Modelling and Simulation of Surface Run-off patterns in Hydrological Cycle, DA-IICT

Group 1

SC209

Environmental Studies

-: Made by :-

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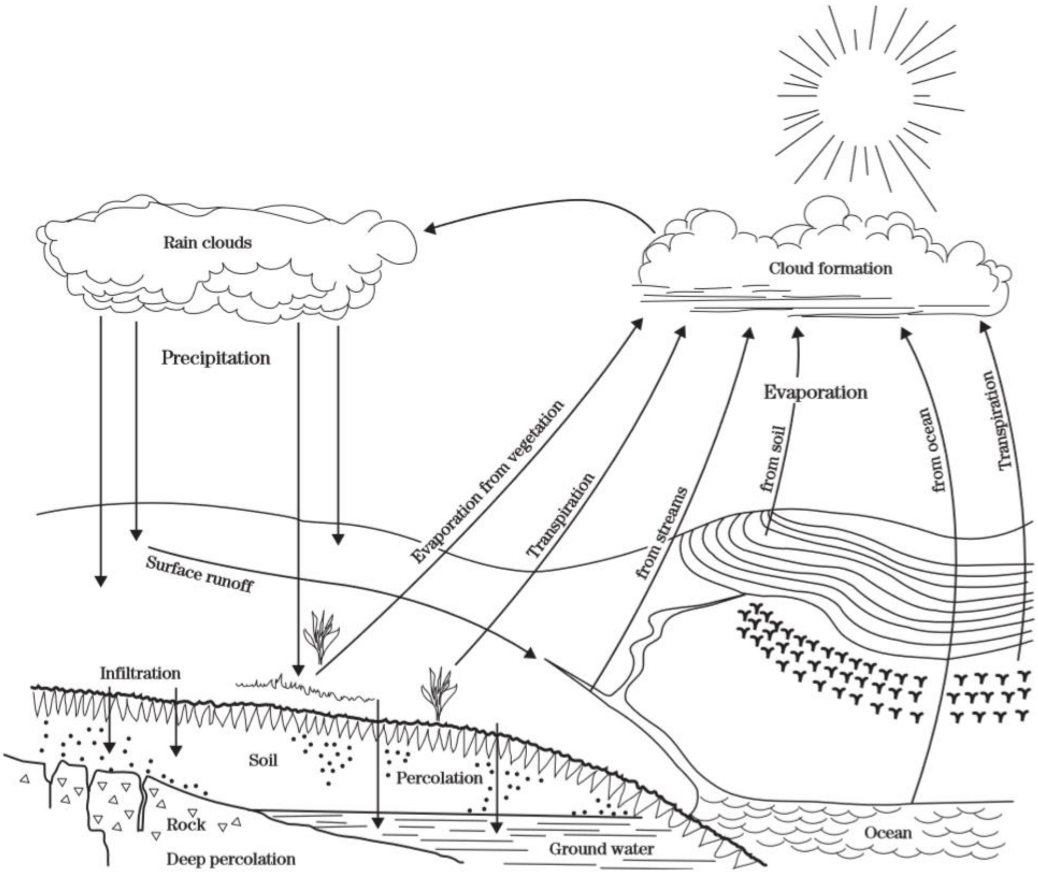
Last but not the least, we thank our benevolent friends and parents, for their persistent backing, all along the way, without which we could not have overcome the impediments in the assembly of this project.

Abstract

(BACKGROUND)

The Hydrological Cycle is one of the most significant ecological cycles. The water cycle is essential for the maintenance of most life and ecosystems on the planet. It is one that shapes the rate of growth and determines the nature of lifeforms pertaining to an ecosystem. Hydrological cycle describes the continuous movement of water on, above and below the surface of the Earth. It majorly consists of the following factions, which are quite interlinked:

1) Evaporation
2) Condensation
3) Precipitation
4) Percolation and infiltration
5) Plants uptake
6) Run-off



Our focus remains on that component of the hydrological cycle, which is responsible for transporting the water back to the reservoirs from where the cycle began, i.e., Surface runoff. The Surface Water runoff - generation process, is highly complex, nonlinear, dynamic in nature, and is affected by many interrelated physical factors. Further, the temporally and spatially variable nature of these factors, causes more uncertainty in the parameterization of the model. Therefore, modelling the runoff becomes a more challenging task. However, with present technological capabilities, computing techniques and software tools, it is possible to identify, assess and understand the response of the dominant processes rather accurately.

