Research Article

GIS, GPS And Dumpy Level Survey for Estimation Of Runoff By SCS-CN Method For VIIT Campus, Visakhapatnam

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Abstract: Globally majority of countries in the worldare worrying about declining of groundwater levels day by day. The one of the best solutions to improve the Groundwater levels is the artificial recharge of Groundwater. The estimation of runoff is very essential for the recharge of Groundwater. Exactly here a study has been madeto estimate the runoff by Soil Conservation Service Curve Number (SCS-CN) method for Vignan's Institute of Information Technology (VIIT) campus, Visakhapatnam. In this study, the Land Use/Land cover (LU/LC)map of the study area has been extracted using GIS software from the Google Earth Remote Sensing imagery. The ground truth survey has been done using Global Position System (GPS) to update the missing data in the imagery. The Digital Elevation Model (DEM) of the study area has been generated using elevation data which was collected through dumpy level survey along with GPS. The soil texture map has been extracted from Soil Map which was bought from the National Bureau Soil Sciences (NBSS). The rainfall data of the study area has been collected from the nearest Gajuwaka Rain gauge station. The runoff of the study area has been estimated using the SCS-CN method by using the LU/LC, the Soil Texture map and rainfall data. In the present study the year wise total runoff varies from 30.352 mm to 209.445 mm of the study area. The average Annual rainfall of the study area is 1048.84 mm for the years 2009 to 2018. The average annual runoff volumeof the study area for 10 years is 16293.48 Cu.M.The DEM map has been used to derive the mini watersheds to locate the Artificial Recharge locations to recharge the runoff to the Groundwater.

