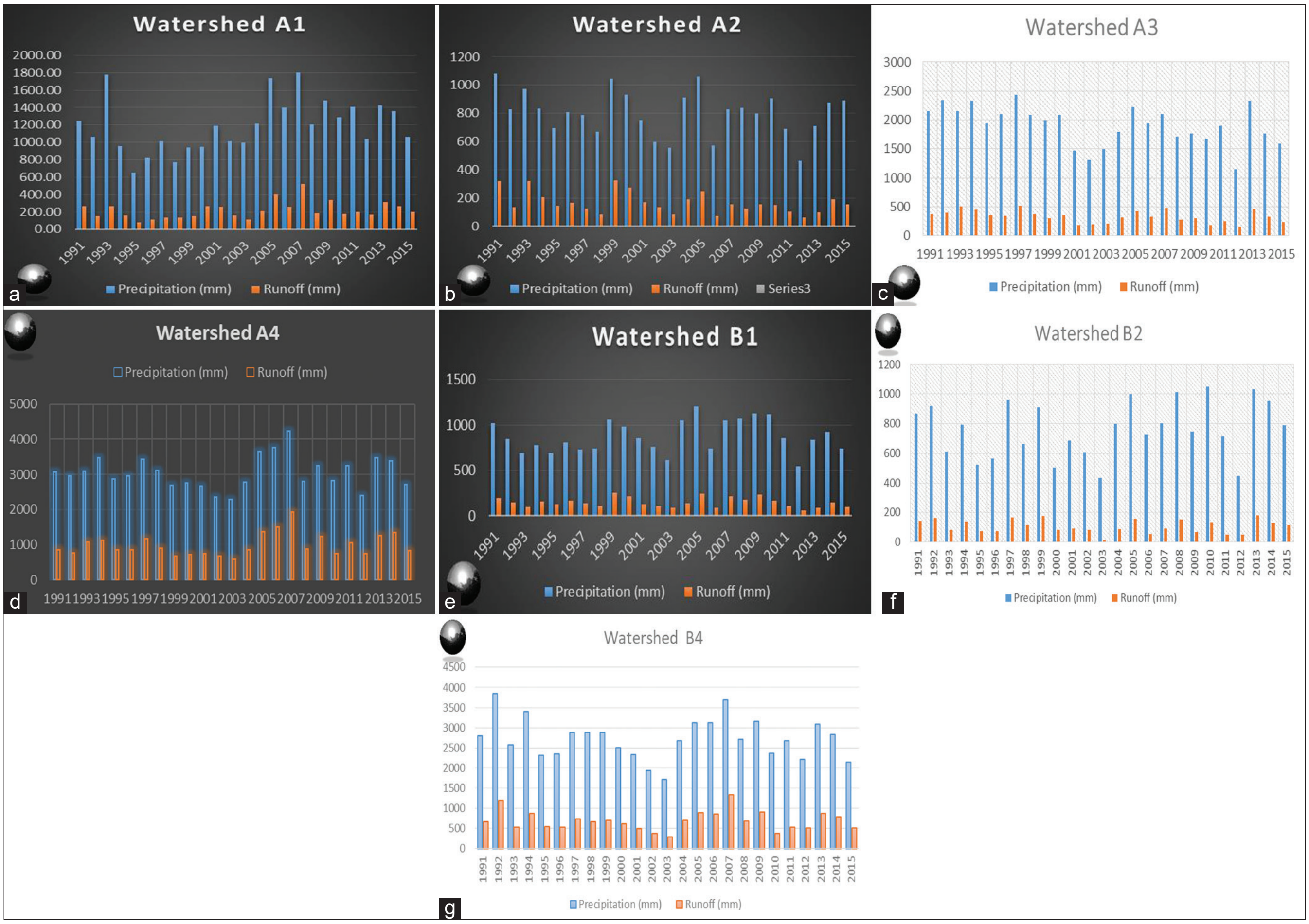

Figure 7: (a-g) Rainfall-runoff yearly depth

coefficient of 70%, with an average rainfall of 1192.52 mm in 25 years. In watershed A2, the average runoff coefficient was about 0.18 with correlation coefficient of 74.5%, with an average rainfall of 805.38 mm. In watershed A3, the average runoff coefficient was about 0.16 with correlation coefficient of 80.8%, with average rainfall of 1913.76 mm in 25 years, and maximum rainfall of 2441.48 mm in 1997. In watershed A4, the average runoff coefficient was about 0.33 with correlation coefficient of 89.56%, with an average rainfall of 3046 mm. In watershed B1, the average rainfall was about 875.16 mm with correlation coefficient of 82% and maximum rainfall of 1205 mm in the year 2005. In watershed B2, the average rainfall was about 764 mm with maximum of 1048 mm in 2010 with correlation coefficient of 70%; in watershed B3, the average rainfall was about 1087.64 mm with maximum of 1485 in 2010 and minimum rainfall of about 622 mm in 2003; and in watershed B4, the average runoff coefficient was about 0.24 with correlation coefficient of 90% and average rainfall of about 2727 mm. The weighted of all these values gives the amount for the total area as rainfall varies from 1042.65 to 1912 mm from 1991 to 2015 with an average value of 1486.80 mm; the runoff of these areas varies from 170.12 to 599.84 mm with the average value of 342.99 mm. The correlation coefficient of the total area is as high as 86%. Figure 7 gives rainfall and runoff of depth of each watershed. Figure 8 give the correlation between rainfall and runoff for all the watersheds. Runoff volume of Watershed A1 is shown in Table 5. Runoff volume of Watershed A2 is shown in Table 6. Runoff volume of Watershed A3 is shown in Table 7. Runoff volume of Watershed A4 is shown in Table 8. Runoff volume of Watershed B1 is shown in Table 9. Runoff volume of Watershed B2 is shown in Table 10. Runoff volume of Watershed B3 is shown in Table 11. Runoff volume of Watershed B4 is shown in Table 12.

