Seasonal and Annual Surface Runoff from various land use / land cover of the southern sub-watersheds of India

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1. Introduction

The advent of recent geomatic technology namely Remote Sensing, Global Positioning System (GPS) and Geographic Information System (GIS) has opened new vistas in the study of various processes of hydrological cycle, which in turn helps for the forecasting, evaluation, assessment and management of highly dynamic water resources. Hydrological cyclical processes and controls are necessary at basin level for solving water resource problems like water supply, flood control etc. The various hydrological measurements or hydrological data collected at a point may be valid in one basin but may not be in the neighboring basin. Thus, the concept of the hydrological unit or basin measurements becomes more significant from the point of water resources development, and thus the study of hydrological measurements of basins becomes essential. Surface water feature, a component of geo-hydrological cycle is ultimately derived from a major climatic element called rainfall. A sizeable portion of rainwater is temporarily detained in the surface depressions, most of which is lost through evaporation. When the available interception or the depression storage is completely exhausted and when the rainfall intensity on the soil surface reaches the maximum infiltration capacity, the overland flow begins. Once the overland flow reaches a stream channel, it is called surface runoff. The quantity of the water flowing in a hydrological unit cannot be directly measured by remote sensing techniques. However, it can provide quantitative data about the surfacial features of the basin, which is valuable for the model input. Thus, the present study aims at to quantify the runoff water flowing through an un-gauged basin within a normal rainfall year using SCS method. Various scholars like Kumar(1989), Sturbe(1990), Kumar et al.(1997), Dilip(2000), Chatterjee et al.(2001) and Tripathi et al.(2002), Satheeshkumar, S. et.al (2017) Suresh Kumar (2019) have used this method for the estimation of surface runoff. The model is simple and it uses land use / land cover that can be directly derived from Remote Sensing data, infiltration property of the soil and daily precipitation data. The study has been done for the two adjacent river basins namely Kanyakumari and Nambiyar located at the southern most tip of the Indian sub continent.

2. The Study area

The two adjacent river basins namely Kanyakumari and Nambiyar that lies between the latitudes 8º 04' N to 8º 34' N and longitudes 77º 05' E to 77º 57' E with an area of about 2,918 sqkm in the southern most part of Tamil Nadu in Peninsular India have been chosen for the present study (see Figure 1). These river basins fall under the district level administrative units viz., Kanyakumari district and a part of Tirunelveli district that comprises Nanguneri and Radhapuram taluks. They are coastally located and are mainly drained by Kodayar and Nambiyar rivers. These two river basins are morphologically divided into 4 watersheds, 15 sub-watersheds, 163 mini-watersheds and 539 micro-watersheds. While all the sub-watersheds of Kanyakumari basin drain into the Arabian sea, the sub-watersheds of Nambiyar basin drain into the Gulf of Mannar, whereby the entire study area has coastal lines in both the sea (see Figure 2). There is no single unified river basin due to their coastal location and the proximity of their catchment area to the sea. Hence, the present study is confined to sub-watershed level.

The average annual rainfall of the Kanyakumari basin in the west is 1492 mm whereas in the eastern part namely the Nambiyar basin it is about 750 mm.

3. Methodology

Surface runoff is the response of a catchment to precipitation reflecting the integrated effects of a wide range of parameters like catchment area, climate, precipitation, rainfall intensity, size and shape of the catchment, orientation of the catchment, direction of the storm, slope, soil and land use. Unfortunately, runoff records are available only in very few areas in sufficient quantity. Several models have been developed for estimation of direct surface runoff from storm rainfall. Out of those, United States Department of Agriculture (USDA) Soil Conservation Service (SCS) now known as Natural Resource Conservation Service, rainfall - runoff curve number model (USDA-SCS, 1969; 1972; 1986) is a typical widely accepted method to estimate the runoff from an un-gauged watershed on daily basis. The SCS model computes direct runoff through an empirical relation that requires rainfall and watershed coefficient namely the runoff curve number (CN) as input. Curve number is a dimensionless coefficient, which reflects hydrologic soil group, antecedent moisture condition, land use and land treatment classes.

As satellite data can be used for estimating the land use/ land cover distribution, remote sensing provides useful input support for SCS model. SCS model enables the hydrologist to simulate various alternatives with respect to land use/ land cover and treatment practices and compare the result. Since this is a spatial model susceptible to dynamic changes, an efficient spatial database alone can manage and so the application of geographical information system that includes remote sensing database becomes essential. The parameter defined by land use allows the user to experiment with alternative form of land development and management and to assess the impact of the proposed changes. Hence, most of the planning agencies in watershed management use this method to estimate water yield from a given storm.

Basic data requirement for this model

1. Type of land use/ land cover and land treatment practice if necessary,
2. The hydrologic soil group which is based on the intake of water on bare soil when thoroughly wetted,
3. Daily rainfall data and
4. The antecedent moisture condition (AMC) which is the index of soil conditions with respect to runoff potential before the storm,

The input GIS layers for this model are

1. Watershed boundary map,
2. Land use / land cover map,
3. Contour map,
4. Hydrologic soil group map and
5. Rainfall map.

3.1. Estimation of surface runoff

Based on the existing land use/ land cover, the antecedent moisture condition and hydrologic soil group

