RAINFALL-GIS BASED RUNOFF MODEL: A CASE STUDY OF GURUGRAM DISTRICT

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Abstract: Urbanization foster the economic and social advancement that improved overall quality. There is less information of runoff available for urban areas in India which results to urban flood. The soil conservation service curve number (SCS-CN) and the hydrological parameters are studied for small watershed at local level. The basic hydrological parameters are infiltration and runoff which is influenced by urbanization. CN (Curve Number) is used to estimate the surface runoff of Gurugram district, Haryana. Weighted curve number, runoff depth and runoff volume are estimated by using SCS-CN method. The parameters used for this method are Land cover Map, Hydrological soil group (HSG), remote sensing data and GIS. Runoff potential areas is also identify by using SCS-CN method. Then the total runoff volume for Gurugram (2016) is calculated. Critical areas carrying high runoff are also identified and compared with Flooding in Gurgaon (July 27-28, 2016). Sustainable urban drainage system and ground water recharge techniques can be taken into account for solving the water related problem at urban level.

Keywords: GIS, Rainfall, Runoff Depth, Runoff Volume and SCS-CN Method.

Introduction: India having geographical area 328.6 million ha with average annual rainfall from 100mm in the west and 11,000 mm in the northeast. With increase in population, the availability of water per captia in most of the parts of India will be touching the water stress level. In future, surface water pollution, climate change and population growth may produce decline in fresh water. So it is essential to estimate surface runoff at micro watershed level to know its potential yield in this way water can be conserve which will further help to maintain sustainability. But most often there is records of precipitation but no records of runoff to estimate runoff from watershed. An empirical parameter known as soil conservation service –curve number is used in hydrology for predicting direct runoff or infiltration from rainfall excess. The curve number depends on the soil type, effects of land use and cover, hydrologic condition. To obtain runoff potential layer and for computing the peak runoff rate, The Soil Conservation Services (SCS) runoff model is useful for evolving the runoff potential for every feature utilizing different antecedent moisture condition (AMC). The sites for water conservation measures depend on annual rainfall as well as other terrain factors like, slope, aspect, ground undulations, soil permeability and land use variation in space and time. The use of GIS technology as a spatial data management and an analysis tool provides an effective mechanism for hydrologic/ hydraulic studies, it also identifies the spatial relationships between map features.

Study Area: Gurgaon District falls in the southern most region of the state of Haryana. Its headquarters is at Gurgaon. It lies in between the 27° 27' 20" and 28° 32'25" latitude, and 76° 39' 39" and 77° 20' 50" longitude. Being in the vicinity of Delhi, Gurgaon falls under National Capital Region. The total area of Gurugram Planning area is 732 sq. m and the population is around 2.3 million. On its north, it is bounded by the District of Jhajjar and National Capital Territory of Delhi; Faridabad District lies to its east; Palwal District lies to its south east. On south it shares boundaries with Mewat whereas Rewari lies to its west. To its South, lies the state of Rajasthan.

The study area selected in Gurgaon watershed areas are at micro level. Runoff is estimated at micro shed areas. There are 80 watersheds in this Gurgaon planning area.

Figure 1: Location of Gurugram

Material & Methodology:

Data Collection: The data's collected for the study are: The Remote satellite data; landsat8 image is used for the study which is taken from USGS earth explorer. The topo sheet (53D/11, 53D/15, 53H/3, 53H/4, 53D/16, 53D/12) are used for the study and were collected from survey of India Delhi. The Rainfall data for the period of 30 years (1986-2016) and the Haryana soil map is collected from National bureau of soil survey and Land use planning, Delhi. The delineation of the mini watershed is done using the software Arc Map 10 and micro watershed atlas of India.

Soil Conservation Service Curve Number (SCS-CN) Method: There are several method for runoff estimation – empirical formula and rational formula. The soil conservation service curve number method developed by Ogrosky and Mockus in 1957 for determing runoff depth and run off volume. The soil conservation service curve number (SCS-CN), the hydrological parameters are studied for small watershed. The basic hydrological parameters are infiltration and runoff which is influenced by urbanization. In this method, for land use/ land cover, Satellite image (Landsat8) are used, these satellite image has been procured with the help of ERDAS 2015. Firstly, different images have been stacked into one image, then 10 signature samples of each class has been taken out, merge them and finally supervised classification image is taken out. Hydrological soil is classified into A, B, C & D group on the basis of infiltration rate of soil with the help of USDA classification. AMC conditions is also determined for the calculation of runoff. AMC is also divided into three conditions where AMC-I is dry condition, AMC-II is medium condition and AMC-III is wet conditions. A value of CN curve number for given AMC conditions is determined on the basis of land use/ land cover and hydrological soil group. Then, weighted curve number is calculated, when study area consist of different land use. Losses are calculated by Initial abstractions due to infiltration, detention storage and interception. Initial abstractions (la) and potential maximum retention(S) for Indian continents are related by la = 0.1S. Potential maximum retention (S) is calculated by:

CN=2540/ (25.4+S)

Runoff depth is calculated by: Q_d**= (P-0.2S)** ^{2}**/ (P+0.8S)**

Where, P= Mean rainfall in cm Q_d= Runoff depth in (cm)

S= potential maximum retention (cm)

If same watershed is consist of different land use, then weighted curve number can be obtained by:

$CN_W = \Sigma (CN_i * A_i) / A$

Where CN_W is weighted curve number, CN_i is curve number, A_i is area represented to CN_i and **A** is total area. The Antecedent moisture condition is determined by total rainfall in five day period preceding a rainfall event.

Table 1: Classification Of Antecedent Moisture Conditions

AMC CLASS	Dormant Season	Growing Season
I	<12.5	<35
II	12.5 to 27.5	35 to 52.5
III	>27.5	>52.5

Source: (United States Department of Agriculture, 1986)

Table 2: Hydrological Soil Classification

Hydrological Soil group	Description	Soil Texture
Group A	Low runoff potential ,high Infiltration rates, well to drained sands or gravels and transmit a high rate of water	Sand, sandy loam or loamy sand
Group B	Moderate infiltration rates, moderately well to drained soils with moderately fine to moderately coarse textures. Moderate rate of water transmission	Silt loam, gravelly loam soils or loam gravelly
Group C	Low infiltration rates when wetted thoroughly and soils with moderately fine to fine texture. Low rate of transmission	Gravelly loam soils, clayey soils
Group D	High runoff potential and have low infiltration rates when wetted thoroughly and consists chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soil with a clay layer at or near the surface, and shallow soils over nearly impervious material. low rate of water transmission	Rocky outcrops, clayey soils

Source: (United States Department of Agriculture, 1986)

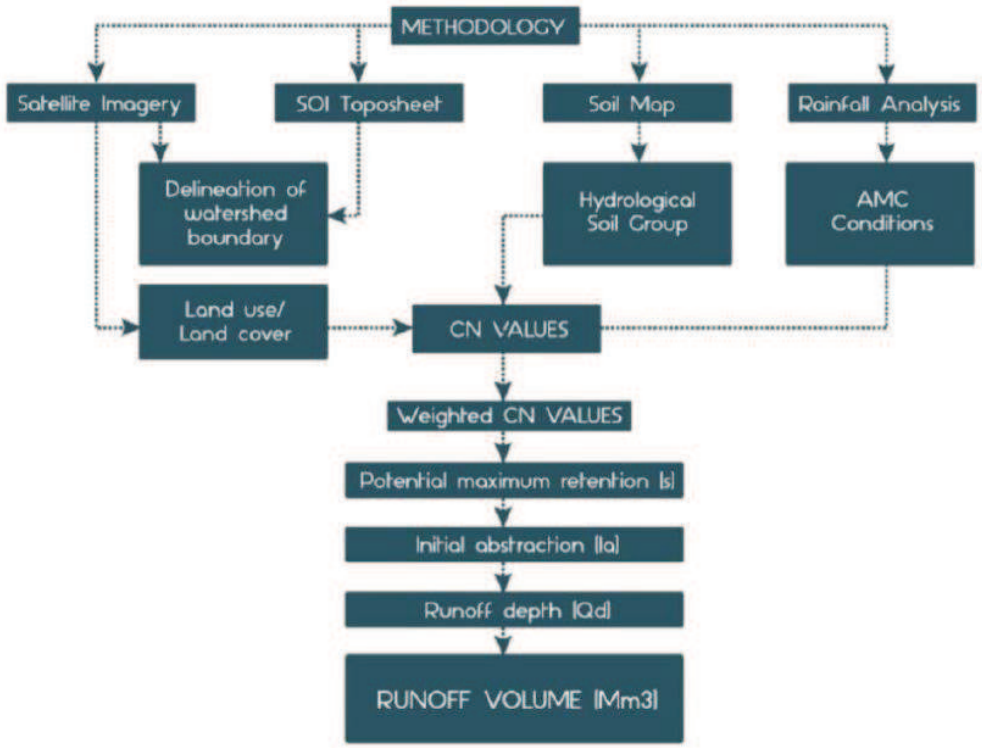


Figure 7: Methodology For Runoff Model *(R. Vinithra, 2013)*

Table 3: Curve Number

Land use	Hydrological Soil Group			
	A	**B**	**C**	**D**
Agriculture land	76	86	90	93
Built up	49	69	79	84
Plantation	41	55	69	73
Waste land	71	80	85	88
Water bodies	97	97	97	97

