

## Research Article

# Assessment of Surface Runoff for Tank Watershed in Tamil Nadu Using Hydrologic Modeling

Marykutty Abraham <sup>1</sup> and Riya Ann Mathew <sup>2</sup>

<sup>1</sup>Sathyabama University, Chennai, India

<sup>2</sup>Anna University, Chennai, India

Correspondence should be addressed to Marykutty Abraham; marykutty\_ab@yahoo.co.in

Received 1 February 2018; Accepted 16 April 2018; Published 5 June 2018

Academic Editor: Yun-tai Chen

Copyright © 2018 Marykutty Abraham and Riya Ann Mathew. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Providing safe and wholesome water in sufficient quantity on a sustainable basis remains elusive for large population especially in semiarid regions and hence water balance estimation is vital to assess water availability in a watershed. The water balance study is formulated to assess the runoff that can be harvested for effective utilization. The study area is Urapakkam watershed with a chain of 3 tanks having an aerial extent of 4.576 km<sup>2</sup> with hard rock formation underneath and thus has limited scope for groundwater recharge. Hence surface water is the main water source in this area. Runoff computed for the watershed using USDA-NRCS model varied from 94.95 mm to 2324.34 mm and the corresponding rainfall varied from 575.7 mm to 3608.0 mm, respectively. A simple regression model was developed for the watershed to compute runoff from annual rainfall. Average annual runoff estimated for the watershed was around 37% of the rainfall for the study period from 2000-01 to 2013-14. Statistical analysis and test of significance for runoff obtained by NRCS model and regression model did not show any significant difference thus proving that regression model is efficient in runoff computation for ungauged basins. The volume of water accessible for fifty percent dependable flow year is obtained as 2.46 MCM and even if 50% of it can be effectively harnessed the water available in the watershed is 1.23 MCM. The water demand of the area is estimated as 0.148 MCM for domestic purpose and 0.171 MCM for irrigation purpose, which is much lower than the available runoff that can be harnessed from the watershed. Thus there is scope to harvest 1.23 MCM of water which is more than the demand of the watershed. The study reveals that it is feasible to harvest and manage water effectively if its availability and demand are computed accurately.

## 1. Introduction

The global annual per capita water supply is around 7000 m<sup>3</sup> [1], which shows that the earth has sufficient freshwater for the needs of the population. According to Food and Agriculture Organisation [2] average per capita water availability ranges from near zero in Kuwait to around 10,000 m<sup>3</sup> in Tajikistan. In addition to the spatial variability, there is seasonal variability in these areas, which results in extreme events. Cosgrove and Rijsberman [3] predicted that by the year 2025 about 60% of the world's population will face acute water shortage. Groundwater table is highly influenced by urbanization of an area.

Water demand is increasing in most of the cities as per capita water use of an urban citizen is almost twice than that of a rural citizen and India is rapidly urbanizing. As

the Indian cities are facing water problems, groundwater exploitation has become inevitable which leads to the decline of groundwater table. To sustain urban cities there is an urgent need to augment groundwater resources. The per capita water availability of India is 1545 m<sup>3</sup> per annum [4].

Monsoonal climate prevalent in India causes half of the precipitation to occur within a period of 15 days and more than 90% of the annual runoff during four monsoon months. The large regional and seasonal variation in rainfall and runoff in India have prompted human interferences in hydrological cycle. Options that combine augmentation of surface water and groundwater resources can ensure sufficient water availability in a sustainable manner. As the study area is on the threshold for rapid development and urbanization there will be an impetus for drastic increase

in water demand. The villages in the study area are already experiencing rapid urbanization.

Water balance estimates are essential to strengthen the decision-making pertaining to water management. Rainwater harvesting and water conservation measures deserve the highest priority in water management compared to other measures because of the huge investment required and longer time period involved [5]. So estimation of water potential is very important for the effective utilization of the available water resources in the context of fast urbanization.

The widely accepted empirical method to estimate runoff for an ungauged watershed is Natural Resource Conservation Service (NRCS) model, formerly known as Soil Conservation Service (SCS) model, which is based on water balance equation developed by United States Department of Agriculture [6]. Rainfall-runoff relation was first proposed by Sherman [7]. Surface runoff based on land use, soil, rainfall, duration of storm, and annual temperature for watersheds was developed by Mockus [8]. Mishra and Singh [9] conducted extensive research on Soil Conservation Service-curve number (SCS-CN) method. Mishra et al. [10] investigated SCS model for US fields with size ranging from 0.3 to 30352 hectare using rainfall-runoff events and found that the model is appropriate for high rainfall (>50.8 mm) areas. SCS method was successfully applied for a forest watershed having permeable soils [11]. Rainfall-runoff relationships using various empirical and numerical methods have been developed by various researchers [12–16]. Applicability of NRCS model was successfully demonstrated by many researchers worldwide for computing runoff [11, 17–19]. NRCS method is widely accepted and is proved useful for surface runoff estimation by several authors for various watersheds of Tamil Nadu [20, 21]. Modifications were made for SCS model for steep slopes by Gupta et al. [22]. Water balance computation of Noyil Basin in Tamil Nadu was presented by Chatterjee et al. [23]. Central Ground Water Board [24] conducted water balance studies for upper Yamuna basin and the recharge estimated was compared with water table fluctuation method.

Thakuria and Saikia [25] successfully demonstrated methodology for runoff estimation by integrating remote sensing and geographic information system (GIS) in Buriganga watershed of Assam. Remote sensing data along with ground truth verification is widely utilized for mapping various resources in an economic and efficient way including soil mapping, land use mapping, and fertility mapping [26, 27]. The applicability of SCS model was improved by accounting for spatial and temporal variability in soil and land use with remote sensing and geographic information system [28–34].