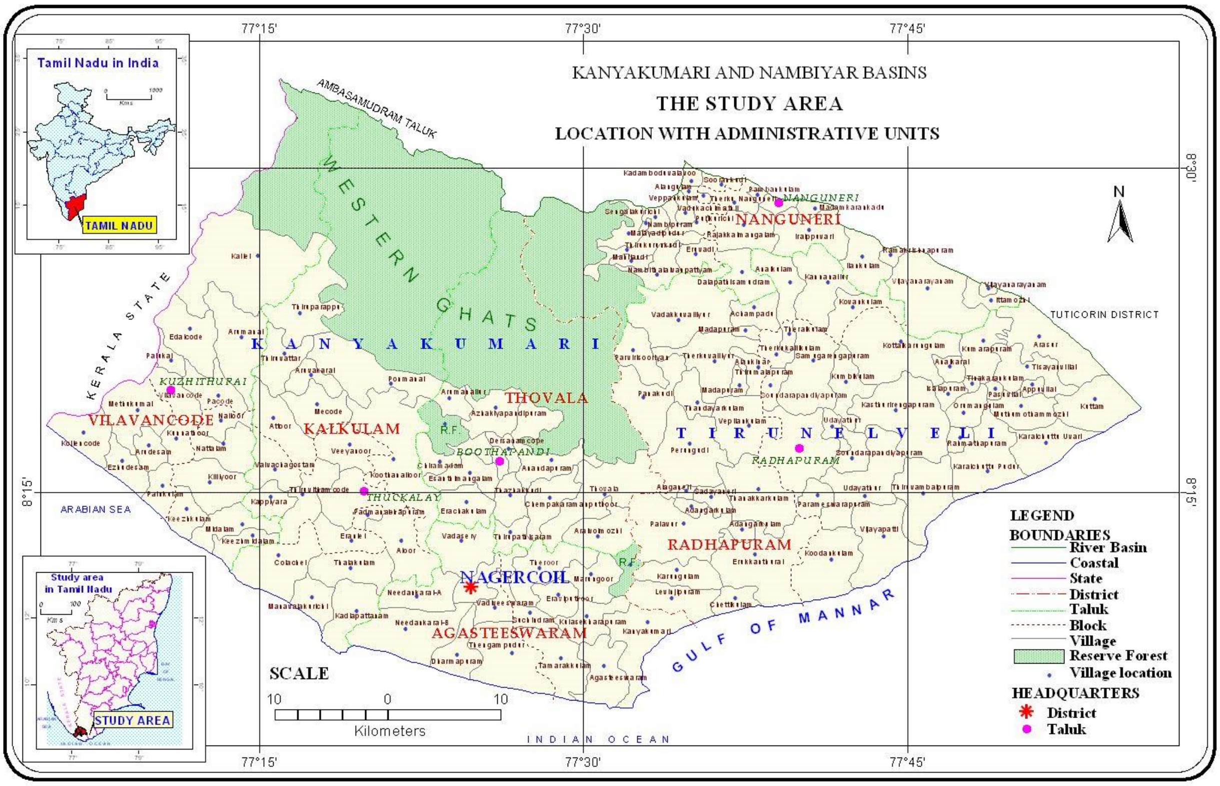

FIGURE 1

Figure 1: Map showing the location of the study area

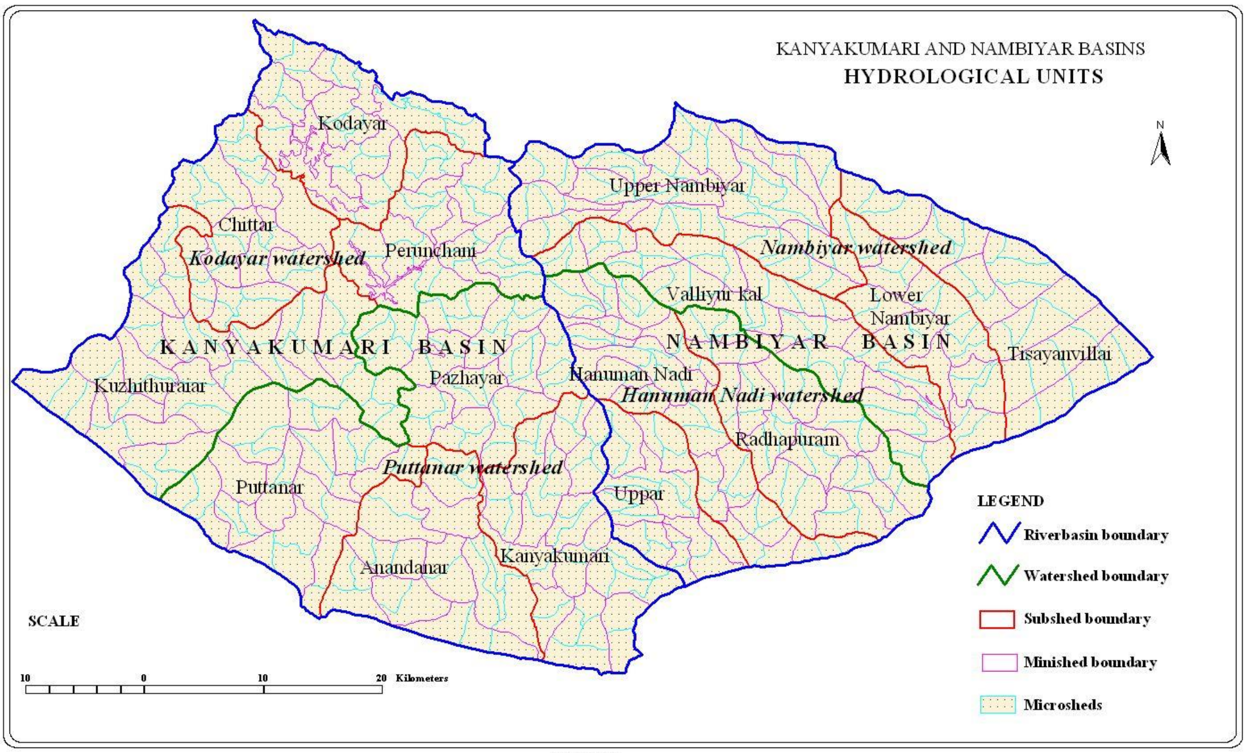

FIGURE 2

Figure 2: Map showing the hydrological units in the study area

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of a given area, the surface runoff can be estimated. Let *Ia* be the initial quantity of interception depression storage that must be satisfied by any rainfall before runoff can occur. The ratio of the direct surface runoff *Q* the daily rainfall *P*, the initial depression storage *Ia* and the storage capacity *S* are related by the equation,

$$\frac{Q}{P-Ia}=\frac{P-Q-Ia}{S}$$

where, *Q* – daily runoff

P – daily rainfall

S – Surface retention which is calculated using runoff curve number and *Ia* – Initial abstraction

Q has the same unit as that of *P*.

Surface retention or storage capacity is derived from curve numbers that are obtained from a two-dimensional table or cross table of land use and hydrologic soil group. Curve numbers for each land use - hydrologic soil group complexes, has been arrived from standard tables published in standard hydrology books (USDA-SCS National Engineering Hand books, Section IV – NEH 4, 1972). These published *CN* values are for the average conditions of antecedent moisture (AMC II). The curve numbers for extreme AMC (I & III) can be calculated from *CN II* by using the following formulae:

$$CN\ I=\frac{4.2\times CN\ II}{10-0.058\times CN\ II}$$ and

$$CN\ III=\frac{23\times CN\ II}{10+0.13\times CN\ II}$$

Thus, the curve number can be modified by antecedent moisture condition for very wet or dry conditions. This conversion has been used by scholars like Suresh(1997), Tiwari et al.(1991) and Debnath et al.(2001) for the estimation of surface runoff.