Keywords: SCS-CN, LU/LC, GIS,GPS,DEM, NBSS

1.0 Introduction

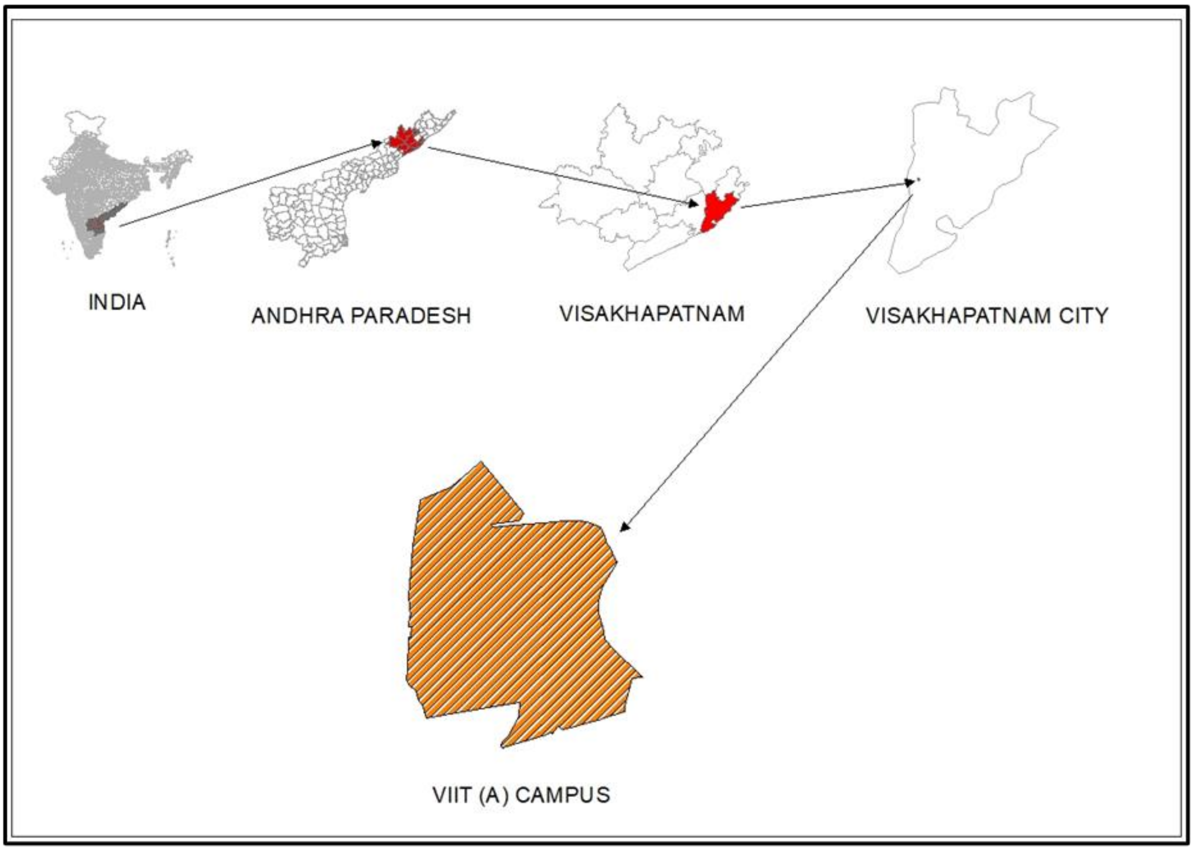
Water scarcity and over-misuse of groundwater resources are common in several places of India (Garg and Hassan,2007; Tiwari et al.2009; Tiwari and Singh,2014).. Nearly two-thirds of the population of the world will be prejudiced by water shortage in the following couple of decades (Alcamo et al. 2000; Wallace and Gregory, 2002).The rainfall is Important source of water and primary of the hydrological elements, rainfall is used as one of the main elements to estimate the runoff process (Anand B Kudoli and Prof. R.A.Oak., 2015).The runoff estimation is very essential for designing of artificial recharge structures to recharge the Groundwater, check dams to preventing soil erosion and hydraulic structures to store the water. Rainfall-runoff method is a mathematical model describing the rainfall-runoff relations of a watershed area (Mohammad Golshan and Payam Ebrahimi, 2014). There are various methods available for rainfall runoff modelling such as empirical equations,hydrologic models and data driven techniques to correlate rainfall and runoff (Zakwan, M. 2016). Among these various methods, the Soil Conservation Service Curve Numbermethod (SCS–CN, 1972) is an adaptable and most widely used for the runoff estimation.This method was developed by the US Department of Agriculture, SCS and documented in detail in the National Engineering Handbook, Sect. 4: Hydrology (NEH-4) SCS, 1956, 1964, 1971, 1985, 1993. Due to its effortlessness, that has become the most popular method for small watershed (Mishra and Singh, 2002).Due to its low input data requirements and also its effortlessness, many watershed models such as SWAT (Arnold et al. 1996), EPIC (Sharpley and Williams, 1990), AGNPS (Young et al. 1989) and CREAMS(Knisel, 1980) used this method to calculate the runoff(Shi et al. 2009).

In this method the soil texture, land use/land cover and antecedent soil water conditions are taken into consideration (Bansode et al. 2014).Land Use/Land cover information is used in hydrologic modelling to estimate the value of surface friction or roughness as it affects the velocity of the overland flow of water (Ara, Z. 2018,Zakwan, M., & Muzzammil, M. 2016).The amount of rainfall, that will infiltrate into the soil, may also be determined by the Land Use/Land cover information (Zakwan, M. 2017). The data on land use, soil, storm durationand antecedent rainfall is used in SCS-CN method (Mockus, V. 1949).The aim of this method is to calculate the accurate curve numbers of the study area of interest that helps in estimating the runoff potential. Hydrologic Soil Group (HSG) number, land use/ land cover type, soil texture, Antecedent Moisture Conditions (AMC) are the basic catchment characteristics used for calculation of curve numbers.