The literature study reveals that NRCS model is used for hydrologic simulation of small watersheds worldwide for a long period and can also give realistic results even for larger watersheds. Hence NRCS model is used in the present study for runoff computation owing to its efficiency, precision, and simplicity for ungauged watersheds.

## 2. The Study Area and Data Collection

The study area is Urapakkam watershed which consists of three tanks, namely, Urapakkam tank, Karanaipuducheri

tank, and Periyar Nagar tank. Urapakkam watershed with an area of 4.576 km<sup>2</sup> is part of Guduvanchery watershed in the Adyar basin, in Kanchipuram district of Tamil Nadu, India. The area falls under geographical coordinates 12° 52' N to 12° 47' N and 80° 42' E to 80° 52' E. Elevation of the district varies from 0.5 m to 230 m above mean sea level. The temperature ranges between 37.1°C and 20.5°C [35]. Index map of study area is presented in Figure 1. Rainfall occurs mainly during October to December through Northeast monsoon. The area receives an average rainfall of around 1150 mm per annum. Rainfall data was collected from India Meteorological Department (IMD) Chennai for fourteen years from 2000 to 2014. Agriculture is the main livelihood of the watershed community. Paddy is the major crop and groundnut, sugarcane, cereals, millets, pulses, etc. are also cultivated. Water from Palar river, tanks, and wells is used for irrigation in the watershed [36].

## 3. Methodology

**3.1. Runoff Computation.** Watershed boundary for Urapakkam watershed was delineated using District Soil & Watershed Atlas [37] and verified with Survey of India toposheet and satellite imagery. Land use map was prepared for the tank watershed in GIS platform using ArcGIS-9.8 software and the area under each land use is calculated.

Surface runoff was assessed by applying NRCS-Hydrologic model using daily time step [38]. The runoff equation is

$$Q = \frac{(P - I_a)^2}{(P - I_a + S)} \quad (1)$$

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

where

$P$  is Rainfall, in mm

$CN$  is curve number which ranges between 0 and 100

$S$  is storage index, depending on the curve number

$I_a$  is initial abstraction, a fraction of  $S$

$Q$  is runoff, in mm

Using  $I_a = 0.2S$ , (2) takes the form

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

Daily rainfall data, land use map, hydrological soil group, and infiltration study were used to arrive at runoff curve numbers for NRCS model. The watershed curve number is closely related to soil storage index. According to infiltration characteristics, soil is grouped under four hydrologic soil groups, namely, A, B, C, and D, where A has the highest infiltration rate and D has the least infiltration rate [39].

Surface conditions of a watershed are taken care of by curve numbers. The curve numbers corresponding to various land uses and hydrologic soil groups can be obtained from

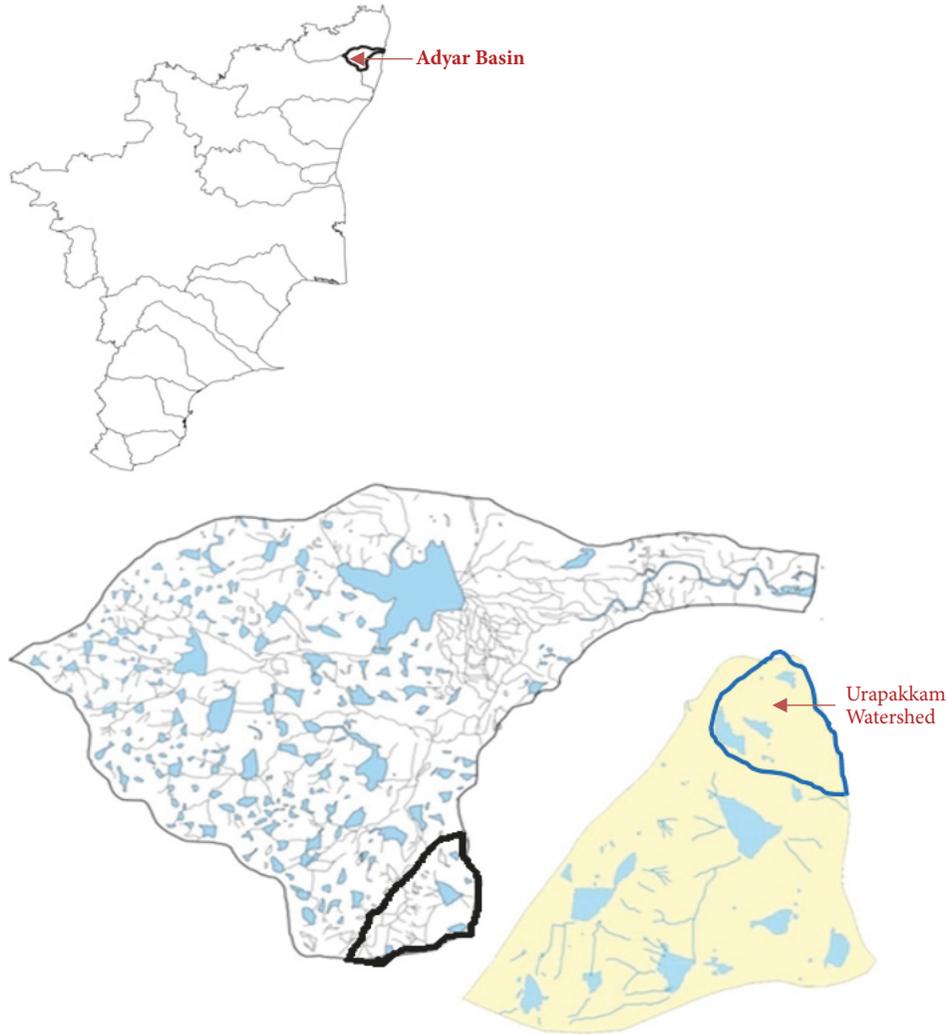


FIGURE 1: Index map of study area.