The weighted curve number for each sub-watershed has been derived by using the formula

$$CN_w=\left(\sum\left(CN_i\times A_i\right)\right)/A$$

where, CN_w – Weighted curve number

CN_i – Curve number from 1 to any N

A_i - Area of the polygon with curve number CN_i and

A – Total area of the sub-watershed.

This methodology was used by Pandey, V.K. et.al. and Ashish Pandey, et.al, for the estimation of runoff from un-gauged watersheds.

S value is derived from curve number using the following formula

$$S=\frac{25400}{CN_w}-254$$ when *P* is in mm

Where, CN_w – weighted function of, watershed land use/ land cover units, hydrologic soil group and antecedent moisture condition.

According to the morphological studies, basin slope is an important parameter which alters the surface runoff from the basin. So slope factor *(1-(*θ_A */100))* where θ_A – the average percentage of slope of watershed, is used to modify the *S* factor and consequently the computed *Q* values, assuming that the impact of basin slope may not cause a reduction of more than 25% in the storage capacity of the soils. The impact of basin slope on runoff has been analysed for the sub-watersheds by introducing the slope factor as well as without the slope factor (Das et al.1992).

The initial abstraction *Ia* is assumed to be a fraction of *S.* The Central Soil and Water Conservation Research and Training Institute (ICAR) Dehradun, India has suggested some of the following empirical relations for Indian conditions (Vandersypen et al.1972).

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$Ia = 0.1\ S$ for Black soil region of AMC II & III,

$Ia = 0.3\ S$ for Black soil region of AMC I and

$Ia = 0.3\ S$ for all other regions.

The value of $Ia = 0.3\ S$ is considered for the present study area. Applying all the above factors the daily runoff Q in mm is given by the equation

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

which is appropriately used for the present study.

Runoff volume for the watershed is calculated using the formula (SCS, 1985) and (IWS 2001, 2003))

$$Q_v = 10 \times Q \times A$$

where, Q_v - runoff volume in m^3

Q – runoff depth in mm

A – catchment area in ha.

The resultant value is converted to million cubic meters.

4. Results and Discussion

In the following sections, using suitable methodology as described earlier, the surface water resources for all the 15 sub-watersheds of the two river basins for a normal rainfall year have been estimated, and a scenario of the sub-watersheds with respect to their hydrological behavior to surface runoff, has been arrived at.

4.1. Sub-watershed parameters responsible for surface runoff

According to SCS model, the surface runoff depends on the land use, its treatment practice, hydrologic soil group, rainfall and water storage capacity of the soil. The spatial distribution of these parameters in the selected 15 sub-watersheds is discussed in the forth-coming paragraphs.

4.2. Land use/ land cover of the sub-watersheds

The land use is the important factor, which determines the surface runoff of the sub-watershed. For the surface runoff estimation, the level I classes developed by Anderson et al.(1976) has been followed. Out of the nine level I classes developed, only five classes have been selected appropriately for the study. Based on the land use/ land cover classification scheme the level I land use/ land cover of the study area in the year 2001 has been broadly classified into five classes namely built-up, agriculture, forest, water body and barren land (see Figure 3). The areal extent of the land use/land cover of the sub-watersheds is given in Table 1. The land use/ land cover classes that have been interpreted are verified in the field and the map is finalized and used for the estimation of surface runoff. The field verification is systematically done by selecting six justified sample sub-watersheds and generating random area samples. These random area samples of the sample sub-watersheds has been verified in the field using GPS and the pre-field interpretation accuracy was found to be 89.34%, which lies within the accuracy limit (Verbyla, 1995). The land use feature maps prepared are again finalized based on the observed land use features. On considering the land use classes, built-up is more in Anandanar sub-watershed (30.61km^2) of Kanyakumari basin and in Upper Nambiyar (19.84 km^2) of Nambiyar basin; whereas the two sub-watersheds of Kanyakumari basin namely Kodayar and Perunchani no built up can be delineated from the IRS 1C LISS III FCC imagery, because the built up is in the form of huts where only few tribal residents stay, as both are of hilly undulating terrain sub-watersheds.

Agriculture is mostly predominant in Kanyakumari basin where Kuzhithuraiar stands first having an agricultural area of 286.83 km^2 out of 312 km^2 area of the sub-watershed. In the sub-watersheds of Kodayar, Perunchani and Chittar only forest plantations

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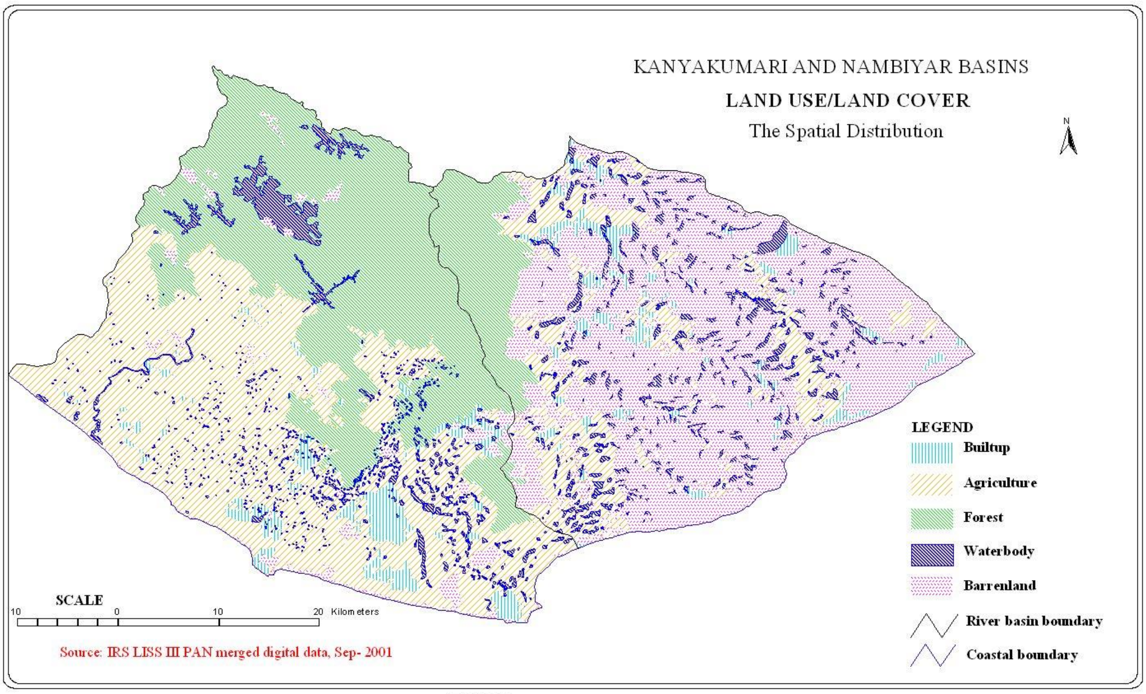