Over the years, the water cycle has changed drastically, as a result, producing far-reaching and adverse environmental effects. However, majority of the concerning talk about Hydrological cycle disturbance was historically rhetorical and not backed by Science and facts, which had led to its not so strong stance. Hence, a need was felt to produce a mathematical model that could simulate to a remarkable degree of accuracy the above-mentioned components of the cycle, so that the effects of changes in environmental as well as management parameters, could be quantified and appropriate policies could be formulated.

SWRRB stands for Simulator for Water resources in rural basins, which is such a model, that was developed for simulating hydrological and related processes in rural basins. It has now been expanded for generic areas as well. This model was developed to mathematically simulate various factions of the hydrological cycle. The objective was that, with the help of these simulations, we could accurately measure the effects of change in various parameters (of the equations) on the hydrological cycle, which would have arisen due to change in management practices.

For achieving this objective, the simulator had to be:

1) Empirical-based, backed with science
2) Computationally capable of quantifying the effects of changes in conditions
3) Computationally efficient.
4) Economically feasible to implement.
5) Capable for simulating long periods, for use in frequency analysis.

The processes which are simulated using the SWRRB Model are:

1) Surface Runoff
2) Percolation
3) Return Flow
4) Evapotranspiration
5) Transmission Losses
6) Reservoir Storage
7) Sedimentation
8) Crop Growth

Surface Runoff is modelled using one specific technique that is part of the SWRRB Model, called the Curve Number Technique. However, before we proceed into that, in order to model Run-off, one needs to first understand the essence of water balance equation. Water Balance equation is basically mass conservation law, where the total amount of water remains conserved and hence, we can write an equation for the final soil water content.

The **Water Balance equation** is:

$$\mathbf{SW_t = SW + \sum_{i=1}^{t}(Ri - Qi - ETi - Pi - QRi)}$$

Where SW_t is the Soil Water content in inches on t^{th} day. It is logically speaking, the Intial Soil Water Content, in addition to all the changes that might have taken place till the t^{th} day. The final content is therefore, the **total daily rainfall (R)**, from which, some of the water content is leached out through **percolation (P)**, some through **evapotranspiration (ET)** and the rest through **Surface runoff (Q**) and **return flow (QR)**, all expressed in their daily amounts in inches. The essence here is that any particular amount of any of the above factors, can be deduced from the total input minus whatever amount is lost through various processes.

In this project, we model Surface Run-off in the hydrological cycle. Surface runoff or overland flow occurs when the rainfall rate is greater than the infiltration rate. This might occur because soil is saturated to full capacity, because rain arrives more quickly than soil can absorb it, or because impervious areas (roofs and pavement) send their runoff to surrounding soil that cannot absorb all of it. Surface runoff is a major component of the water cycle. It is the primary agent in soil erosion by water. This type of runoff appears in the hydrograph after the initial demands of interception, infiltration, and surface storage have been satisfied.

Thus, we may conclude, *from the essence of water balance equation, that the Total runoff should be the total rainfall that occurs, minus the amount of water that goes in through percolation, the amount that is taken up by plants and also the amount of water that is stored in the soil.* This is exactly the basis for the equation of surface runoff, as we shall soon see.

So, without further ado, let's introduce the project.