Table 1 [40]. From this, the weighted curve number of the watershed can be determined which corresponds to the average Antecedent Moisture Condition (AMC II). AMC for dry and wet situations is determined using five-day antecedent rainfall which corresponds to less than 13 mm and more than 28 mm rainfall, respectively, and gives rise to AMC I and AMC III. The curve number determined for AMC II can be converted for other conditions, namely, AMC I and AMC III using the following relations [38]:

$$CN_I = \frac{4.2CN_{II}}{10 - 0.0584CN_{II}} \quad (4)$$

$$CN_{III} = \frac{23CN_{II}}{10 + 0.13CN_{II}}, \quad (5)$$

where

- CN<sub>I</sub> is curve number for AMC I
- CN<sub>II</sub> is curve number for AMC II
- CN<sub>III</sub> is curve number for AMC III

A simple regression model was developed to compute annual runoff from rainfall which was then calibrated and validated with NRCS model. Such simpler equations can be used for computation of runoff for ungauged watersheds instead of arduous and data intensive computation methods. Performance of developed regression model was evaluated using statistical methods such as coefficient of determination, standard error of estimate, and mean absolute error. The statistical test of significance used was t-test.

*Coefficient of Determination* ( $R^2$ ) shows the degree of linear relation between the two variables.  $R^2$  value close to unity indicates a high degree of association between the two variables [41].

*Standard Error of Estimate* (SEE) is an estimate of the average deviation of the regression value from the observed data.

$$SEE = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 2}} \quad (6)$$

TABLE 1: Runoff curve numbers.

Description of Land use	Hydrologic Soil Group			
	A	B	C	D
<b>Paved parking lots, roofs, driveways</b>	98	98	98	98
<b>Streets and Roads:</b>				
Paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
<b>Cultivated (Agricultural Crop) Land*:</b>				
Without conservation treatment (no terraces)	72	81	88	91
With conservation treatment (terraces, contours)	62	71	78	81
<b>Pasture or Range Land:</b>				
Poor (<50% ground cover or heavily grazed)	68	79	86	89
Good (50–75% ground cover; not heavily grazed)	39	61	74	80
<b>Meadow (grass, no grazing, mowed for hay)</b>	30	58	71	78
<b>Brush (good, &gt;75% ground cover)</b>	30	48	65	73
<b>Woods and Forests:</b>				
Poor (small trees/brush destroyed by over-grazing or burning)	45	66	77	83
Fair (grazing but not burned; some brush)	36	60	73	79
Good (no grazing; brush covers ground)	30	55	70	77
<b>Open Spaces (lawns, parks, golf courses, cemeteries, etc.):</b>				
Fair (grass covers 50–75% of area)	49	69	79	84
Good (grass covers >75% of area)	39	61	74	80
<b>Commercial and Business Districts (85% impervious)</b>	89	92	94	95
<b>Industrial Districts (72% impervious)</b>	81	88	91	93
<b>Residential Areas:</b>				
1/8 Acre lots, about 65% impervious	77	85	90	92
1/4 Acre lots, about 38% impervious	61	75	83	87
1/2 Acre lots, about 25% impervious	54	70	80	85
1 Acre lots, about 20% impervious	51	68	79	84

Source: United States Department of Agriculture, Soil Conservation Service, 1986 [40]. Technical Release 55.

Mean Absolute Error (MAE) is the average of all absolute errors which can be expressed as

$$MAE = \frac{1}{n} \sum_{i=1}^n |x_i - x|, \quad (7)$$

where

$x$  is runoff by NRCS model

$x_i$  is runoff by regression model

$n$  is number of data sets

*Test for significance:*  $t$ -test was used to test whether there is significant difference between runoff computed by NRCS model and those estimated by regression model.

The assumptions used in this test were samples which are independent and random in nature and samples which are normally distributed.

Two-independent sample  $t$ -test statistics is defined as

$$t = \frac{(\sum |x_i - x|) / n}{\sqrt{((\sum |x_i - x|)^2 - ((\sum |x_i - x|)^2 / n)) / (n - 1) (n)}} \quad (8)$$

*3.2. Water Balance Study.* Water availability and demand for domestic use and irrigation in the watershed were computed separately. Domestic water demand was obtained as the product of per capita water requirement and the population. The difference between water availability and water demand will give a comprehensive understanding on the total utilizable water.

*Estimation of Irrigation Demand.* Irrigation water demand was calculated from the method given by Brouwer and Heibloem, 1986 [42]. Potential evapotranspiration was computed from Blaney–Criddle equation [43] and is given by

$$ET_o = p(0.46T_{\text{mean}} + 8), \quad (9)$$

where

$T_{\text{mean}}$  is mean daily temperature ( $^{\circ}\text{C}$ )

$p$  is mean daily percentage of annual daytime hours.

Crop coefficient ( $K_c$ ) for paddy for various growth stages was estimated and crop water requirement was determined from

$$ET_{\text{crop}} = ET_o \times K_c \quad (10)$$

TABLE 2: Land use details and the corresponding curve numbers.

Land use category	Area km <sup>2</sup>	Curve Number
Forest /Forest Plantations	1.089	79
Crop land	0.193	81
Water bodies	0.600	89
Barren land	0.167	80
Settlement/Residential area	2.527	87

Other water needs such as water to saturate the soil (SAT), percolation and seepage losses (PSL), and water needed for standing water layer (WL) were used to compute the irrigation need.