FIGURE 3

Figure 3: Map showing the spatial distribution of Level I land use / land cover types

Table 1: Areal extent of major Land use/ Land cover level I classes in the sub-watersheds of Kanyakumari and Nambiyar basins

Sl. No	Sub-watersheds	Built-up	Agriculture	Forest	Water body	Barren land
1	Kodayar	-	-	134.23	30.2	5.46
2	Perunchani	-	-	160.34	2.97	-
3	Chittar	3.10	-	150.11	4.63	4.95
4	Kuzhithuraiar	7.89	286.83	7.16	5.10	5.56
5	Pazhayar	0.79	40.88	144.18	3.25	-
6	Puttanar	16.44	173.30	18.97	4.81	5.23
7	Anandanar	30.61	129.04	15.59	7.76	11.46
8	Kanyakumari	17.04	125.69	39.84	13.64	17.47
9	Uppar	2.57	56.22	5.52	7.14	36.42
10	Hanuman Nadi	2.32	26.15	44.70	10.71	108.49
11	Radhapuram	8.81	10.08	-	13.23	158.39
12	Valliyur kal	12.45	26.54	24.72	14.62	135.37
13	Tisayanvillai	9.05	7.22		13.11	171.46
14	Upper Nambiyar	19.84	49.49	56.42	19.59	111.99
15	Lower Nambiyar	4.51	44.18	-	13.48	70.09

are seen where teak, rubber, cardamom, and pepper which comes under forest plantation class are grown and there is no specified agricultural land due to its elevation. The less areal extent of agriculture is found at Tisaiyanvillai sub-watershed (7.22 km^2) due to its coastal sand deposits.

Forest land cover is almost found in all the sub-watersheds of Kanyakumari basin, and is dominant in Perunchani (160.34 km^2) and Kodayar sub-watershed (134.23 km^2). The sub-watersheds of Nambiyar basin show less forest cover as the sub-watersheds namely Radhapuram, Tisaiyanvilai and Lower Nambiyar have no forest cover.

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Water bodies are present in all the 15 sub-watersheds. The water bodies of Kanyakumari basin are small in areal extent due to the undulating terrain of the basin; but completely filled with water and almost all of them are perennial. Man made and natural reservoirs also exist in the hilly terrain sub-watersheds of this river basin. Whereas in Nambiyar basin, the water bodies have larger areal extent; but all of them dry throughout the year.

The barren land dominates the Nambiyar basin. Almost all the sub-watersheds of this basin have extensive wasteland which comes under this category. The largest waste land area is found to be 171.46 km^2 for Tisaiyanvillai sub-watershed. This proves the drought condition prevailing in this river basin.

4.3. Hydrologic soil group of the sub-watersheds

The soil infiltration capacity described as the hydrologic soil group falls into four categories namely A, B, C, and D as described earlier, in which A group of soils have higher infiltration rate and D group of soils have very low rate. Out of these four groups of soil, only the first three types of soils are seen in the study area. It is to be noted that portions of Kodayar and Perunchani sub-watershed have not been surveyed because of its dense forest cover, rugged terrain with steep slopes besides the soil profile is also less and there is no need of soil data for that area.

The Figure 4 shows the distribution of hydrologic soil groups in the various sub-watersheds. Accordingly 'B' type of soils is predominantly present in the study area. But in the Puttanar, Anandanar and Kanyakumari sub-watersheds of Kanyakumari basin and Upper Nambiyar sub-watershed of Nambiyar basin, the 'C' type of soil is seen. The 'A' type of soil is seen in Tisaiyanvillai sub-watershed and in the northern portions of Puttanar sub-watershed and along the coastal region of the study area as a narrow stretch. 'A' type of soil is also seen as pockets of area in the foot hill zone of Pazhayar sub-watershed. The areal extent of the distribution of the HSG soils for each sub-watershed is given in Table 2.

Table 2 Areal extent of major hydrologic soil groups in the sub-watersheds of Kanyakumari and Nambiyar basins

Sl. No	Sub-watersheds	A	B	C	Forest
1	Kodayar	-	48.95	-	120.93
2	Perunchani	4.49	-	-	158.84
3	Chittar	3.34	144.01	4.13	11.31
4	Kuzhithuraiar	1.08	255.98	48.5	6.91
5	Pazhayar	19.59	155.89	13.62	-
6	Puttanar	47.23	46.07	124.96	-
7	Anandanar	5.39	56.08	132.98	-
8	Kanyakumari	16.68	88.01	109.01	-
9	Uppar	-	36.95	70.91	-
10	Hanuman Nadi	15.31	105.76	71.29	-
11	Radhapuram	7.59	169.08	13.84	-
12	Valliyur kal	2.15	165.78	45.77	-
13	Tisayanvillai	133.34	45.5	21.99	-
14	Upper Nambiyar	2.08	130.19	68.01	57.08
15	Lower Nambiyar	29.29	97.1	5.89	-

4.4. Daily rainfall data

The daily rainfall data in millimeters of all the rain gauge stations has been collected for the year 2001. The average daily rainfall of the sub-watersheds has been estimated and has been subjected to further runoff calculations. In order to estimate the antecedent moisture conditions, the total rainfall of the previous five days has been considered. The daily rainfall of the sub-watersheds shows very high variations. They range from rainless days to a rainy day with a maximum of 120.4mm in Chittar sub-watershed on Nov 10, 2001. The maximum rainfall per day is also the highest in Kanyakumari basin compared to that of the Nambiyar basin. Number of rainy days is more in the monsoon months for both the river basins. The western river basin receives rain in almost all the seasons whereas the eastern river basin of the study area receives rain predominantly in the northeast monsoon season.