Introduction to the Project

To model run-off, the technique used is called Curve Number Technique, or more specifically: **Soil Conservation Service (SCS) Curve Number Technique.** Accurate runoff estimation is prerequisite for effective management and development of water resources. Many methods are being used to estimate runoff in literature; however, the SCS-CN method still remains the most popular, fruitful and frequently used method. The major reasons for this popularity may be attributed to ease of use, lesser number of input parameters, robustness of model results, and acceptability among both researcher and practitioner community. The curve number **technique relates runoff to soil type, land use and management practices.** It is also reliable and computationally efficient.

It computes the surface runoff volume for a given rainfall event from small agricultural, forest, and urban watersheds. The method is simple to use and requires basic descriptive inputs that are converted to numeric values for estimation of direct runoff volume. **Curve number indicates runoff potential of land area** and it is the function of

1) Hydrologic soil group.
2) antecedent rainfall
3) land use pattern
4) density of plant cover
5) conservation practices followed in the land area.

Generally, with time, all these patterns keep on changing and there is an impact on the runoff volume from that particular area. By observing the patterns of runoff from catchments, the United States Conservation Service developed an empirical method to model it. This technique produces quite useful results. The attractive feature of the SCS-CN method is that it integrates the complexity of runoff generation into single parameter, i.e. CN.

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad P > I_a \qquad [10\text{–}1]$$

$$Q = 0 \qquad P \le I_a$$

where:
Q = depth of runoff, in inches
P = depth of rainfall, in inches
I_a = initial abstraction, in inches
S = maximum potential retention, in inches

$$S = \frac{1000}{CN} - 10$$

CN generally has a range from 30 to 100; lower numbers indicate low runoff potential while larger numbers are for increasing runoff potential. The lower the curve number, the more permeable the soil is.

Thus, S is related to curve number, which for a given hydrologic soil type, given land use pattern, and given kind of vegetation and also the degree of moisture, is fixed and can be easily obtained. Therefore, the efforts now, were to model these empirical equations.

Our endeavours in this project, in brief, are as follows: -

1) The first task was to procure the data of rainfall at DA-IICT. Since, we can't directly do that, we obtained the daily rainfall amounts from different measuring stations, which are placed at different directions to DA-IICT. The objective was to use these various data points and apply geostatic analysis techniques to measure rainfall at different locations within the campus.

2) The daily data of rainfall amounts was obtained from these stations:
   a. Sanand
   b. Ahmedabad
   c. Khedbrahma

3) For each measuring station, we plotted the recorded amounts of daily rainfall for 4 months – June, July, August and September from 2009-2018. Thus, we have 122 x 10 = 1220 data points for each station. We aimed to find the envelope of the curve for this data set (daily rainfall amount vs. time) and applying time-scale prediction techniques (LSTM), predict the daily rainfall for DA-IICT, accounting for both temporal and spatial variations. This was done for all the stations and we took the appropriate contributions from each. By this, we were able to predict how much rainfall would be expected on which day and thereby, correctly estimate runoff from different locations at different times.

4) Having done the rainfall estimations at different locations with time, we also realized that since the terrain of DA-IICT, broadly varies from Lawns, to shrubbery, to impervious spots and also roads and pavements, we needed to find out the run-offs from all these spots individually, taking into account the differing Curve numbers of these regions. This is because, only then could we actually estimate the locations from where the runoff would be highest. Note that, here we made an experimental assumption that the initial abstraction of water by the plants, is 0.2S, which has been found to hold good in multiple practical scenarios.

5) We got a satellite view of DA-IICT Campus from google earth. We measured the areas of these components, using the given map-scale:

a. Open Lawn
b. Cafeteria (Outer, since inner is impervious)
c. Shrubbery (majority portion)
d. Roads and pavements
e. Impervious areas

For each of the above areas, we estimated the corresponding Hydrologic Soil Group, the pattern of Land-use, the kind of vegetation, and thereby, obtained the CN values for each zone.

6) We calculated the areas in the form of percentage of total area. We found out the CN values for each of the areas, and formulated a weighted CN for the entire campus. This weightage gives us an approximation, of the kind of terrain we have at DA-IICT. This parameter would give us, for an average rainfall over the campus, the average run-off per day.