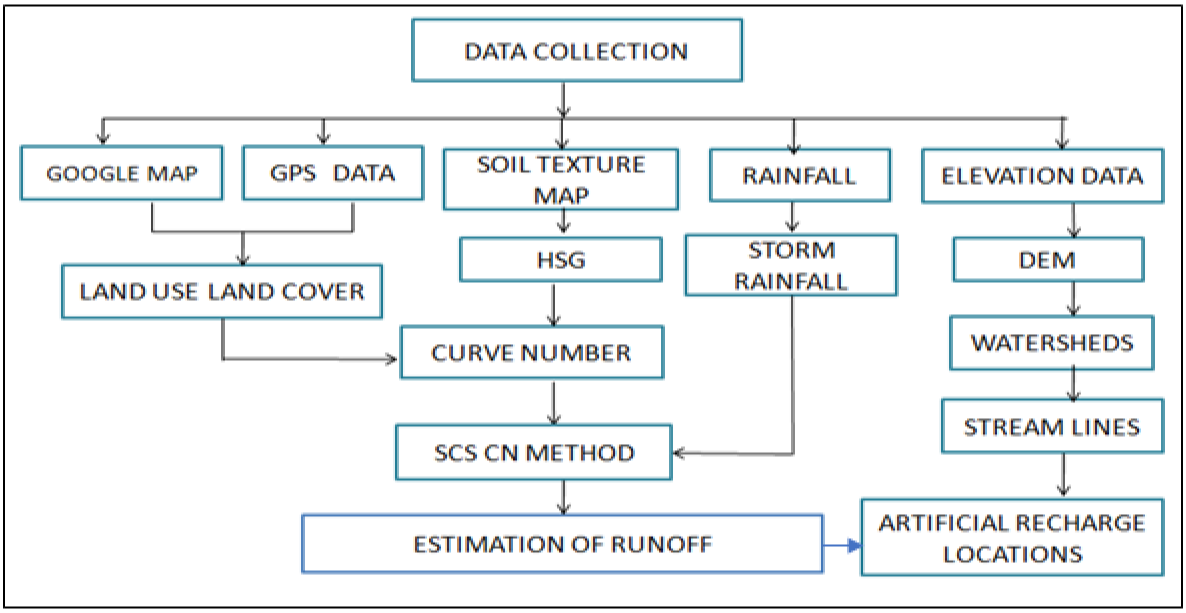
In traditional method for estimation of runoff by composite CNs using charts and tables are time consumingand tedious. These problems can overcome by SCS-CN method coupled with Remote Sensing and GIS facilitate fast and precise estimation of composite CN and truthful estimation of runoff (Zhan and huang, 2004; Xu, 2006).In present years, Remote Sensing and GIS have emerged as powerful tools for collecting the necessary information on land use/land cover of large areas (Shih, 1988; Subudhi et al., 1989). Further, the information on land use/land cover and hydrologic soil type can be integrated in a GIS environment for a accurate and quick estimation of runoff curve numbers (Stuebe et al, 1990). The Remote Sensing and GIS is playing noteworthy role for preparation of Curve Number (CN) and it is very crucial for runoff estimation.The GIS and Remote Sensing technology can be used accurately to study the hydraulic response of a watershed to land use/ land cover changes (Sharma et al. 2001). The GIS and Remote Sensing based hydrological modelling requires estimation of the spatial and temporal distribution of the water resources parameters (Gangodagamage and Agarwal, 2001).
This present study includes GIS, GPS, Dumpy level coupled with SCS-CN method for estimating the runoff of the VIIT, Visakhapatnam

2.0 The Study Area

The study area is situated in Greater Visakhapatnam Municipal Corporation in Zone V and ward number 57.This study area, Vignan Institute of Information Technology (VIIT), is located between 17 º 42.528' to 17 º 42.819' northern latitudes and 83 º 9.809' to 83 º 10.062' eastern longitudes with an area of 0.1437 km^2. It is in Duvvada region, the suburban area of Visakhapatnam city. This area consisting of khondalites, charnockites and granites andis being located in an folded and faulted region in the eastern margin of the Eastern Ghats (A. Sriramadas , M. S. Murty,1975).The major geomorphic units of this area are the hill slope elements of free face and debris slope along with piedmont fans, colluvium and pediment. Laterites are present both as altered product of hard rock as weIl as colluvium (K.N.Prudhvi Raju and R. Vaidyanadhana,1978)