CONCLUSION

The SCS curve number method uses, minimum data as input, and gives reliable output by using remote sensing and GIS techniques in most efficient way. The purpose of this study was to evaluate the performance of the procedure using land cover database from remotely sensed data. From the Table 13 it is observed that during the year 2007 maximum runoff depth of 599.84 mm has occurred. It was also observed

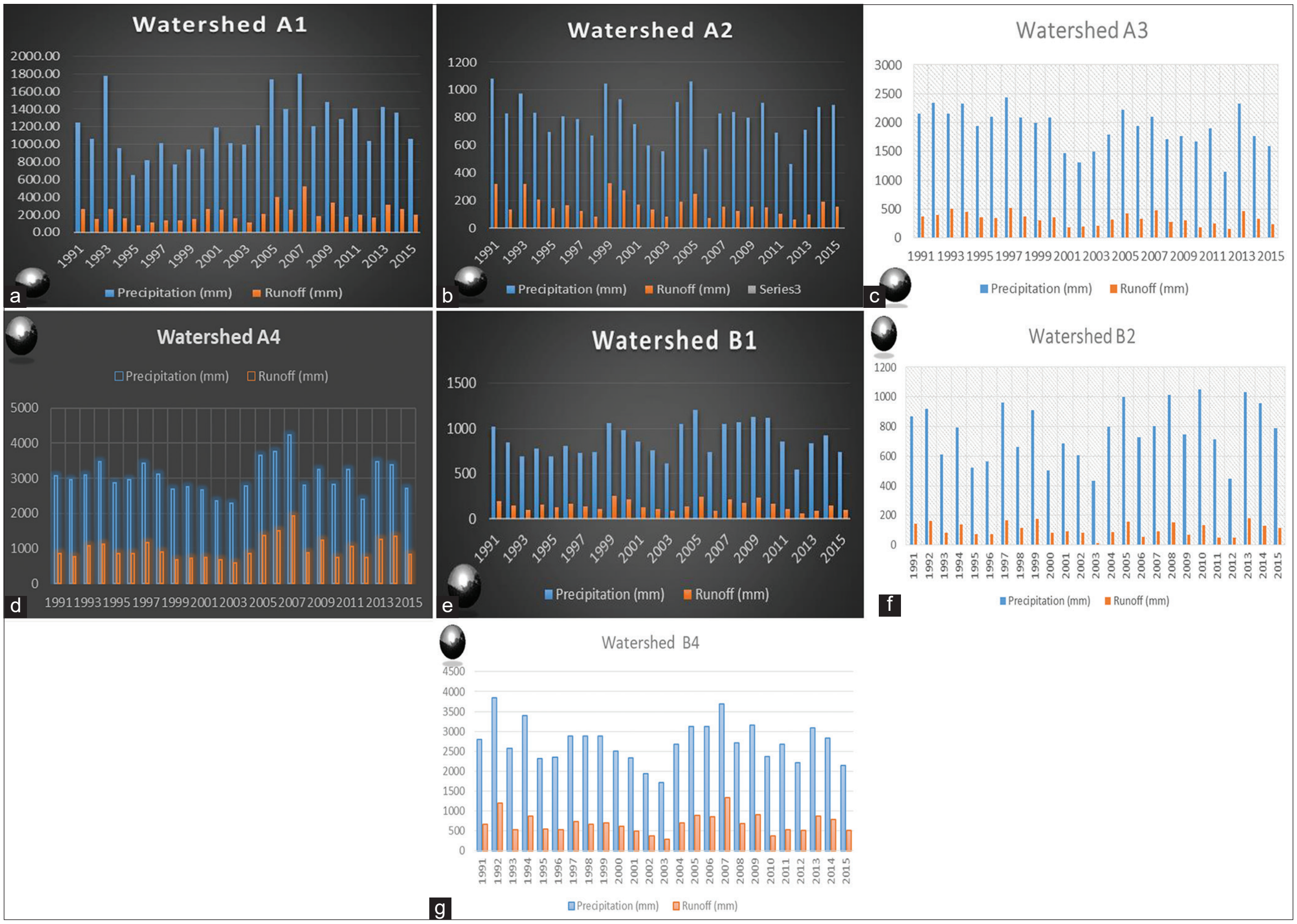

Figure 8: (a-g) Rainfall-runoff correlation

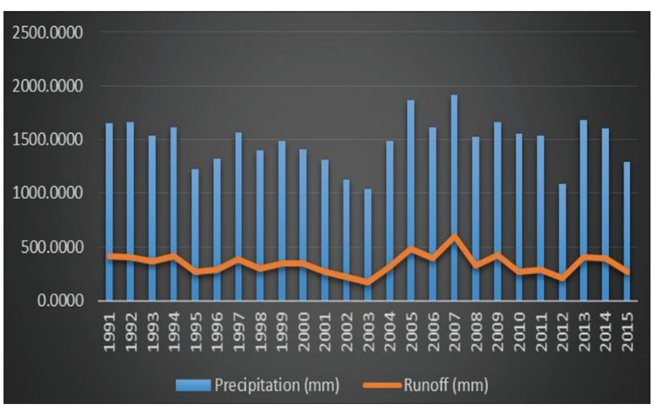

Figure 9: Rainfall-runoff of upper Cauvery

that the minimum runoff depth of 170.12mm has occurred in the year 2003. The values of correlation coefficients are very high as it ranges from 0.79 to 0.95 Watershed A4 has high value of it. The value of runoff coefficient varies from 0.16 to 0.31. 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. Figure 9 shows rainfall and runoff of upper cauvery from 1991 to 2015. 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.

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