Effective rainfall ( $P_e$ ) was calculated from the formulae

$$\begin{aligned}
 P_e &= 0.8P - 25 && \text{if } P > 75 \text{ mm/month} \\
 P_e &= 0.6P - 10 && \text{if } P < 75 \text{ mm/month,}
 \end{aligned}
 \tag{11}$$

where

$P$  is rainfall in mm/month

Irrigation Need (IN) is calculated as

$$IN = ET_{\text{crop}} + SAT + PSL + WL - P_e \tag{12}$$

### 4. Result

The runoff for Urapakkam watershed in Adyar basin was computed using USDA-NRCS model. A simple regression model was also developed and validated for its suitability for runoff computation of the watershed. By knowing the utilizable water available in a watershed, water supply for irrigation and other purposes can be planned and alternative cropping patterns can be adopted to avoid losses.

#### 4.1. Runoff Computation

4.1.1. NRCS Model. Watershed boundary for the chain of tanks was taken from District Soil & Watershed Atlas and verified with Survey of India toposheet and satellite imagery. Land use map for Urapakkam watershed was prepared from satellite imagery with field verification in GIS platform using ArcGIS and the area under various land uses was determined (Figure 2).

The watershed is in the hydrologic soil group D as per the soil details. Hydrological modeling considers water year from July to June of ensuing year and uses daily time step. Urapakkam tank has both free catchment and intercepted catchment. The hydrological model estimated the runoff for fourteen water years from 2000-01 to 2013-14 with daily time step. Land use details and corresponding curve numbers are given in Table 2.

Weighted curve number for the watershed with a drainage area of 4.576 km<sup>2</sup> is 84.85. The curve numbers for Antecedent Moisture Conditions I, II, and III are 70.17, 84.85, and 92.80, respectively.

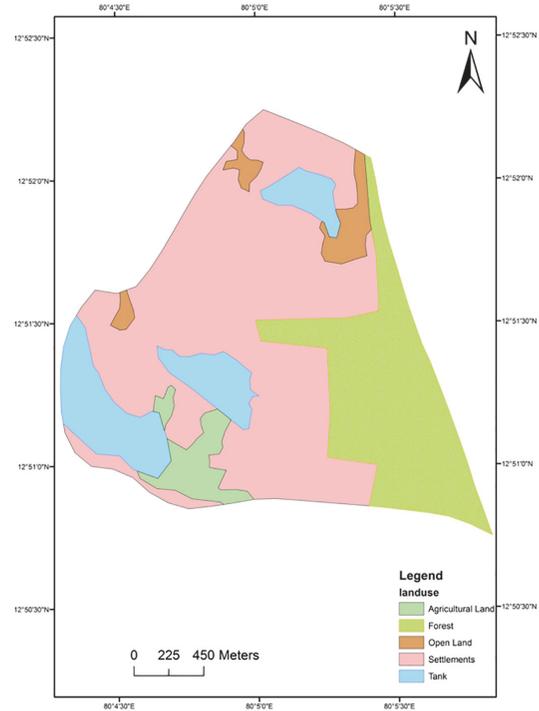


FIGURE 2: Land use map of Urapakkam watershed.

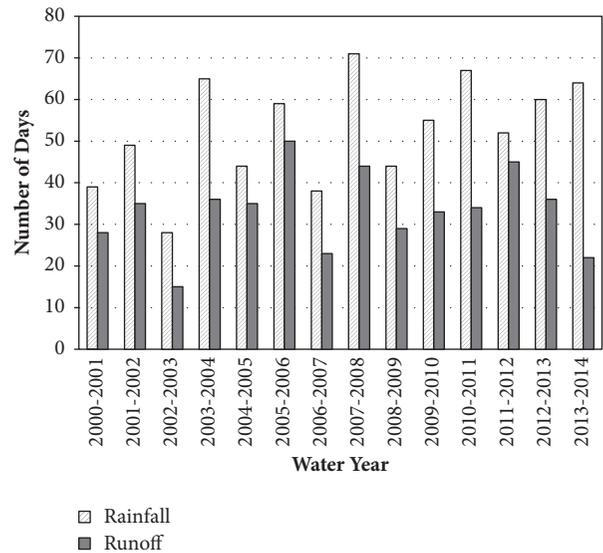


FIGURE 3: Number of days with rainfall and runoff by NRCS model.

Days with rainfall and runoff for the study period are given in Figure 3. Monthly rainfall and the corresponding runoff as estimated from NRCS model are given in Figure 4. Table 3 gives monthly rainfall and runoff for the water year 2008–2009, when fifty percent dependable flow was observed.

Annual rainfall for the watershed varied from 575.7 mm (2002–03) to 3608.0 mm (2005–06). The runoff as estimated from NRCS model varied from 94.95 mm to 2324.34 mm and the corresponding percentage varied from 16.49 to 64.42 with an average value of 37.09 percent for the fourteen water years:

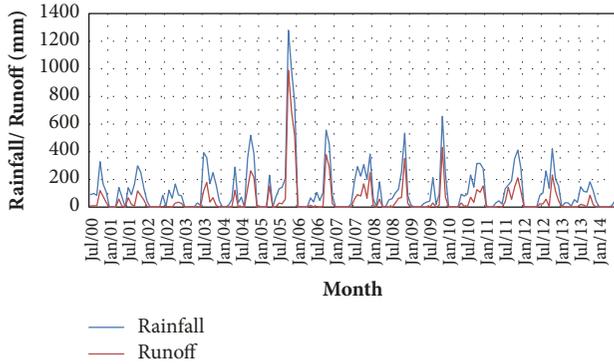


FIGURE 4: Monthly rainfall and runoff by NRCS model for Urapakkam tank watershed.