4.5. Hydrologic soil group – Land use complex of the sub-watersheds

The hydrologic soil group map and the appropriate land use/land cover maps have been added to the view of ArcView GIS 3.2a software. These two

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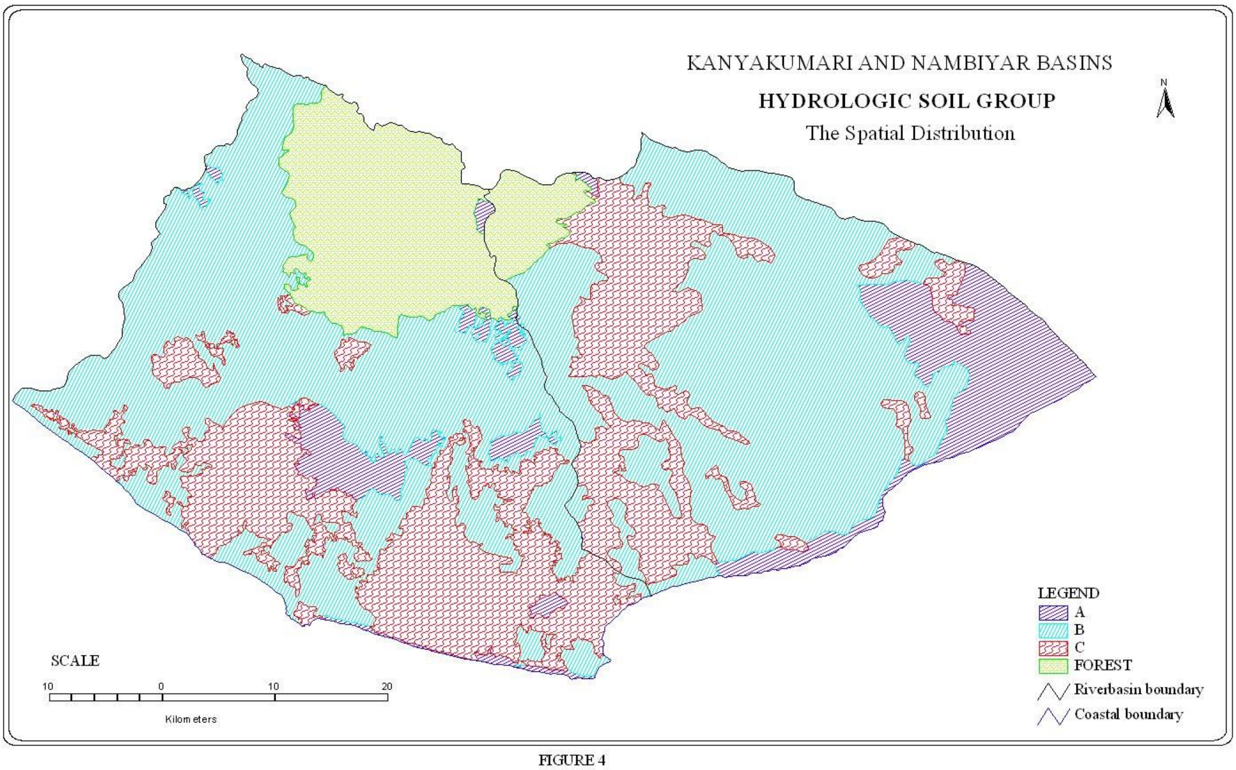

Figure 4: Map showing the spatial distribution of hydrologic soil groups

themes have been overlaid by using intersect option of geo-processing wizard module. The polygons having three categories of hydrologic soil group and five categories of land use have been spatially overlaid to form a HSG – LU complex of 19 categories. The areal extent these categories are given in Table 3. Now the appropriate curve numbers for these HSG – LU combination have been attributed from the standard table to form curve number map. Then the initial abstraction is calculated and the daily surface runoff is estimated.

4.6. Surface runoff of the sub-watersheds

The surface runoff of the sub-watersheds have been estimated using SCS rainfall- runoff curve number model. In the present study, daily runoff has been estimated and total runoff has been studied on monthly, seasonal and annual basis. The daily runoff estimated for the year 2001 has been added to get the total monthly runoff and are given in Table 4a. From the table it is evident that almost all the months have appreciable quantity of runoff.

The Kodayar and Perunchani sub-watersheds of Kanyakumari basin have received heavy rainfall in the year 2001, out of which the major percentage of runoff is from northeast monsoon, even though the rainfall is more in southwest monsoon (see Table 4b). This is due to the fact that during northeast monsoon the rainfall is heavy. These sub-watersheds are also covered by forest, which reduces runoff and whatever runoff, is stored in the reservoirs. The winter season rain produces no runoff (Figure 5a and b). The decreased runoff in forest has also been observed by Chartterjee et al.(2001) and Sharma et al.(2001). Similarly, the Chittar and Pazhayar which are smaller sub-watersheds also have more forest cover and is dominated by B type of hydrologic soil group that produces less runoff. The Kuzhithuraiar sub-watershed shows maximum runoff due to the fact that the major land use is agricultural; and due to its larger areal extent, more of the rainfall (39%) is intercepted and flows as runoff. The major quantity of the runoff is contributed by southwest monsoon (313 mm) and a significant quantity, by the North East monsoon (221 mm). When the land use is of agricultural, the soil is saturated with water and so almost all the intercepted rainfall, flows as runoff. This is

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Table 3:Areal extent of LU/LC-HSG complex and weighted CN in the sub-watersheds of Kanyakumari and Nambiyar basins