Source: (United States Department of Agriculture, 1986)

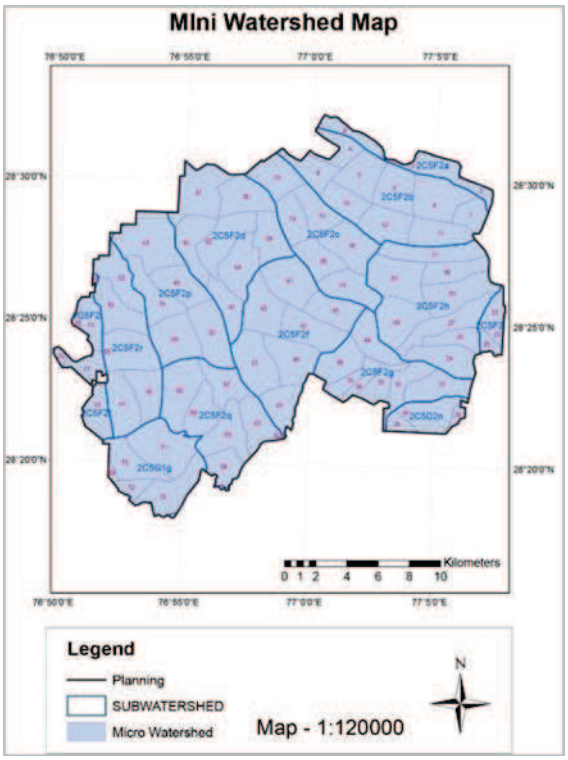
SCS-CN Method of Estimating Runoff - Overlay of layers: In this data the precipitation is probable the single most important characteristics for estimation the runoff volume. The land use and hydrological soil type are the watershed factors. The areas under different land use/land cover and different hydrological soil group is shown in the following tables. Mini watershed Map is generated using the software GIS, taking the reference from Micro watershed Atlas of India. The percentage of land use in different watersheds is just calculated by the intersection of Land use and watershed map using GIS tool given in Table 4

Table 4: Percentage Of Land Use In Different Watersheds

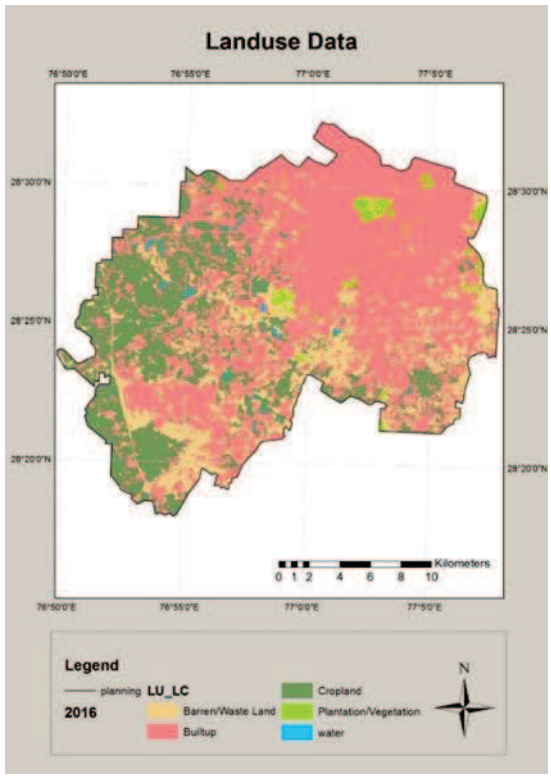
Micro water shed	Barren/Waste Land (%)	Built up (%)	Crop land (%)	Plantation/ Vegetation (%)	Water (%)
0	-	99.83	-	0.08	-
1	0.34	99.59	-	-	-
2	2.13	91.97	-	5.89	-
3	28.96	57.18	-	13.82	-
4	0.99	98.97	-	-	-
5	2.91	91.74	-	5.35	-
6	7.13	80.31	-	12.56	-
7	15.75	72.18	-	12.06	-
8	0.54	96.71	-	2.75	-
9	5.55	94.45	-	-	-
10	0.86	90.15	-	8.99	-
11	3.90	95.66	-	0.44	-
12	4.38	84.92	-	10.69	-
13	6.97	89.29	1.82	1.70	0.20
14	10.21	84.78	3.29	1.30	0.41
15	2.50	97.42	-	0.07	-
16	1.04	98.61	-	0.35	-
17	10.05	85.08	1.53	3.21	0.12
18	16.74	72.54	6.26	4.45	0.01
19	27.94	67.72	0.21	4.08	0.04
20	4.33	95.24	0.02	0.41	-
21	20.17	62.35	17.06	0.14	0.27
22	63.33	32.27	3.74	0.42	0.22
23	41.68	49.22	8.88	-	0.22
24	46.27	45.25	8.47	-	-
25	47.34	49.13	3.49	-	-
26	29.14	67.06	3.80	-	-
27	33.61	64.43	0.84	1.12	-
28	61.91	33.05	4.59	-	0.39
29	38.69	37.58	20.81	2.73	0.18