TABLE 3: Monthly rainfall and runoff for Urapakkam watershed using NRCS model for the water year 2008-2009.

Month	Rainfall mm	Runoff mm
Jul-08	61.00	0.05
Aug-08	101.00	27.49
Sep-08	129.00	63.11
Oct-08	254.00	69.09
Nov-08	534.00	352.89
Dec-08	84.00	26.33
Jan-09	15.00	0.00
Feb-09	0.00	0.00
Mar-09	0.00	0.00
Apr-09	0.00	0.00
May-09	24.00	0.00
Jun-09	36.80	0.00

2000-01 to 2013-14. Bar chart showing annual rainfall and runoff is given in Figure 5. Volume of runoff for the watershed varied between 0.434 MCM and 10.637 MCM during the fourteen years of study. Annual runoff for a representative water year (2008-09) is obtained as 2.46 MCM (Table 4). When the rainfall exceeds the threshold limit, the proportion of rainfall contributing to runoff was found to be higher. Wide variations were observed in the quantum of runoff from rainfall of same magnitude due to varying antecedent moisture conditions in the soil. Figure 6 shows the average annual rainfall and runoff estimated for Urapakkam watershed.

4.1.2. *Regression Model.* A Linear regression model was developed for the watershed to compute annual runoff from the annual rainfall. Ten-year data from NRCS model was used for model calibration and four-year data was used for validation. The regression relationship obtained between annual rainfall (mm) and annual runoff (mm) is given as

$$\text{Runoff} = 0.736 \times \text{rainfall} - 467.8 \quad (13)$$

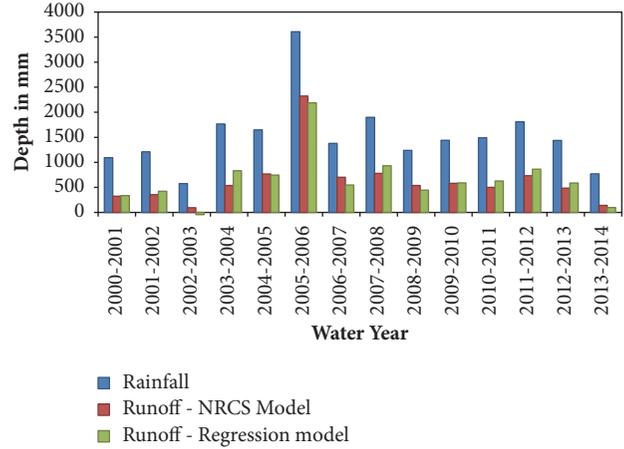


FIGURE 5: Annual rainfall and runoff for Urapakkam watershed.

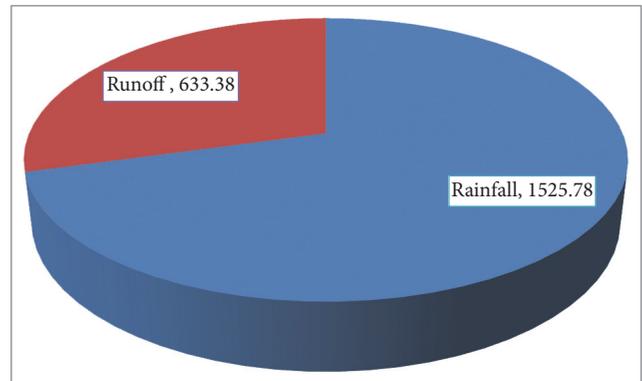


FIGURE 6: Average annual rainfall and runoff estimated for Urapakkam watershed.

$R^2$  value was obtained as 0.944 during calibration and 0.988 during validation period. The plots of rainfall versus runoff as obtained from NRCS model during calibration and validation period are shown in Figure 7.

4.1.3. *Validation of Regression Model.* Figure 8 shows the comparison between the annual runoff by NRCS model and the developed regression model which illustrates that the regression model could be used to effectively predict runoff for the watershed even during the validation phase. The coefficient of determination ( $R^2$ ) for runoff by NRCS model versus runoff by regression model was 0.939 at 95% confidence level (Figure 9). The statistical tests such as t-test, MAE, and SEE obtained for the two runoff estimates (NRCS model and regression model) were 0.55, 10.60, and 13.90, respectively. The average runoff for the watershed by linear regression model was obtained as 37.17 percent of the rainfall which ranges from 12.79% to 60.63%. It shows no considerable deviation from runoff computed by NRCS model. Thus the statistical analysis proves that tedious and data intensive computation methods can be eliminated and the volume of runoff from a watershed can be efficiently and easily computed using simple regression model.

TABLE 4: Annual rainfall and runoff estimated for Urapakkam watershed using NRCS model for the period 2000-01 to 2013-14.

Water Year	Rainfall		Runoff			
	No. of days	Depth mm	No. of days	Depth mm	Percentage of Rainfall	Volume MCM
2000-2001	39	1092.30	28	323.96	29.66	1.483
2001-2002	49	1211.10	35	355.39	29.34	1.626
2002-2003	28	575.70	15	94.95	16.49	0.434
2003-2004	65	1765.80	36	537.50	30.44	2.460
2004-2005	44	1648.00	35	768.59	46.64	3.517
2005-2006	59	3608.00	50	2324.34	64.42	10.637
2006-2007	38	1379.00	23	701.20	50.85	3.209
2007-2008	71	1899.50	44	780.43	41.09	3.571
2008-2009	44	1238.80	29	538.97	43.51	2.466
2009-2010	55	1439.00	33	582.24	40.46	2.665
2010-2011	67	1489.00	34	499.09	33.52	2.284
2011-2012	52	1810.00	45	734.11	40.56	3.359
2012-2013	60	1435.40	36	484.12	33.73	2.215
2013-2014	64	769.30	22	142.48	18.52	0.652
<b>Minimum</b>	<b>28</b>	<b>575.7</b>	<b>15</b>	<b>94.95</b>	<b>16.49</b>	<b>0.434</b>
<b>Maximum</b>	<b>71</b>	<b>3608.0</b>	<b>44</b>	<b>2324.34</b>	<b>64.42</b>	<b>10.637</b>