Sub-watershed/ HSG-LU complex	100 A	100B	100C	200A	200B	200C	200 Forest	300A	300B	300C	300 Forest	400A	400B	400C	400 Forest	500A	500B	500C	500 Forest	Weighted CN
Kodayar	-	-	-	-	-	-	-	-	45.32	-	88.91	-	3.63	-	26.57	-	-	-	5.46	62
Perunchani	-	-	-	-	-	-	-	4.49	-	-	155.87	-	-	-	2.97	-	-	-	-	58
Chittar	-	-	-	-	-	-	-	1.97	135.80	4.13	11.31	-	4.63	0.00	-	1.37	3.58	-	-	43
Kuzhithuraiar	-	4.89	2.96	0.58	240.49	41.67	3.90	0.51	3.74	-	2.90	-	3.12	1.92	0.07	-	3.62	1.95	-	91
Pazhayar	-	0.78	0.01	5.11	35.58	0.19	-	14.47	117.33	12.38	-	0.01	2.20	1.03	-	-	-	-	-	56
Puttanar	2.86	8.73	4.85	24.61	33.90	114.80	-	18.79	0.19	-	-	0.97	1.12	2.21	-	-	2.14	3.10	-	84
Anandanar	-	0.08	30.52	2.04	37.53	89.47	-	-	15.02	0.57	-	-	2.19	5.57	-	3.35	1.25	6.85	-	89
Kanyakumari	1.36	9.59	6.09	1.92	38.57	85.21	-	8.48	28.99	2.37	-	0.12	4.63	8.89	-	4.79	6.23	6.45	-	74
Uppar	-	0.82	1.75	-	20.49	35.73	-	-	4.93	0.59	-	-	1.23	5.91	-	-	9.48	26.94	-	80
Hanuman Nadi	-	1.45	0.87	-	10.07	16.09	-	0.27	40.94	3.49	-	0.05	3.96	6.69	-	14.99	49.34	44.16	-	80
Radhapuram	-	8.20	0.60	0.10	9.37	0.61	-	-	-	-	-	-	11.87	1.37	-	7.49	139.64	11.26	-	81
Valliyur kal	-	10.08	2.37	0.12	19.40	7.02	-	-	24.57	0.15	-	0.05	11.27	3.30	-	1.98	100.45	32.93	-	77
Tisayanvillai	4.69	1.02	3.34	7.14	-	0.08	-	-	-	-	-	4.95	6.73	1.43	-	116.56	37.76	17.14	-	75
Upper Nambiyar	-	7.09	12.75	1.29	18.22	29.32	-	0.02	-	0.89	57.08	-	14.22	5.37	-	0.74	90.65	19.68	-	73
Lower Nambiyar	3.06	1.45	-	4.82	34.45	4.90	-	-	-	-	-	1.97	11.24	0.27	-	19.44	49.96	0.70	-	78

100 – Built-up
200 – Agriculture
300 – Forest
400 – Water body
500 – Barren land

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Table 4a: Monthly runoff (mm) of the sub-watersheds in Kanyakumari and Nambiyar basins during the year 2001

Sl. No	Sub-watersheds	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Kodayar	0	0	0	17	1	0	3	0	56	29	34	0
2	Perunchani	0	0	0	37	3	0	13	0	90	7	52	0
3	Chittar	0	0	0	0	0	0	2	0	12	6	36	0
4	Kuzhithuraiar	0	6	6	294	52	34	103	6	320	183	180	0
5	Pazhayar	0	0	0	11	0	5	31	0	51	1	7	0
6	Puttanar	0	1	0	74	18	18	42	0	221	56	32	0
7	Anandanar	0	23	0	114	69	18	28	0	117	55	87	0
8	Kanyakumari	0	0	0	15	0	0	0	0	71	22	20	0
9	Uppar	0	0	0	14	0	0	4	0	12	42	7	0
10	Hanuman Nadi	0	5	0	29	0	0	0	0	0	44	33	0
11	Radhapuram	0	5	0	28	0	0	0	0	0	43	35	0
12	Valliyur kal	0	0	0	0	0	0	10	0	0	0	26	31
13	Tisaiyanvillai	0	11	0	53	0	0	0	1	0	1	38	0
14	Upper Nambiyar	0	0	0	8	0	0	0	0	0	0	25	9
15	Lower Nambiyar	0	13	0	62	0	0	0	3	0	2	46	0

evident from Kuzhithuraiar sub-watershed. The runoff water drains as Tambraparni River into the sea directly. The Puttanar, again an agricultural sub-watershed, has high runoff, where the runoff drains into the sea through the Valliyar river. The higher runoff is accelerated by the settlements also as in the case of Anandanar sub-watershed (509.5 mm) which is dominated by settlements, (since the district head quarters fall in this sub-watershed) gives runoff of about 38.5% of the total rainfall (1323.7 mm).

Table 4b: Seasonal and annual runoff (mm) of the sub-watersheds in Kanyakumari and Nambiyar basins during the year 2001

Sl. No	Sub-watersheds	Winter	Summer	SW Monsoon	NE Monsoon	Annual
1	Kodayar	0	18	59	63	140
2	Perunchani	0	40	103	59	202
3	Chittar	0	0	14	42	56
4	Kuzhithuraiar	1	136	313	221	671
5	Pazhayar	0	11	86	9	105
6	Puttanar	1	93	282	88	463
7	Anandanar	23	182	163	142	510
8	Kanyakumari	0	15	71	42	128
9	Uppar	0	14	16	49	79
10	Hanuman Nadi	5	29	0	76	112
11	Radhapuram	5	28	0	78	111
12	Valliyur kal	0	0	10	57	67
13	Tisaiyanvillai	11	53	1	40	105
14	Upper Nambiyar	0	8	0	34	42
15	Lower Nambiyar	13	62	3	48	126

Since this is a coastal sub-watershed, the excess water drains into the sea through the natural drainage, Pazhayar, which flows along the east of this basin. This sub-watershed produces significant winter runoff of 22.6 mm due to the fact that the impervious urban surfaces enhance runoff even though there is scanty rainfall. Thus all the sub-watersheds of Kanyakumari basin contributes for surface runoff in all the three seasons except winter, where there is no runoff in the few sub-watersheds of Kodayar, Perunchani, Chittar, Pazhayar and Kanyakumari.

In the Nambiyar basin, the winter rainfall produces very low runoff in the sub-watersheds namely, Hanuman Nadi (5mm), Radhapuram (5mm), Tisaiyanvilai (11mm) and Lower Nambiyar (13mm) whereas the rainfall in the other sub-watersheds is not sufficient to produce runoff. In summer also, Valliyur kal sub-watershed does not produce runoff due to the poor rainfall. In the southwest monsoon period (see Figure 5c), there is low runoff in the coastal sub-watersheds namely Uppar (16mm), Valliyur kal (10mm), Tisaiyanvilai (1mm) and Lower Nambiyar (3mm). In the northeast monsoon season, all the sub-watersheds of Nambiyar basin, in spite of their dominant barren lands, have runoff (Figure 5d).