2.0 Methodology

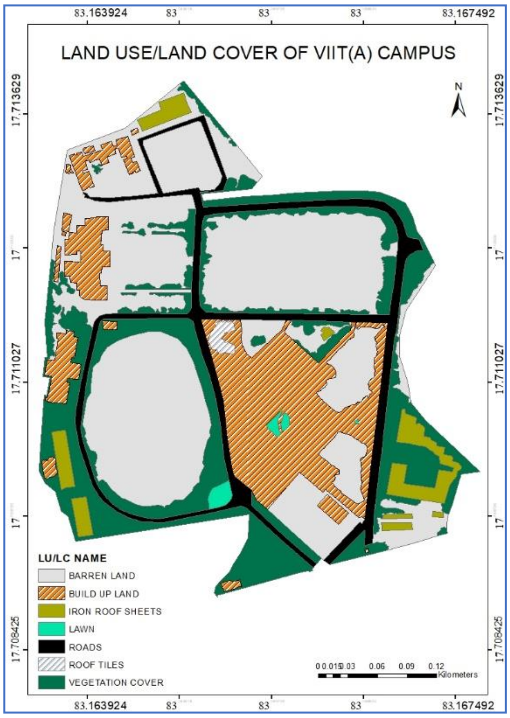


Flow Chart

3.0 Runoff Estimation

3.1.1 Land Use/Cover Map, Soil Texture Map, Rainfall Data and Curve Numbers

The runoff estimation has been done by using SCS-CN method. This method include preparation of Land Use/Land Cover map, Soil Texture map and collection of rainfall data. The Land use/Land cover map (Fig.1.0) was extracted from the Google earth map using ArcGIS 10.8.2 through visual interpretation. The Soil Texture map (Fig. 2.0) was prepared by conducting soil tests at various locations in the study area.Rainfall data (Table 2.0) was collected from Gajuwaka rain gauge station which is situated nearest to the study areaduringthe period 2009-2018.The SCS curve numbers(Table 1.0) were assigned to each Land use/Land Cover Class and Hydrological Soil Group (HSG). The HSG for the study area is ‘A’ as the soil is sandy loam.



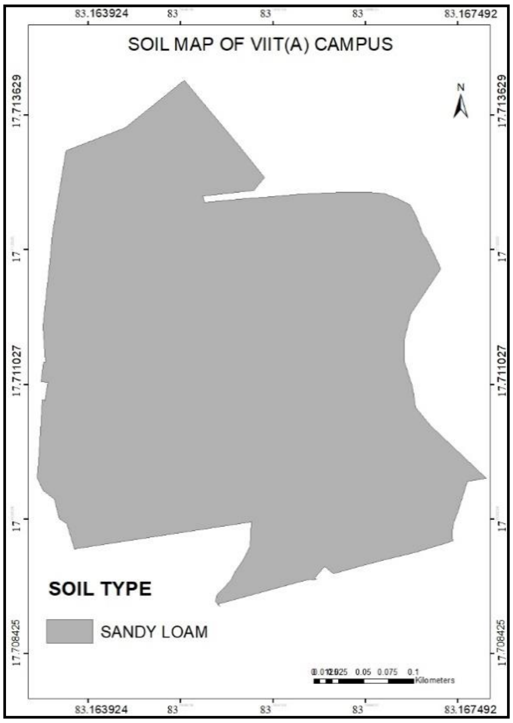


Fig. 1.0. Land Use/ Land Cover**Fig. 2.0.**Soil Texture Map

Table 1.0. Curve numbers and statistical distribution of land use categories with HSG

LAND USE	HSG	CURVE NUMBER(CN)	AREA(A)	CN*A
Vegetation cover	A	41	0.0328	1.34
Barren land	A	71	0.067	4.75
Iron Roof Sheet	A	98	0.0052	0.51
Roads	A	83	0.0126	1.05
Buildup Land	A	77	0.0249	1.92
Roof Tiles	A	98	0.0005	0.05
Lawn	A	49	0.0007	0.03