30	29.90	50.02	20.05	-	0.03
31	24.12	36.58	38.68	0.02	0.60
32	23.18	54.61	20.33	1.87	-
33	12.18	59.83	25.43	2.52	-
34	10.00	44.39	45.61	-	-
35	31.24	40.30	28.43	-	-
36	5.77	35.23	58.24	0.01	0.76
37	11.80	61.14	25.27	1.45	0.34
38	3.66	72.82	22.46	0.85	0.21
39	19.36	75.81	3.78	0.71	0.34
40	20.79	73.15	2.61	2.80	0.64
41	18.89	64.36	8.68	7.83	0.24
42	34.04	50.72	12.12	2.06	1.06
43	38.50	24.70	28.97	4.09	3.74
44	14.96	82.58	2.30	0.16	-
45	58.84	30.84	10.23	0.07	-
46	38.38	35.96	22.28	3.12	0.26
47	43.69	37.50	17.97	0.81	0.04
48	16.10	29.88	51.28	0.38	2.34
49	11.39	21.61	63.40	0.01	3.59
50	18.56	54.16	26.85	-	0.43
51	4.66	13.58	81.71	0.03	0.02
52	5.07	23.81	70.94	0.04	0.13
53	3.45	12.32	83.34	-	0.82
54	10.68	12.31	76.90	0.03	0.08
55	13.24	24.43	62.13	0.01	0.19
56	26.22	61.59	11.64	0.53	0.03
57	38.55	30.40	30.67	0.04	0.34
58	18.64	39.20	42.16	-	-
59	0.33	5.00	94.59	-	-
60	30.29	67.91	1.81	-	-
61	33.10	28.32	37.85	0.01	0.69
62	21.46	71.54	6.68	-	-
63	27.50	46.56	24.08	0.01	1.82
64	12.47	48.42	38.05	0.05	1.02
65	5.21	47.92	44.55	0.06	2.27
66	20.41	62.24	17.23	0.07	0.05
67	28.09	41.13	29.08	0.12	1.58
68	33.95	52.46	13.53	-	-
69	34.32	59.49	6.17	0.01	0.01
70	47.49	30.85	21.59	-	0.04
71	31.02	13.76	55.13	-	0.09
72	13.07	21.77	64.49	-	0.62
73	11.67	18.07	69.67	-	0.59
74	7.75	19.37	72.64	0.01	0.19
75	-	21.51	78.40	-	-
76	27.71	14.31	57.94	-	-
77	17.53	23.36	58.34	-	0.69
78	1.32	98.68	-	-	-
79	20.91	74.64	0.64	3.82	-
80	18.09	81.44	0.22	0.23	0.02
Grand Total	1584.85	4487.31	1871.95	126.45	27.97

Source: Author



Map 1: Mini Watershed Map



Map 2: LU/LC 2016

Hydrologic soil group has categorized for all mini watersheds as given in Table 5 and soil map (Map 3) is also given. Antecedent moisture condition is decided (i.e. AMC-II) on the basis of rainfall in the study area. Finally weighted curve numbers are determined.

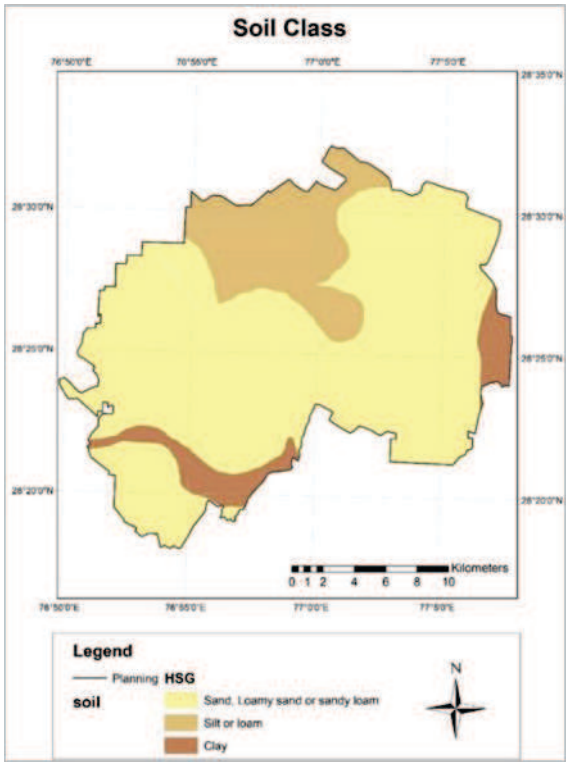
Table 5: Watershed Wise Percentage Of Hydrological Soil Group