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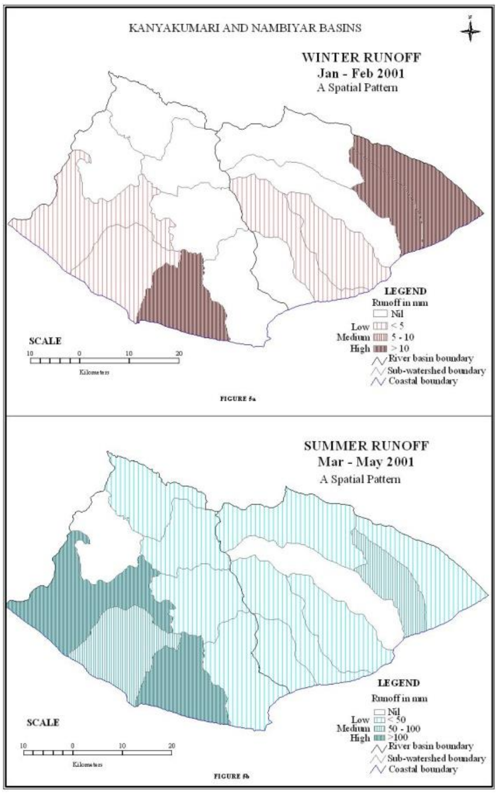

Figure 5a &b: Map showing Winter and Summer runoff of the sub-watersheds

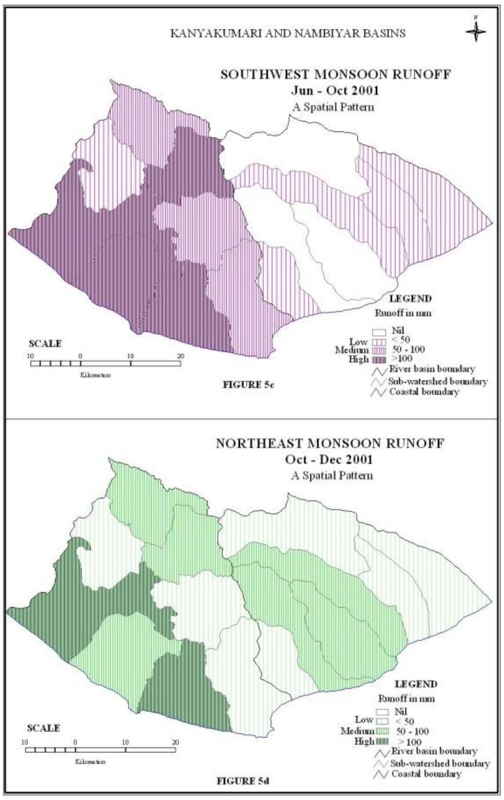

Figure 5c&d: Map showing SW and NE monsoon runoff of the sub-watersheds

It is evident from the surface runoff estimation, that the sub-watersheds respond variously for the intercepting rainfall. In Kanyakumari basin runoff is the highest in the month of September (826.5mm); whereas there is no runoff in the month of January in spite of the significant amount of rainfall (Figure 6). This is due to the fact that the rain received is scanty which increases infiltration rather than surface flow. There is no runoff during the months of August and December also. In Nambiyar basin, there is no runoff during the months of March, May and June; the maximum runoff is in the month of November (208.9mm). The lesser runoff is also due to the high temperature and the land use mostly being wasteland. So, even if there is little rainfall, it is utilized to retain the soil moisture storage loss due to evapotranspiration. On analyzing the seasonal rainfall-runoff characteristics, in winter season there is comparatively lesser runoff whereas runoff is more in the southwest monsoon season. Even though the rainfall is more in northeast monsoon season the runoff is less due to the scanty nature of rainfall, which contributes more to ground water rather than runoff. The percentage of runoff ranges from 3% for Chittar sub-watershed to 39.8% for Kuzhithuraiar sub-watershed. Generally, the sub-watersheds of Kanyakumari basin give more runoff due to their heavier rainfall and the predominant land use being agricultural. But few sub-watersheds have comparatively less runoff like Kodayar, Perunchani, Chittar and Pazhayar due to their forest cover. Built-up dominant sub-watersheds like Anandanar have high runoff whereas barren land dominant sub-watersheds like Radhapuram have less runoff.

5. Summary, suggestions and conclusion

In this paper, the estimation of surface runoff of the study area has been attempted for the year 2001. It is found that, the sub-watersheds of Kanyakumari basin receive the heaviest rains in the summer and monsoon seasons due to their nearness to the sea as well as due to their high relief, which reveal the fact, that it is a wet basin. Whereas it is found that the Nambiyar basin is dry, receiving rain only in the north-west monsoon season,

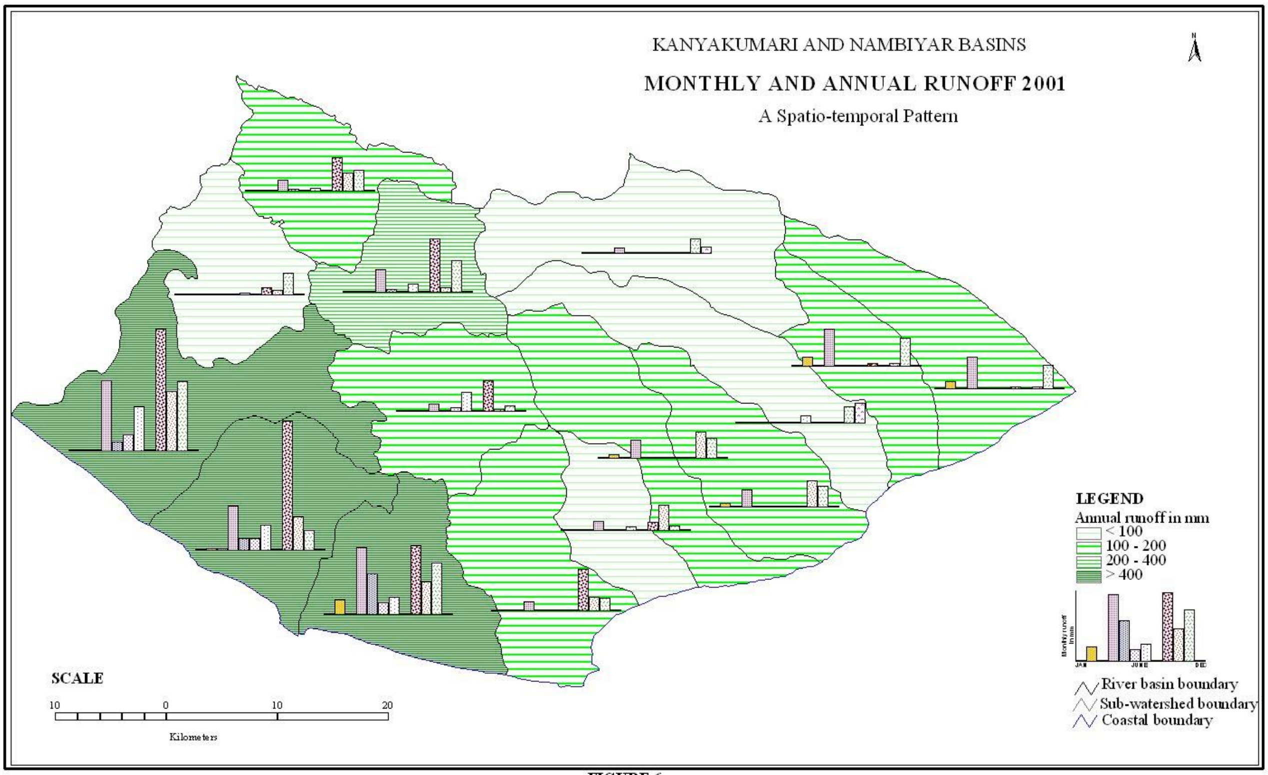

FIGURE 6

Figure 6: Spatio-temporal pattern of the monthly and annual runoff of the sub-watersheds

which reveal the drought condition and the dry nature of the sub-watersheds.