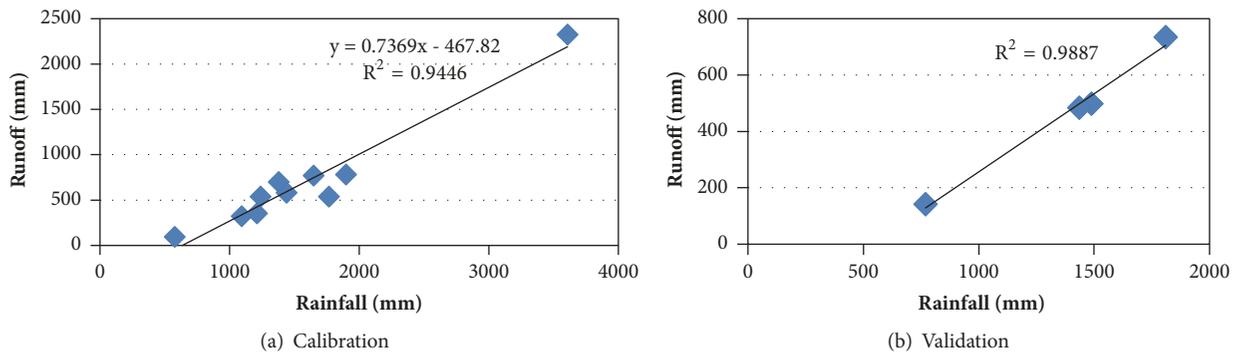


FIGURE 7: Relationship between annual rainfall and runoff by NRCS model during calibration and validation period.

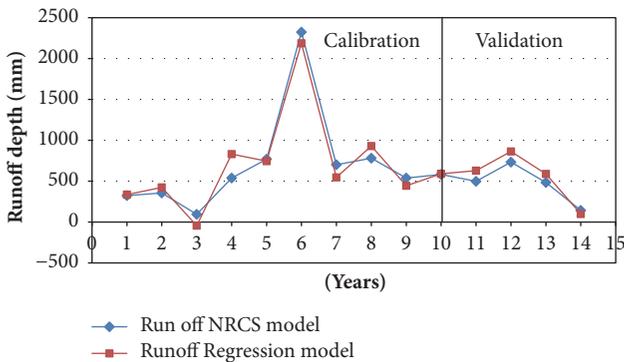


FIGURE 8: Comparison of annual runoff from NRCS model and regression model.

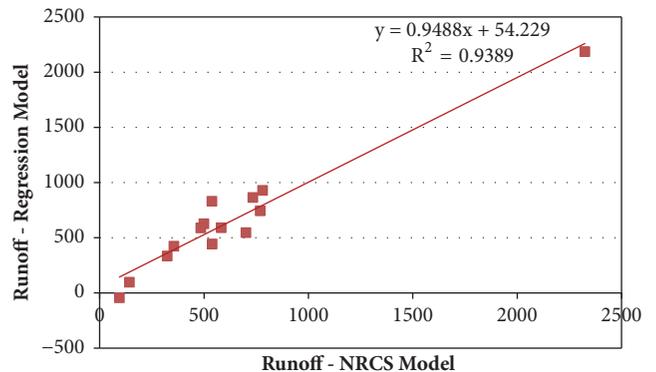


FIGURE 9: Scatter plot of annual runoff by NRCS model and regression model for Urapakkam watershed for 2000-01 to 2013-14.

4.2. Water Balance Study. Population density of Kanchipuram district is 892/km<sup>2</sup> [44]. Assuming the per capita water demand to be 100 liters/day for domestic purposes, the

total domestic water requirement for the population of the watershed with 4.576 km<sup>2</sup> is estimated at 407 m<sup>3</sup>/day, which is 0.148 MCM per annum.

TABLE 5: Computation of irrigation demand for paddy for the year 2008-09.

Item	Month						Season
	September	October	November	December	January	February	
Percentage of annual daytime hours, $p$		0.26	0.27	0.26	0.27	0.27	
Average Temperature $T_{\text{mean}}$ ( $^{\circ}\text{C}$ )		26.00	24.80	24.60	25.8	27.80	
Potential evapotranspiration $E_t$ (mm/day)		5.19	5.14	5.02	5.27	5.61	
Crop coefficient $K_c$		1.10	1.10	1.20	1.30	1.00	
Crop water requirement							
mm/day		5.71	5.66	6.03	6.84	5.61	
mm/month		171.26	175.38	186.82	191.65	174.00	
SAT, mm	200.00						
PSL, mm/month @4 mm/day		120.00	124.00	124.00	112.00	124.00	
WL, mm							
$P_e$ , mm	48.60	499.80	167.80	0.00	0.00	0.00	
Irrigation demand, mm	151.40	0.00	131.58	310.82	303.65	298.00	<b>1195.45</b>

Irrigation is practiced in a small area of 10 ha in the watershed. The average irrigation demand for the watershed area is computed to be around 1195 mm. By considering an efficiency of 70%, the actual irrigation water requirement is 1708 mm. The total irrigation demand for 10 ha of paddy crop in the watershed is estimated as 0.171 MCM. Details of the computation of irrigation demand for paddy are presented in Table 5.