Table 2.0. Monthly Average Rainfall data during 2009-2018

MONTHLY RAINFALL DATA RECORDED DURING 2009-2018											
MON	YEAR										AVG(mm)
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Jan	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	47	0	8.4	0	0.2	0.2	0	0	5.58
Mar	0	0	0	0	0	0	0.9	0	37.5	0	3.84
Apr	0	0	41.4	4	17.6	0	38.6	0	0	58.6	16.02
May	7	231	122.2	19.4	21.4	92.4	3.1	232	113.2	110.6	95.23
June	182.4	156.8	35	60.4	30	54.2	372.5	167.7	128.3	43.2	123.05
July	86.6	341.4	374.2	65.8	39.8	0	118.4	188.2	53	93.2	136.06
Aug	56.3	124	97.8	120.2	96.6	317.6	180.6	91	204	197.6	148.57
Sepr	232.3	199.5	98.8	339.6	4.2	157.6	244.4	215.7	122	120.4	171.45
Oct	117	274.7	81.6	156.6	566.8	284.8	25.6	66.1	83.4	48.2	170.48
Nov	100.8	499	0	293.2	214	11.2	237.4	1.3	3.6	0	136.05
Dec	0	169.8	15.2	0	0	11.2	31.5	0	0	77.2	30.49

3.1.2 Curve numbers(CN) and Runoff

The runoff was calculated from the different storm events of observed rainfall during the years 2009 to 2018. Curve Numbers are obtained on basis of land use and soil group combination. For every land Use and Land Cover feature and HSG the curve numbers will vary.The SCS-CN method for calculating runoff is represented as

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

The potential maximum retention storage S of watershed is related to a CN, which is a function of land use/land cover, soil type and antecedent moisture condition of watershed. The CN is dimensionless and its value varies from 0 to 100.The S-value in mm can be obtained from CN by using the relationship

$$S = 25.4\left(\frac{1000}{CN} - 10\right)$$

Where,

CN = Weighted Curve Number

Weighted Curve Number values are considered on basis of Antecedent Moisture Condition of the soil. We have three Weighted Curve Number Equations for corresponding three AMC conditions. The equations for Weighted Curve Numbers are as follows:

CN II for AMC II is calculated as follows:

$$\mathrm{CNII} = \sum_{i=1}^{n} \frac{\mathrm{CN}_i \times \mathrm{A}_i}{\mathrm{A}_i}$$

The conversion of CNII to other two AMC conditions can be made through the following correlation equations:
For AMC I

$$CNI = \frac{4.2 \times CNII}{10 - (0.058 \times CNII)}$$

For AMC III

$$CNIII = \frac{23 \times CNII}{10 + (0.13 \times CNII)}$$

3.1.3 HYDROLOGICAL SOIL GROUPS

The Sandy loam soil class of VIIT (A) campus comes under the Hydrological Soil Group (HSG) of A. HSG A include the soil have low runoff potential and high infiltration rates even thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have high rate water transmission (greater than 0.3 in/Hr)

Table 3.0. Soil Classification

SOIL TEXTURAL CLASS	HSG	AREA (Sq km)
Sandy loam	A	0.144129

3.1.3 AMC LIMITS

Table 4.0. Antecedent Moisture Condition limits

AMC CLASS	5 DAY ANTECEDENT RAINFALL(mm)	
	DORMANT SEASON	GROWING SEASON
I	< 12.5	< 35
II	12.5-27.5	35-52.5
III	> 27.5	> 52.5