Likewise, the daily surface runoff characteristics of the basins have been studied using SCS curve number model in which remote sensing and GIS techniques have been used. Accordingly, all the sub-watersheds show proportionate runoff with respect to rainfall in both the dormant and growing season. The sub-watersheds of Kanyakumari basin show more positive response to the received rainfall. Sub-watersheds, having heavy rainfall, agricultural land use, medium textured soils, circular shape, larger area and steep slope produce higher surface runoff. It is evident from the study that the surface runoff is directly dependent on the intensity of rainfall, land use, soil and morphological condition of the sub-watersheds. The seasonal results show that the sub-watersheds of Kanyakumari basin produce more surface runoff during the summer months and southwest monsoon; whereas, in the Nambiyar basin only the northeast monsoon gives runoff. Thus the fact that differences in the terrain conditions and the water resources have resulted in the disparity in these sub-watersheds of the 2 river basin may pave the way for suitable environmental planning.

6. References

Anderson J.R., E.T. Hardy, J.T. Roach and R.E. Witmer (1976). A land use and landcover classification system for use with remote sensor data. USGS Professional, Paper No. 466, pp1-26.

Ashish Pandey, P.P. Dabral, V.M. Choudry, and B.C. Mal. "Estimation of runoff for agricultural watershed using SCS curve number and GIS" Available electronically from: www.gis@development.net/application/water/watershed/watws 0015a.htm.

Chatterjee, C. Rakesh Kumar, A.K. Lohani, R. Jha, and R.K. Jaiswal (2001). Runoff estimation using remote sensing and GIS based SCS method. Proceedings. Workshop on Remote Sensing and GIS Applications in Water Resources Engineering, Lucknow, India, August 29-31, 2001.

Das, S.N., K.K. Narula and Raymond Laurin (1992). Runoff potential indices of watersheds in Tilaiya catchment, Bihar, India through use of remote sensing and implementation of GIS. Journal of the Indian Society of Remote Sensing, 20(4), 207-221.

Debnath, A.C. and P.V. Seethapathi (2001). Morphological study of Gai river. Proceedings.

Workshop on Remote Sensing and GIS Applications in Water Resources Engineeing, Lucknow, India, August 29-31, 2001, pp.14-25.

Dilip, G. and T. Chandramohan (2000). Application of remote sensing technique for estimation of surface runoff from an ungauged watershed using SCS curve number method. Journal of Applied Hydrology, 13(1 & 2), 1-9.

Institute of Water Studies (2001). Water plan, Kodayar river basin. TAHAL Consulting Engineers Ltd. Association with Li CES & DHV, PWD, WRO, Chennai, India, Volume 1&2.

Institute of Water Studies (2003). Micro level study, Nambiyar river basin. PWD, WRO, Chennai, India, Volume 1&2.

Kumar, V. and R.A. Rastogi (1989). Determination of direct runoff from small agricultural watershed. Journal of Agri. Engg. (ISAE), 26(3), 223.

Kumar, P., K.N. Tiwari, and D.K. Pal (1997). Establishing SCS curve number from IRS digital database. Journal of Indian Society of Remote Sensing, 19(4), 246-251.

Pandey, V.K. and S.N. Pandey "Curve number estimation for watershed using digital image of IRS 1D LISS III" Available electronically from: www.gis@development.net.

Satheeshkumar, S., Venkateswaran, S. & Kannan, R. Rainfall–runoff estimation using SCS–CN and GIS approach in the Pappiredipatti watershed of the Vaniyar sub basin, South India. Model. Earth Syst. Environ. 3, 24 (2017).

Sharma, D.C. and O.C. Dubey (2001). Remote sensing applications to study the effect of land cover on stream flow. Proceedings. Workshop on Remote Sensing and GIS Applications in Water Resources Engineering, Lucknow, India, August 29-31, 2001.

Sturbe, M. Mik, and , M. Johnston Douglas (1990). Runoff volume estimation using GIS technique. Water Resources Bulletin, American Water Resources Association, 26(4), 611-620.

Suresh, R. (1997). Soil and Conservation Engineering, Standard Publishers Distribution, New Delhi, pp.48-51.

Suresh Kumar R. and G. Venkata Ramana (2019) Analysis of Runoff Through SCS-CN Method For Sustainable Agriculture Using Remote Sensing And GIS Modules, International Journal of Agriculture Research and Development (IJARD) Volume 1, Issue 1, pp. 27-37, Article ID: IJARD_01_01_004

Tiwari, K.N., P. Kumar, M. Sebastian and D.K. Pal (1991). Hydrologic modeling for runoff determinations: Remote sensing techniques. Water Resource Development, 7(3), 178-184.

Tripathi, M.P., R.K. Panda, S. Pradhan and S. Sudhakar (2002). Runoff modeling of a small watershed using satellite data and GIS. Journal of Indian Society of Remote Sensing, 30(1 & 2), 39-52.

U.S. Department of Agriculture (1969). Computer programme for project formulation, Soil Conservation Service, Washington, DC, Tech. Release No. 20,

U.S. Department of Agriculture (1972). Soil Conservation Service, National Engineering Hand book,: Hydrology, U.S. Govt. Printing Office, Washington, DC, Section 4

U.S. Department of Agriculture (1986). Urban Hydrology for Small Watersheds, (2nd Edition), Soil Conservation Service, Washington, DC, Tech. Release No.55.

Vandersypen, D.R., J.S. Bali and Y.P. Yadav (1972). Hand book of Hydrology, Soil Conservation Division, Ministry of Agriculture, Government of India, New Delhi.

Verbyla, D.L. (1995). Satellite Remote Sensing of Natural Resources, CRC Lewis Publishers, New York, pp.198.