The current total domestic and irrigation water requirement of the watershed is 0.320 MCM. After meeting all the water demands of the watershed there is sufficient water available even if only 50% of the total available rainwater can be effectively harvested.

## 5. Conclusions

Accurate estimation of runoff is essential for the effective management of water resources especially in semiarid regions like Tamil Nadu. NRCS model is a widely accepted model for the estimation of runoff for small watersheds. It is extensively used by engineers and hydrologists but the lack of sufficient data may give poor results. With the understanding of available water in a watershed, irrigation scheduling, crop rotation, and cropping pattern can be planned.

Total volume of runoff available for Urapakkam watershed from NRCS model for a representative year is 2.46 MCM. A simple regression model was developed to estimate depth of annual runoff for the watershed which is given as runoff (mm) =  $0.736 \times \text{rainfall (mm)} - 467.8$ . Statistical tests confirm that there is no significant difference between the runoff estimates from the two models. Hence the study confirms that it is advantageous to have calibrated regression

models for easy computation of runoff and for the effective management of water resources for ungauged basins.

Water balance study shows that 1.23 MCM of water can be effectively stored in the watershed after losses by improving the drainage and capacity of the storages. The total domestic and irrigation demand is estimated at 0.320 MCM. Hence apart from meeting the present domestic and irrigation demand in the watershed, additional demand due to future development and demand of adjoining areas can also be met from the water available in the watershed if properly harvested.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

## References

- [1] I. A. Shiklomanov, "Appraisal and Assessment of world water resources," *Water International*, vol. 25, no. 1, pp. 11–32, 2000.
- [2] FAO, "FAO Activities on Promoting Fertigation," in *Proceedings of the Regional Workshop on Guidelines for Efficient Fertilizers Use through Modern Irrigation*, FAO Regional Office for the Near East, Cairo, Egypt, 1998.
- [3] W. Cosgrove and F. Rijsberman, *World Water Vision: Making Water Everybody's Business*, World Water Council, Earthscan Publications, 2000.