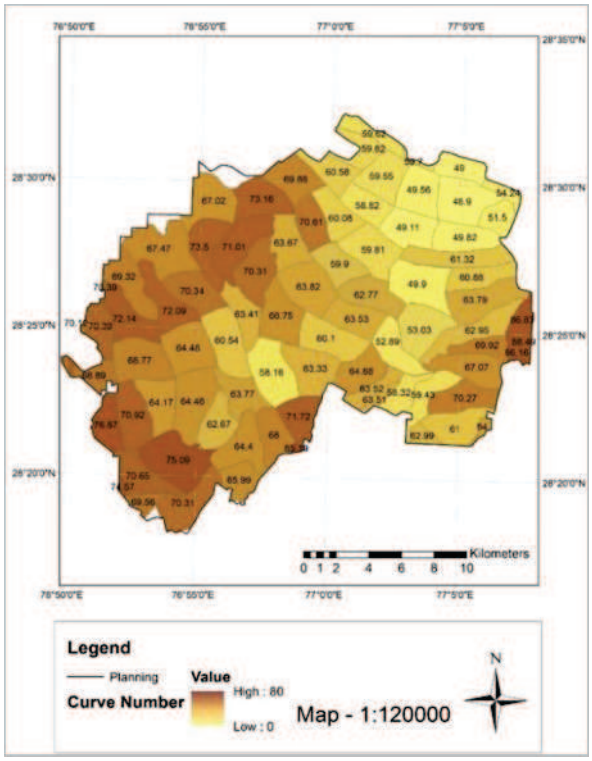
Watershed code	A (%)	B (%)	C (%)	D (%)
0	0.81	99.19	-	-
1	80.42	19.58	-	-
2, 3, 6, 7, 8, 11, 12, 20, 21, 28, 29, 30, 32, 33, 34, 35, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 54,55,58,59, 67,72,73,74, 75,76,77,80	100	-	-	-
4	0.4	99.6	-	-
5	93.55	6.45	-	-
9	1.93	98.07	-	-
10	79.82	20.18	-	-
13,14,38	-	100	-	-
15	0.65	99.35	-	-
16	86.38	13.62	-	-
17	99.91	0.09	-	-
18	92.27	-	-	0.09
19	76.8	23.2	-	-
22,23,25	-	-	-	100
24	96.47	-	-	3.53
26	80.69	-	-	19.31
27	75.44	-	-	24.56

31	99.76	-	-	0.24
36	79.09	20.91	-	-
37	12.23	87.77	-	-
39	4.49	95.51	-	-
40	70.57	29.43	-	-
41	68.7	31.3	-	-
53	79.47	-	-	20.54
56	74.82	-	-	25.81
57	77.21	-	-	22.79
60	86.53	-	-	13.47
61	77.06	-	-	22.94
62	-	-	-	100
63	67.82	-	-	32.81
64	59.49	40.51	-	-
65	16.42	83.58	-	-
66	82.34	-	-	17.66
68	20.41	-	-	79.59
69	59.64	-	-	40.36
70	90.5	-	-	9.5
71	77.11	-	-	22.89
78	13.24	-	-	-
79	39.31	-	-	-

Source: Author (using GIS)

The study area has two types of soil; clay soil and clay loam-sandy clay loam as shown in Map 3. These are categorized in group C and D. Group "C" has low infiltration rate 1-4 mm/hr whereas group "D" has high runoff potential and very low infiltration rates 0-1 mm/hr. Watershed wise curve numbers have been generated (Map 4) where the highest curve number indicates the maximum runoff potential and lowest curve numbers shows low runoff potential.





Map 3: HSG Soil Map **Map 4:** Curve Number

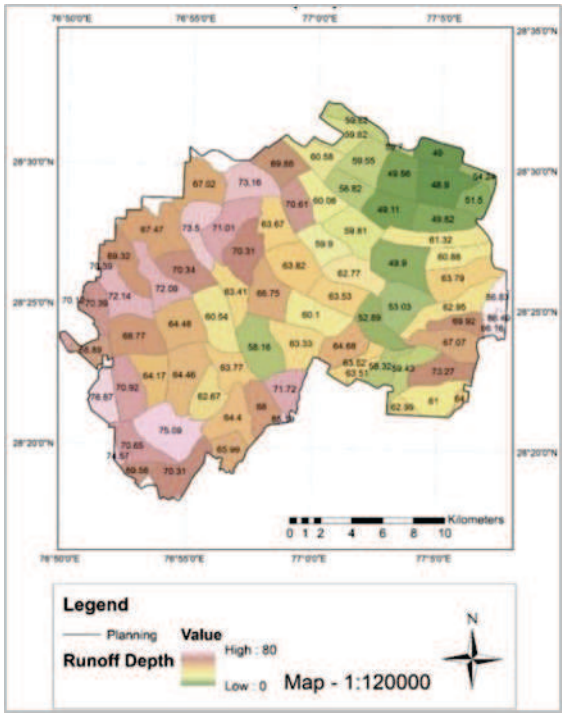
Similarly runoff depth for all 80 mini watersheds has been estimated and map (map 5) has been generated. After estimating the runoff depth, volume of all mini watersheds is estimated by considering storm water duration of 60 days for all micro watershed as shown in (Table 6). Further map (map 6) is also generated.