3.1.4 RESULTS

Table 5.0: Runoff estimation for each storm event during 2009-2018

Runoff estimation for each storm event during the period from 2009-2018					
DATE OF STORM EVENT	STORM RAINFALL (P) (mm)	5 DAY TOTAL ANTECEDENT RAINFALL(mm)	AMC	STORM RUNOFF	
				mm	%
05.06.2009-07.06.2009	15.5	17.2	I	7.689	49.61
25.06.2009-28.06.2009	137.2	12.5	I	15.956	11.63
06.07.2009-09.07.2009	20	12.4	I	6.092	30.46
18.07.2009-20.07.2009	15.2	34	I	7.8	51.32
15.08.2009-18.08.2009	23.6	2.2	I	4.97	21.06
25.08.2009-31.08.2009	16.2	8.9	I	7.42	45.80
22.09.2009-24.09.2009	60.6	16.1	I	0.002	0.00
30.09.2009-04.10.2009	54.2	186.6	III	19.167	35.36
12.11.2009-18.11.2009	80	20.8	I	1.288	1.61
21.05.2010-23.05.2010	117.7	113.3	III	70.708	60.07
10.06.2010-14.06.2010	97.6	11.2	I	4.262	4.37
06.07.2010-09.07.2010	51	65	III	16.994	33.32
26.07.2010-31.07.2010	36	121.4	III	7.912	21.98
06.09.2010-10.09.2010	20	99	III	1.301	6.51
17.09.2010-18.09.2010	71.5	9	I	0.446	0.62
06.10.2010-09.10.2010	35.5	29	I	2.139	6.03
17.10.2010-20.10.2010	16	23.6	I	7.502	46.89
28.10.2010-30.10.2010	38	13.6	I	1.705	4.49
06.11.2010-09.11.2010	119	323	III	71.861	60.39
07.12.2010-10.12.2010	159.8	10	I	25.115	15.72
22.02.2011-24.02.2011	44	3	I	0.874	1.99
28.04.2011-30.04.2011	28.2	13.2	II	0.075	0.27
26.05.2011-30.05.2011	25	97.2	III	2.896	11.58
14.06.2011-15.06.2011	34	1	I	2.425	7.13
07.07.2011-08.07.2011	155.2	42	II	66.27	42.70
18.07.2011-21.07.2011	18.2	4.4	I	6.707	36.85
28.07.2011-30.07.2011	143	11.4	I	18.155	12.70
06.08.2011-09.08.2011	43	29.4	I	0.992	2.31
27.08.2011-31.08.2011	11.4	7	I	9.331	81.85
06.09.2011-12.09.2011	10.2	70.8	III	0.009	0.09
19.09.2011-21.09.2011	15.4	2.4	I	7.724	50.16
11.10.2011-12.10.2011	27.4	6	I	3.924	14.32
01.01.2012-02.01.2012	12.4	5.2	I	8.913	71.88
12.05.2012-16.05.2012	15.4	4	I	7.727	50.18
13.06.2012-14.06.2012	18.2	9.2	I	6.707	36.85
26.06.2012-30.06.2012	18.6	14.4	I	6.569	35.32
20.08.2012-22.08.2012	27.4	14.8	I	3.924	14.32
29.08.2012-31.08.2012	43.4	2.8	I	0.944	2.18
06.09.2012-09.09.2012	151.4	47.2	II	63.398	41.87
15.09.2012-18.09.2012	53.2	28	I	0.145	0.27