7) Having obtained the CN values, using the predicted values of rainfall for different regions on campus, we calculated the expected runoff from different locations, with time, for the monsoon season 2019.

8) Having obtained the runoff depth, we obtained the volume of water runoff from each sector. Now, the water that falls, doesn't run away uniformly, rather there is a formation of network of streams, which transports the water. Various runoff regions, lead to formation of higher order streams and there is an outflow point where the water concentrates. We found out the network of streams and direction of flow, using the elevation profile of the campus, obtained from Google Earth, using Surfer software.

9) Thus, eventually, we obtained the expected runoff volume and the point where this water exits, so that preventive measures can be exercised here.

Data Obtained

Here are the Curve number values for a given Hydrologic Soil type, given landuse pattern, given nature of vegetation and antecedent soil moisture condition (AMC):

Table 2-2a Runoff curve numbers for urban areas [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.
2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2b Runoff curve numbers for cultivated agricultural lands [1]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment [2]	Hydrologic condition [3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

[1] Average runoff condition, and I_a=0.2S
[2] Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.
[3] Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 2-2c Runoff curve numbers for other agricultural lands [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm). [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.

2 ***Poor:*** <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.

3 ***Poor:*** <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

4 Actual curve number is less than 30; use CN = 30 for runoff computations.

5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

6 ***Poor:*** Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

2) The Topography of DA-IICT[1]

CONSIDER SHED HOUSE AS LAWN

OUTER CANTEEN TILL ROAD STARTS

Total area =213404.19 m² ≅ 60 acers (online data)

1) Girls HOR +sac 2 = 3551.80 m²
2) Four buildings (CAMPUS RESIDENCY) = 690.14m2
3) Sac +OAT=3001.99 m²
4) Basketball=1057.58 m²
5) RC=716.55 m²
6) Fb1=305.11 m²
7) FB2=278.08 m²
8) NAAC (FB3) = 359.76 m²
9) FB1=439.42 m²
10) Academic block=532.96 m²
11) CEP mid=3374.92 m²
12) Inner canteen=916.59 m²
13) HOR men – g wing-h wing=4889.09 m²
14) H wing =641.09 m²
15) G wing =725.51 m²
16) LAB =2998.62 m²
17) LT 2 and 3=1297.25 m²
18) LT 1=519.10 m²
19) DA POWER SUPPLY=172.02 m²
20) OUTER CAFÉ=1399.58 m²
21) ROAD=10710.99 m²
22) FOOTBALL GROUND=14824.96 m²
23) ENTRANCE (RIGHT)=1646.27 m²
24) ENTRANCE (LEFT)= 3961.65 m²
25) LP=713.27 m²
26) PAVEMENT =3132.65 m²
27) LAWN OUTSIDE LT=1188.65 m²
28) Side of LT1=521.18 m²
29) Outside lab=376.55 m²
30) Behind Ravan dahan area (consider as lawn) = 521.18 m²
31) For jungle subtracting from total area

[1] Data obtained from Google Maps, followed by analysis by Jay

3) Values relevant to us:

1. Café outer only	1399.58 m²=0.66%
2. Open lawn	14824.96 m²+1646.27 m²+3961.65 m²+1188.65 m²+521.18 m²+376.55 m²+521.18 m²=23040.44 m2= 10.8%
3.Shrubbery	213404.19 m²-(1399.58 m²+23040.44m2+10710.99m2+3132.65 m²+26,467.58m2)-713.27(LP) =147939.68 m²=69.32%
4. Road	10710.99 m²= 5.02%
5. Pavement	3132.65 m²=1.47%
6.Impervious	3551.80m2+690.14m2+3001.99 m²+1057.58 m²+716.55 m²+305.11 m²+278.08 m² +359.76 m²+439.42 m²+532.96 m²+3374.92 m²+916.59 m² +4889.09 m²+641.09 m²+725.51 m²+2998.62 m²+1297.25 m²+519.10 m²+172.02 m² =26,467.58m2 = 12.40% 6. LP= 713.27 m² = 0.33%

4) Data of daily rainfall for the last ten years was obtained from Geo-spatial Lab, DAIICT.
5) The values of elevation of various points on campus, as well as areas of individual establishments, were obtained from Google Earth.