Table 6: Watershed Wise Weighted Curve Numbers, Runoff Depth and Runoff Volume

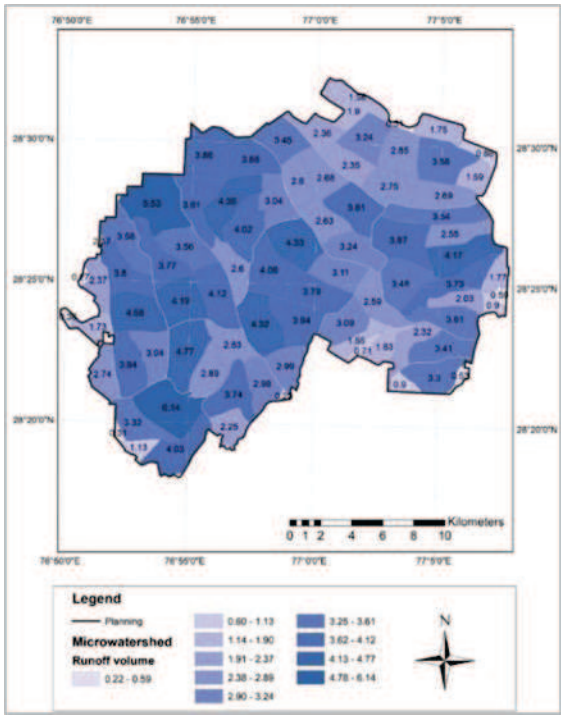
Micro water shed	CN	Potential maximum retention, (cm)	Initial Abstraction (cm)	Precipitation P (cm)	Runoff depth (cm)	Direct Flow Q_d(m)	Storm water Duration (In Days)	area of influence (sq.km)	Runoff volume (Mm3)
0	59.62	17.20	5.16	65.25	48.35	0.48	60	3.26	1.58
1	59.7	17.15	5.14	65.25	48.40	0.48	60	0.64	0.31
2	49	26.44	7.93	65.25	41.62	0.42	60	4.20	1.75
3	54.24	21.43	6.43	65.25	45.11	0.45	60	1.91	0.86
4	59.82	17.06	5.12	65.25	48.47	0.48	60	3.92	1.90
5	59.55	17.25	5.18	65.25	48.31	0.48	60	6.70	3.24
6	49.56	25.85	7.76	65.25	42.01	0.42	60	6.79	2.85
7	51.5	23.92	7.18	65.25	43.33	0.43	60	3.66	1.59
8	48.9	26.54	7.96	65.25	41.54	0.42	60	8.61	3.58
9	60.58	16.53	4.96	65.25	48.90	0.49	60	4.83	2.36
10	58.82	17.78	5.33	65.25	47.89	0.48	60	4.92	2.35
11	49.82	25.58	7.68	65.25	42.19	0.42	60	6.37	2.69
12	49.11	26.32	7.90	65.25	41.69	0.42	60	6.60	2.75
13	69.88	10.95	3.28	65.25	53.73	0.54	60	6.43	3.45
14	70.61	10.57	3.17	65.25	54.08	0.54	60	5.18	2.80
15	60.08	16.88	5.06	65.25	48.61	0.49	60	5.52	2.68
16	59.81	17.07	5.12	65.25	48.46	0.48	60	7.86	3.81
17	61.32	16.02	4.81	65.25	49.31	0.49	60	7.17	3.54
18	60.88	16.32	4.90	65.25	49.07	0.49	60	5.20	2.55
19	63.79	14.42	4.33	65.25	50.66	0.51	60	8.23	4.17
20	49.9	25.50	7.65	65.25	42.24	0.42	60	9.16	3.87
21	58.16	18.27	5.48	65.25	47.50	0.48	60	9.09	4.32
22	86.83	3.85	1.16	65.25	60.84	0.61	60	2.91	1.77
23	86.49	3.97	1.19	65.25	60.72	0.61	60	0.98	0.59
24	67.07	12.47	3.74	65.25	52.35	0.52	60	6.90	3.61
25	86.16	4.08	1.22	65.25	60.60	0.61	60	1.49	0.90
26	69.92	10.93	3.28	65.25	53.75	0.54	60	3.78	2.03
27	62.95	14.95	4.48	65.25	50.21	0.50	60	7.44	3.73
28	64	14.29	4.29	65.25	50.77	0.51	60	1.04	0.53
29	62.99	14.92	4.48	65.25	50.23	0.50	60	1.78	0.90
30	61	16.24	4.87	65.25	49.13	0.49	60	6.71	3.30
31	70.27	10.75	3.22	65.25	53.92	0.54	60	6.33	3.41
32	59.43	17.34	5.20	65.25	48.24	0.48	60	4.82	2.32
33	58.32	18.15	5.45	65.25	47.60	0.48	60	3.84	1.83
34	63.51	14.59	4.38	65.25	50.51	0.51	60	1.41	0.71
35	63.52	14.59	4.38	65.25	50.51	0.51	60	3.07	1.55
36	73.5	9.16	2.75	65.25	55.42	0.55	60	6.87	3.81
37	67.02	12.50	3.75	65.25	52.33	0.52	60	7.38	3.86
38	73.16	9.32	2.80	65.25	55.26	0.55	60	7.02	3.88
39	63.67	14.49	4.35	65.25	50.59	0.51	60	6.01	3.04
40	63.53	14.58	4.37	65.25	50.52	0.51	60	6.16	3.11