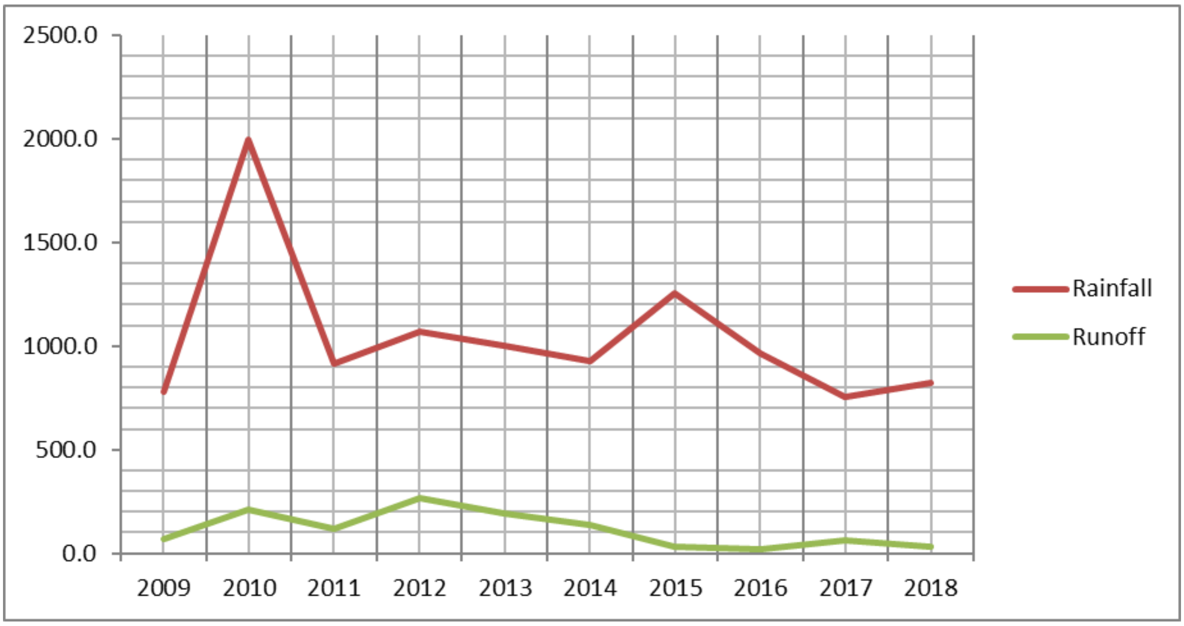
27.09.2012-30.09.2012	43.4	16.4	I	0.944	2.18
06.10.2012-12.10.2012	31.2	113	III	5.507	17.65
04.11.2012-05.11.2012	214	79.2	III	160.122	74.82
19.05.2013-20.05.2013	16	5.4	I	7.501	46.88
22.06.2013-23.06.2013	11.2	0	I	9.416	84.07
09.07.2013-13.07.2013	17.4	10.2	I	6.99	40.17
05.08.2013-06.08.2013	10.2	0.1	I	9.847	96.54
15.08.2013-17.08.2013	10.6	64.6	III	0.0016	0.02
10.10.2013-11.10.2013	34.4	0	I	2.347	6.82
26.10.2013-28.10.2013	155	364.2	III	104.548	67.45
22.11.2013-23.11.2013	214	0	I	52.546	24.55
07.05.2014-10.05.2014	60.4	22.8	II	7.764	12.85
09.06.2014-10.06.2014	24.4	2.4	I	4.74	19.43
17.05.2014-20.06.2014	30.5	0.1	I	3.171	10.40
10.07.2014-13.07.2014	36.2	6.5	I	2.012	5.56
23.07.2014-24.07.2014	212.3	9.5	I	51.588	24.30
30.07.2014-31.07.2014	10.1	8.3	I	9.891	97.93
14.08.2014-15.08.2014	38.4	32.2	I	1.64	4.27
26.08.2014-31.08.2014	191.2	6.6	I	40.184	21.02
16.09.2014-20.09.2014	112.5	10.1	I	7.924	7.04
17.10.2014-20.10.2014	19.7	238.3	III	1.222	6.20
30.12.2014-31.12.2014	17.6	0	I	6.919	39.31
29.04.2015-30.04.2015	31.4	0.3	I	2.969	9.46
29.06.2015-30.06.2015	13.5	178.7	III	0.118	0.87
06.07.2015-11.07.2015	47.5	0.1	I	0.522	1.10
17.07.2015-31.07.2015	40.3	30.4	I	1.352	3.35
23.08.2015-31.08.2015	34.4	3.4	I	2.347	6.82
06.09.2015-07.09.2015	10.7	30.5	I	9.63	90.00
14.09.2015-15.09.2015	28.2	37	II	0.075	0.27
21.09.2015-30.09.2015	51.5	38.6	II	4.599	8.93
20.10.2015-31.10.2015	17.5	5.8	I	6.954	39.74
16.11.2015-20.11.2015	56.6	0	I	0.033	0.06
13.12.2015-20.12.2015	31.4	0.1	I	2.969	9.46
19.05.2016-21.05.2016	59.5	0.2	I	0.00017	0.00
23.06.2016-30.06.2016	71.7	19.8	I	0.461	0.64
24.07.2016-31.07.2016	61.7	22.3	I	0.012	0.02
15.08.2016-17.08.2016	12.7	15.9	I	8.79	69.21
14.09.2016-16.09.2016	15.1	5.9	I	7.841	51.93
07.05.2017-08.05.2017	39.2	0.5	I	1.515	3.86
06.06.2017-08.06.2017	13.4	2.8	I	8.506	63.48
14.06.2017-17.06.2017	48.4	14.1	I	0.446	0.92
25.06.2017-30.06.2017	36.5	10.7	I	1.959	5.37
19.07.2017-20.07.2017	11	19.4	I	9.501	86.37
25.07.2017-30.07.2017	12.4	0	I	8.913	71.88
20.08.2017-23.08.2017	17.4	6.8	I	6.99	40.17
29.08.2017-31.08.2017	15.2	28.3	I	7.803	51.34
29.09.2017-31.09.2017	18.2	28.6	I	6.707	36.85
17.10.2017-20.10.2017	11.2	0.8	I	9.416	84.07