- [4] Ministry of Water Resources. 2012. Per Capita Water Availability. Press Information Bureau, Government of India, 26-April 2012, <http://pib.nic.in/newsite/PrintRelease.aspx?relid=82676>.
- [5] S. K. Gupta and R. D. Deshpande, "Water for India in 2050: First-order assessment of available options," *Current Science*, vol. 86, no. 9, pp. 1216–1224, 2004.
- [6] Soil Conservation Service (SCS). Hydrology, National Engineering Handbook, Supplement A, Section 4, Chapter 10, Soil Conservation Service, U.S.D.A., Washington, DC, USA, 1972.
- [7] L. K. Sherman, "The unit hydrograph method," in *Physics of the Earth*, O. E. Meinzer, Ed., pp. 514–525, Dover Publications Inc., New York, NY, USA, 1949.
- [8] V. Mockus, "Estimation of total (peak rates of) surface runoff for individual storms," in *Exhibit A of Appendix B, Interim Survey Report Grand (Neosho) River Watershed, U.S.D.A.*, 1949.
- [9] S. K. Mishra and V. P. Singh, "Another look at SCS-CN method," *Journal of Hydrologic Engineering*, vol. 4, no. 3, pp. 257–264, 1999.
- [10] S. K. Mishra, M. K. Jain, P. K. Bhunya, and V. P. Singh, "Field applicability of the SCS-CN-based Mishra-Singh general model and its variants," *Water Resources Management*, vol. 19, no. 1, pp. 37–62, 2005.
- [11] K. X. Soulis, J. D. Valiantzas, N. Dercas, and P. A. Londra, "Investigation of the direct runoff generation mechanism for the analysis of the SCS-CN method applicability to a partial area experimental watershed," *Hydrology and Earth System Sciences*, vol. 13, no. 5, pp. 605–615, 2009.
- [12] P. Koteswaram and S. M. A. Alvi, "Secular trends and periodicities in rainfall at west coast stations in India," *Current Science*, vol. 38, no. 10, pp. 229–231, 1969.
- [13] K. V. Ramamurthy, M. K. Sonam, and S. S. Muley, "Long term variation in the rainfall over upper Narmada catchment," *Mausam*, vol. 38, no. 3, pp. 313–318, 1987.
- [14] R. Jha and R. K. Jaiswal, "Analysis of rainfall pattern in a catchment," *IAH Journal of Hydrology (India)*, Roorkee, 1992.
- [15] F. H. S. Chiew, M. J. Stewardson, and T. A. McMahon, "Comparison of six rainfall-runoff modelling approaches," *Journal of Hydrology*, vol. 147, no. 1-4, pp. 1–36, 1993.
- [16] E. M. Lungu, "Detection of changes in rainfall and runoff patterns," *Journal of Hydrology*, vol. 147, no. 1-4, pp. 153–167, 1993.
- [17] J. Meher and R. Jha, "Time series analysis of rainfall data over Mahanadi River basin," *Emerging Science*, vol. 3, no. 6, pp. 22–32, 2011.
- [18] K. X. Soulis and J. D. Valiantzas, "SCS-CN parameter determination using rainfall-runoff data in heterogeneous watersheds—the two-CN system approach," *Hydrology and Earth System Sciences*, vol. 16, no. 3, pp. 1001–1015, 2012.
- [19] R. Kabiri, A. Chan, and R. Bai, "Comparison of SCS and Green-Ampt Methods in Surface Runoff-Flooding Simulation for Klang Watershed in Malaysia," *Open Journal of Modern Hydrology*, vol. 03, no. 03, pp. 102–114, 2013.
- [20] S. Mohan and M. Abraham, "Derivations of simple site-specific recharge-precipitation relationships: A case study from the Cuddalore Basin, India," *Environmental Geosciences*, vol. 17, no. 1, pp. 37–44, 2010.
- [21] R. Viji, P. R. Prasanna, and R. Ilangovan, "GIS based SCS-CN method for estimating runoff in Kundahpalam watershed, Nilgries district, Tamilnadu," *Earth Sciences Research Journal*, vol. 19, no. 1, pp. 59–64, 2015.
- [22] P. K. Gupta, S. Punalekar, S. Panigrahy, A. Sonakia, and J. S. Parihar, "Runoff modeling in an agro-forested watershed using remote sensing and gis," *Journal of Hydrologic Engineering*, vol. 17, no. 11, pp. 1255–1267, 2012.
- [23] R. Chatterjee, "Groundwater resources estimation — case studies from India," *Journal of the Geological Society of India*, vol. 77, no. 2, pp. 201–204, 2011.
- [24] Central Ground Water Board (CGWB). Water Balance Studies in Upper Yamuna Basin – Terminal Report - Project Findings and Recommendations. Chandigarh: Central Ground Water Board 2000.
- [25] G. Thakuria and R. Saikia, "Estimation of Surface Runoff using NRCS Curve number procedure in Buriganga Watershed, Assam, India - A Geospatial Approach," *International Research Journal of Earth Sciences*, vol. 2, no. 5, pp. 1–7, 2014.
- [26] V. K. Dadhwal, "Remote sensing and GIS for agricultural crop acreage and yield estimation," in *Proceedings of the International Archives of Photogrammetry and Remote Sensing, XXXII*, pp. 58–67, 1999.
- [27] G. B. Geena and P. N. Ballukraya, "Estimation of runoff for Red hills watershed using SCS method and GIS," *Indian Journal of Science and Technology*, vol. 4, no. 8, pp. 899–902, 2011.
- [28] K. H. Syed, D. C. Goodrich, D. E. Myers, and S. Sorooshian, "Spatial characteristics of thunderstorm rainfall fields and their relation to runoff," *Journal of Hydrology*, vol. 271, no. 1-4, pp. 1–21, 2003.
- [29] X. Zhan and M.-L. Huang, "ArcCN-Runoff: An ArcGIS tool for generating curve number and runoff maps," *Environmental Modeling and Software*, vol. 19, no. 10, pp. 875–879, 2004.
- [30] K. Geetha, S. K. Mishra, T. I. Eldho, A. K. Rastogi, and R. P. Pandey, "Modifications to SCS-CN method for long-term hydrologic simulation," *Journal of Irrigation and Drainage Engineering*, vol. 133, no. 5, pp. 475–486, 2007.
- [31] V. Kumar, M. Babu, T. V. Praveen et al., "Analysis of the Runoff for Watershed Using SCS-CN Method and Geographic Information Systems," *International Journal of Engineering Science and Technology*, 2010.
- [32] R. Pradhan, P. P. Mohan, M. K. Ghose et al., "Estimation of Rainfall Runoff using Remote Sensing and GIS in and around Singtam, East Sikkim," *International Journal of Geomatics and Geosciences*, vol. 1, article 466, 2010.
- [33] A. Panahi, "Evaluating SCS-CN method in estimating the amount of runoff in Soofi Chay basin using GIS," *Life Science Journal*, vol. 10, no. 5, pp. 271–277, 2013.
- [34] S. Satheeshkumar, S. Venkateswaran, and R. Kannan, "Rainfall-runoff estimation using SCS-CN and GIS approach in the Pappiredipatti watershed of the Vaniyar sub basin, South India," *Modeling Earth Systems and Environment*, vol. 3, no. 1, 2017.
- [35] IMD, *Temperature of Kanchipuram District*, Regional Meteorological Centre, Chennai, India, 2013, *Temperature of Kanchipuram District*. Regional Meteorological Centre.
- [36] ENVIS 2015. Kanchipuram District. ENVIS Centre Tamilnadu, <http://www.tnenvis.nic.in/files/KANCHIPURAM%20.pdf>.
- [37] AIS and LUS, *Watershed Atlas of India, Department of Agriculture and Co-operation. All India Soil and Landuse Survey*, IARI Campus, New Delhi, India, 1990.
- [38] V. T. Chow, D. R. Maidment, and L. W. Mays, *Applied Hydrology*, McGraw-Hill, New York, New York, USA, 1988.
- [39] Natural Resources Conservation Service (NRCS), "Chapter 7- Hydrologic Soil Groups," in *Hydrology National Engineering Handbook, title 630*, Washington, DC, USA, 2007.

- [40] United States Department of Agriculture, Soil Conservation Service (USDA-SCS). Technical Release 55, Urban hydrology for small watersheds, USA, 1986.
- [41] A. G. Bluman, *Elementary Statistics*, McGraw Hill, New York, NY, USA, 6th edition, 2008.
- [42] C. Brouwer and M. Heibloem, "Irrigation Water Needs- Irrigation Water Management," in *Training Manual No. 3*, Food and Agriculture Organisation, Rome, Italy, 1986.
- [43] R. G. Allen, L. S. Pereira, D. Raes, and M. Smith, "Crop evapotranspiration: Guidelines for computing crop water requirements," in *Irrigation and Drainage Paper No. 56*, Food and Agricultural Organization of the United Nations, Rome, Italy, 1998.
- [44] Census of India, *District Census Hand book - Kanchipuram*, Directorate of Census Operations in Tamil Nadu, 2011.



**Hindawi**

Submit your manuscripts at  
[www.hindawi.com](http://www.hindawi.com)