Methods Used

1) **MATLAB:**
    a. We compiled the data of 4 months for each year, appended the data of the 4 months for the next year, and continued with it. This data was plotted (Rainfall depth in inches vs time) on MATLAB.

2) **Google Earth:**
    a. To find the geometrical areas of various establishments on campus, for each of the sector.
    b. To find the elevation of various points, across the campus.

3) **Google Maps:**
    a. To join the measuring stations and applying the median method for determining the weightage of each station on the campus.
    b. Used Geostatical Analysis methods.

4) **Python:** To predict the runoff for the incoming monsoon season, LSTM implemented.

5) **Surfer:**
    a. To find the contour plot for the campus.
    b. Using the elevation profile, to find the pattern of flow network of the runoff water on campus.

Analysis

Since, we can't directly measure the rainfall of DA-IICT, we obtained the daily rainfall amounts from different measuring stations, which are placed at different directions to DA-IICT. We took the rainfall, accounting for both daily variations and the location (which campus zone) of rainfall.

We divided the DA-IICT Campus into 3 regions for the purpose of geometrical analysis:

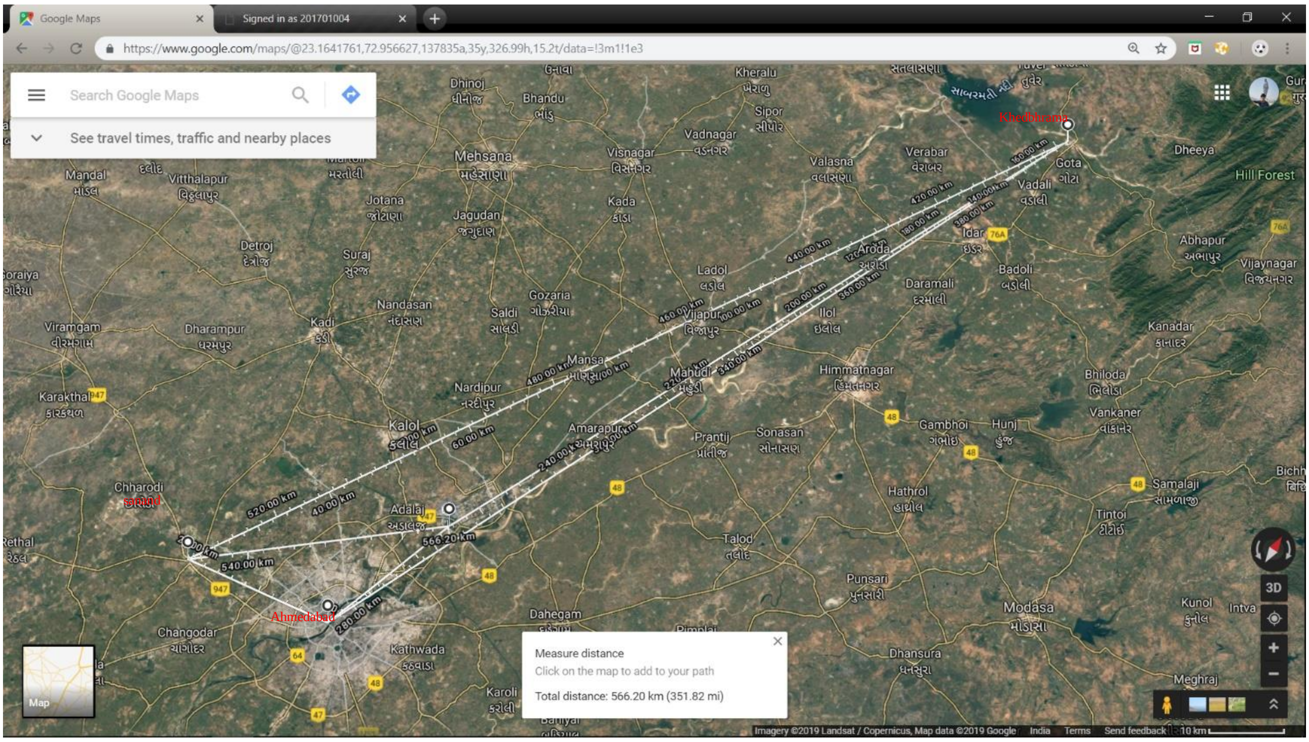
1) Ahmedabad
2) Sanand
3) Khedbrahma

Geometrical Analysis:

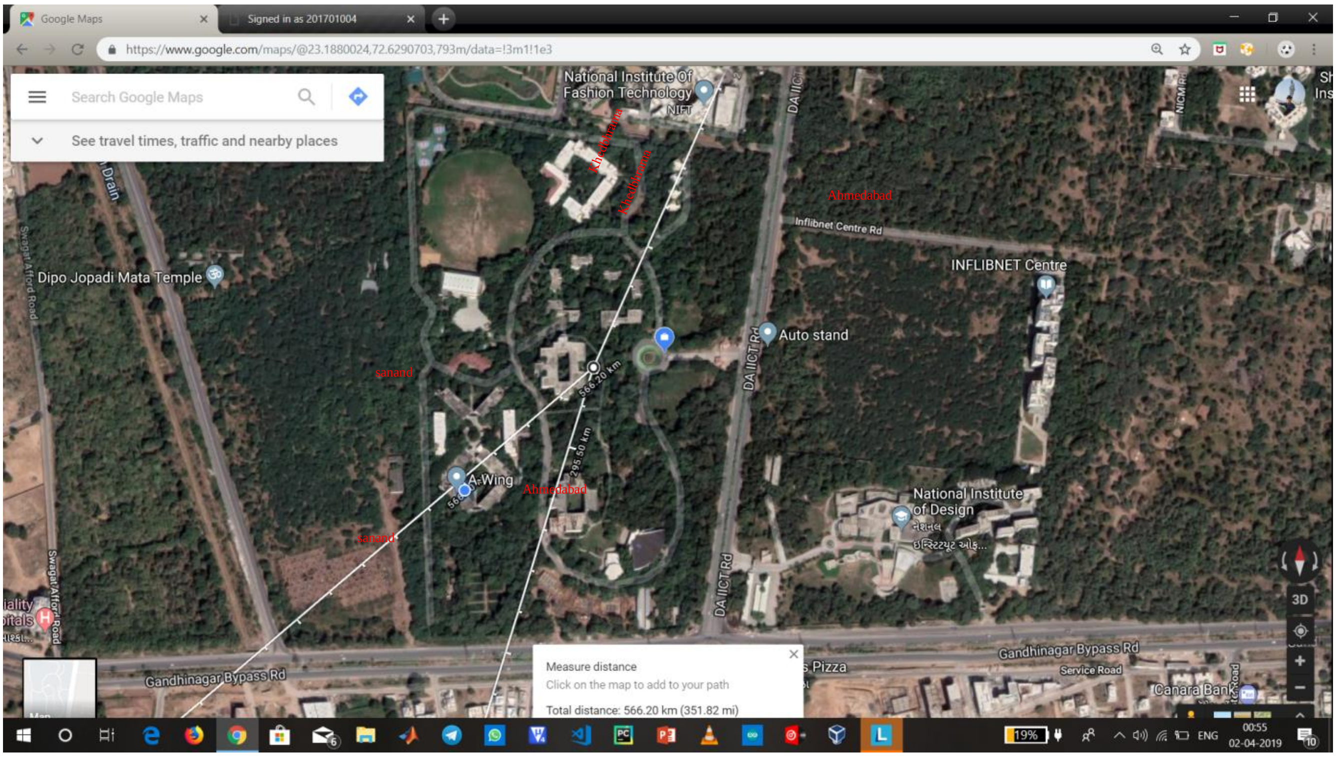
1) We obtained the map of DA-IICT and the measuring stations, using google maps. We joined the three measuring points to the approximate geometrical centre of the campus.