06.04.2018-08.04.2018	10.2	3	I	9.847	96.54
24.04.2018-25.04.2018	37.2	8.2	I	1.838	4.94
06.05.2018-12.05.2018	45.2	61	III	13.246	29.31
15.08.2018-16.08.2018	12	62.8	III	0.021	0.18
24.08.2018-31.08.2018	21	60.06	III	1.578	7.51
06.09.2018-15.09.2018	36.2	38.2	II	0.906	2.50
25.09.2018-31.09.2018	82.2	0	I	1.572	1.91
19.10.2018-31.10.2018	48.2	0	I	0.463	0.96
17.12.2018-18.12.2018	76.4	0.8	I	0.881	1.15

Table 6.0. Year wise Runoff of values and Volume of Runoff

TRENDS IN RAINFALL AND RUNOFF IN THE STUDY AREA

YEAR	RAINFALL	RUNOFF		VOLUME(m3)
		mm	%	
2009	782.4	69.096	8.83	9929.09
2010	1996.2	209.445	10.49	30097.24
2011	913.2	119.382	13.07	17155.19
2012	1071.6	264.9	24.72	38066.13
2013	1002.8	193.1966	19.26	27762.35
2014	930.2	137.055	14.73	19694.8
2015	1253.6	31.568	2.51	4536.32
2016	962.2	17.10417	1.77	2457.86
2017	753.6	61.756	8.19	8874.33
2018	822.6	30.352	3.68	4361.58
AVERAGE	**1048.84**	**113.381**	**10.81**	**16293.48**



Graph 1.0. The trends of rainfall vs Runoff of VIIT (A) Campus

4.0 Locations for Artificial Recharge

Location Id of Artificial	Longitude	Latitude

Recharge Structure		
1	83.16698583540	17.71158089580
2	83.16724385640	17.70943609580
3	83.16521194060	17.71258072740
4	83.16688907750	17.71120999060
5	83.16509905640	17.70956510630
6	83.16376057220	17.71233883270
7	83.16750187750	17.71000051690
8	83.16708259330	17.71053268530
9	83.16372831950	17.71203243270
10	83.16388958270	17.70953285370
12	83.16593762480	17.70908131680
13	83.16387345640	17.70961348530
14	83.16543770900	17.71259685370

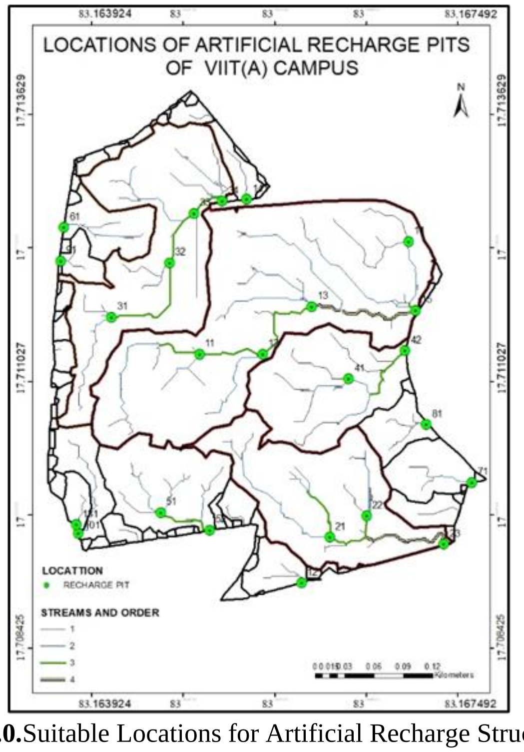


Fig. 3.0. Suitable Locations for Artificial Recharge Structures

5.0 Conclusions and Future Scope

a. The estimated average runoff (113.381 mm) is about 10.81% of average rainfall (1048.84mm).
b. The runoff of the study area varies from 30.352 mm to 209.445 mm
c. The average runoff of the study area of VIIT (A) Campus is 113.381 mm
d. Present trend of runoff is decreasing from the year 2012 even though a small rise in runoff in the year 2017

In Future, the runoff the study area will be estimated using the NRCS method for further improvement.

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