41	63.82	14.40	4.32	65.25	50.67	0.51	60	8.54	4.33
42	60.1	16.86	5.06	65.25	48.63	0.49	60	7.79	3.79
43	66.75	12.65	3.80	65.25	52.19	0.52	60	7.83	4.08
44	52.89	22.62	6.79	65.25	44.24	0.44	60	5.85	2.59
45	64.68	13.87	4.16	65.25	51.13	0.51	60	6.04	3.09
46	63.33	14.71	4.41	65.25	50.41	0.50	60	7.81	3.94
47	63.41	14.66	4.40	65.25	50.45	0.50	60	5.15	2.60
48	67.47	12.25	3.67	65.25	52.55	0.53	60	10.53	5.53
49	70.34	10.71	3.21	65.25	53.95	0.54	60	6.59	3.56
50	60.54	16.56	4.97	65.25	48.87	0.49	60	8.42	4.12
51	72.09	9.83	2.95	65.25	54.77	0.55	60	6.88	3.77
52	69.32	11.24	3.37	65.25	53.46	0.53	60	6.70	3.58
53	76.87	7.64	2.29	65.25	56.90	0.57	60	4.81	2.74
54	72.14	9.81	2.94	65.25	54.80	0.55	60	6.93	3.80
55	68.77	11.53	3.46	65.25	53.19	0.53	60	8.61	4.58
56	64.17	14.18	4.25	65.25	50.86	0.51	60	5.99	3.04
57	70.92	10.42	3.12	65.25	54.23	0.54	60	7.27	3.94
58	64.48	13.99	4.20	65.25	51.02	0.51	60	8.20	4.19
59	74.57	8.66	2.60	65.25	55.90	0.56	60	0.55	0.31
60	62.67	15.13	4.54	65.25	50.05	0.50	60	5.76	2.89
61	71.72	10.02	3.00	65.25	54.60	0.55	60	5.48	2.99
62	85.19	4.42	1.32	65.25	60.23	0.60	60	0.36	0.22
63	68	11.95	3.59	65.25	52.82	0.53	60	5.65	2.98
64	70.31	10.73	3.22	65.25	53.94	0.54	60	7.45	4.02
65	71.01	10.37	3.11	65.25	54.27	0.54	60	8.03	4.36
66	64.46	14.00	4.20	65.25	51.01	0.51	60	9.35	4.77
67	63.77	14.43	4.33	65.25	50.64	0.51	60	5.58	2.83
68	65.99	13.09	3.93	65.25	51.80	0.52	60	4.35	2.25
69	64.4	14.04	4.21	65.25	50.98	0.51	60	7.34	3.74
70	70.31	10.73	3.22	65.25	53.94	0.54	60	7.48	4.03
71	75.09	8.43	2.53	65.25	56.12	0.56	60	10.93	6.14
72	69.56	11.12	3.33	65.25	53.58	0.54	60	2.12	1.13
73	70.65	10.55	3.17	65.25	54.10	0.54	60	6.13	3.32
74	70.39	10.68	3.21	65.25	53.98	0.54	60	4.39	2.37
75	70.12	10.82	3.25	65.25	53.85	0.54	60	0.50	0.27
76	70.71	10.52	3.16	65.25	54.13	0.54	60	0.67	0.36
77	68.89	11.47	3.44	65.25	53.25	0.53	60	3.24	1.73
78	59.9	17.00	5.10	65.25	48.51	0.49	60	5.41	2.63
79	62.77	15.07	4.52	65.25	50.11	0.50	60	6.46	3.24
80	53.03	22.50	6.75	65.25	44.33	0.44	60	7.84	3.48

Source: Author (using GIS)



Map 5: Runoff Depth



Map 6: Runoff Volume (Mm3)

All 80 Micro Water Shed is Compiled into 16 Sub Watershed as Shown in Map 1 And Hence The Runoff Volume in Sub Watershed is Calculated and Then Further Analyzed.

Table 7: Runoff Volume at Sub Watershed Level

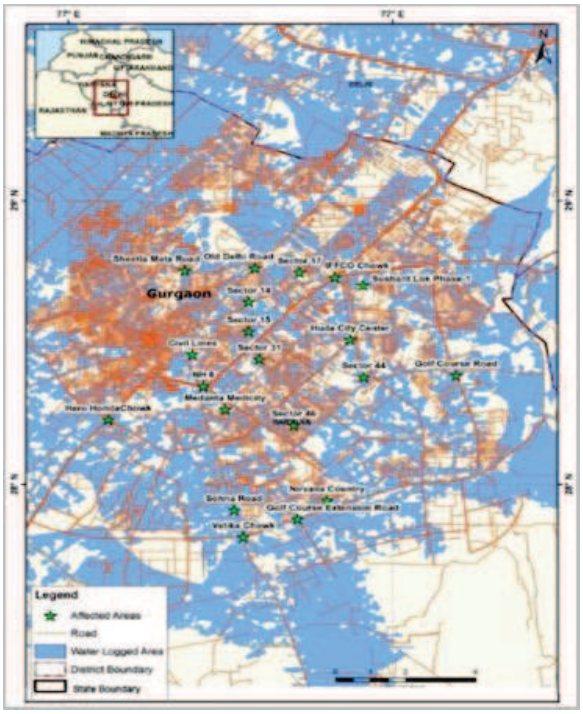
Sub water shed	Micro water shed	Storm days	Area (sq.km)	Runoff volume (Mm3)
2C5F2a	0,1,2,3	60	10.02	4.50
2C5F2b	4,5,6,7,8,9,10,11,12	60	52.39	23.30
2C5F2c	13,14,15,16,78,79	60	36.86	18.61
2C5F2d	36,37,38,39,47,64,65	60	47.92	25.57
2C5F2f	21,40,41,42,43	60	30.32	19.63
2C5F2g	31,32,33,34,35,44,45	60	11.89	15.50
2C5F2h	17,18,19,20,24,26,27,80	60	7.84	26.98
2C5F2j	22,23,25	60	5.37	3.26
2C5F2n	28,29,30	60	9.53	4.72
2C5F2p	48,49,50,51,58	60	40.62	21.16
2C5F2q	60,63,66,67,68,69	60	38.03	19.46
2C5F2r	52,54,55,56,57	60	35.50	18.95
2C5F2t	53,74,75,76,77	60	13.61	7.46
2C5F1g	59,70,71,72,73	60	27.20	14.93

Source: Author (using GIS)

Result:

A.) In 2C5F2h, 2C5Fb & 2C5F2d have a great run off volume watershed due to high densely built up area in the core area of city and maximum areas are located in low lying areas.

2C5F2h watershed have high runoff. This is the same area which got flooded and waterlogged during the rainfall in 2016 (July 27-28, 2016). The worst affected areas include Sector 14, Sector 15, Sector 17, Sector 31, Sector 38, Sector 44, Sector 46, SushantLok Phase-I, DLF areas, Sohna Road, Golf Course Road, IFFCO Chowk, Sheetla Mata Road, Civil Lines and Old-Delhi Road as shown in Map 7.



Map 7: The Water Logged Areas of the City in 2016. (RSMI, 2016)

B.) Total runoff volume from CN method = 231.18Mm^3

C.) Critical Areas have been found out carrying a great runoff volume. This area can be managed through sustainable urban drainage system (SuDS) like swales, filter strips; infiltration devices and constructed wetlands; filtration drains etc.

Conclusion: In this analysis, runoff is mainly depended upon rainfall and soil texture is concluded. To estimate runoff SCS model is used which gives quick estimate of generated runoff in a particular location with reasonably good accuracy but doesn't take into account flow processes due to topographical variations. The GIS technique is useful in spatial intersection of different land use and land cover with various hydrological soil groups in the watershed areas. The results of spatial intersection were used for calculating the weighted curve number (CN) in each watershed. It is found that curve number model predictions are lower than actual observe direct runoff for the watershed. Further on the basis of these weighted curve number, runoff depth and volume of runoff has been calculated. (RSMI, 2016).

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