2) We then joined the adjacent measuring stations, thereby obtaining 3 triangles. The medians of the triangles formed, helped us to divide the campus of DA-IICT, into 3 triangular zones, such that they can be modelled by rainfall corresponding to the rainfall data of the three corresponding stations.

Whole triangle at tilted earth view



How the medians of the 3 triangles above, divided the campus:

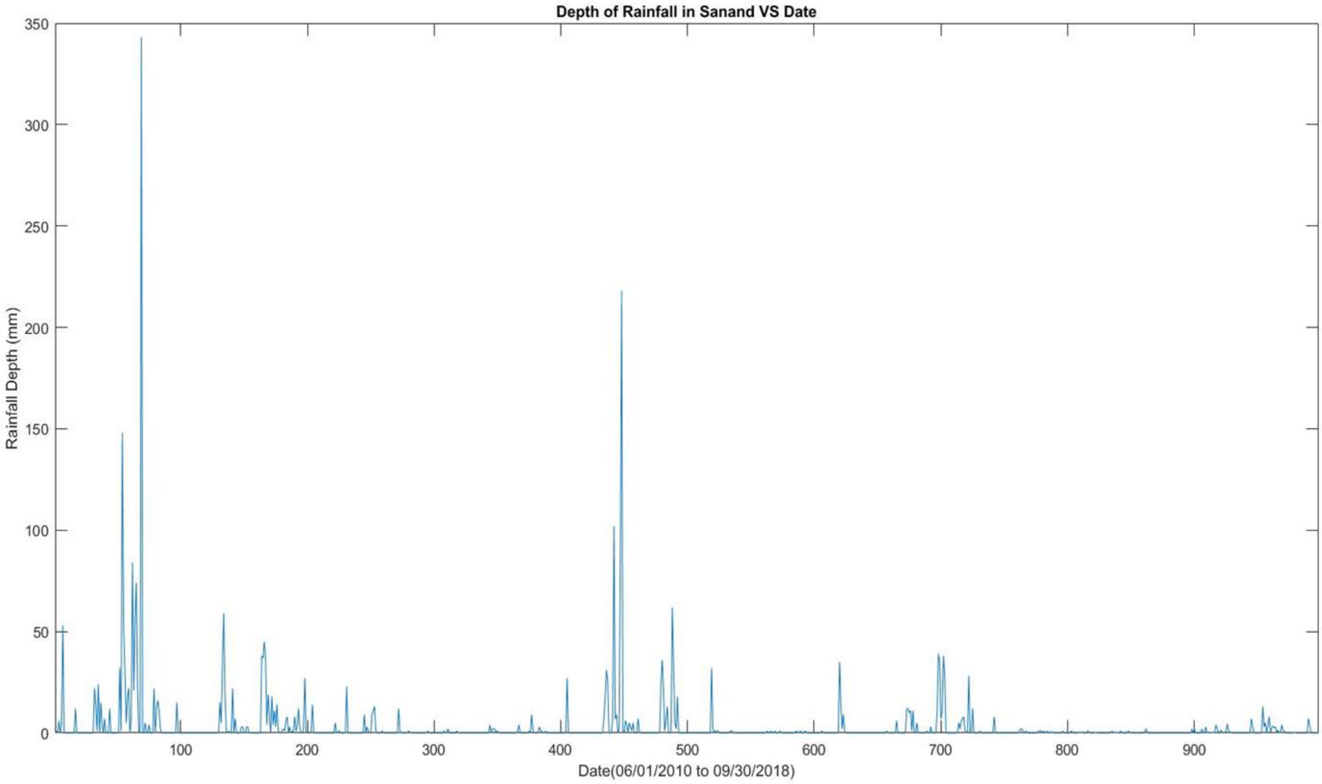


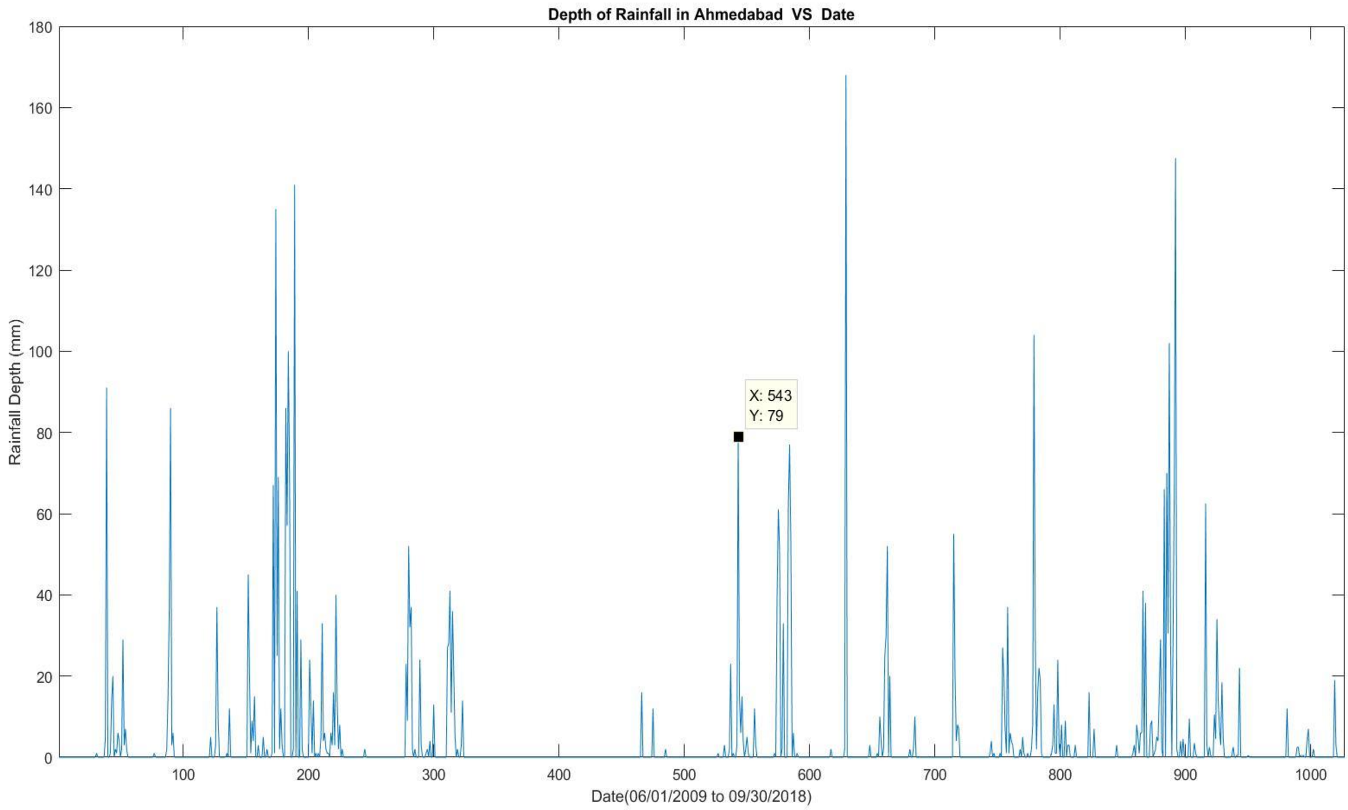
3) The 3 sectors that we made, broadly consist of the following establishments:

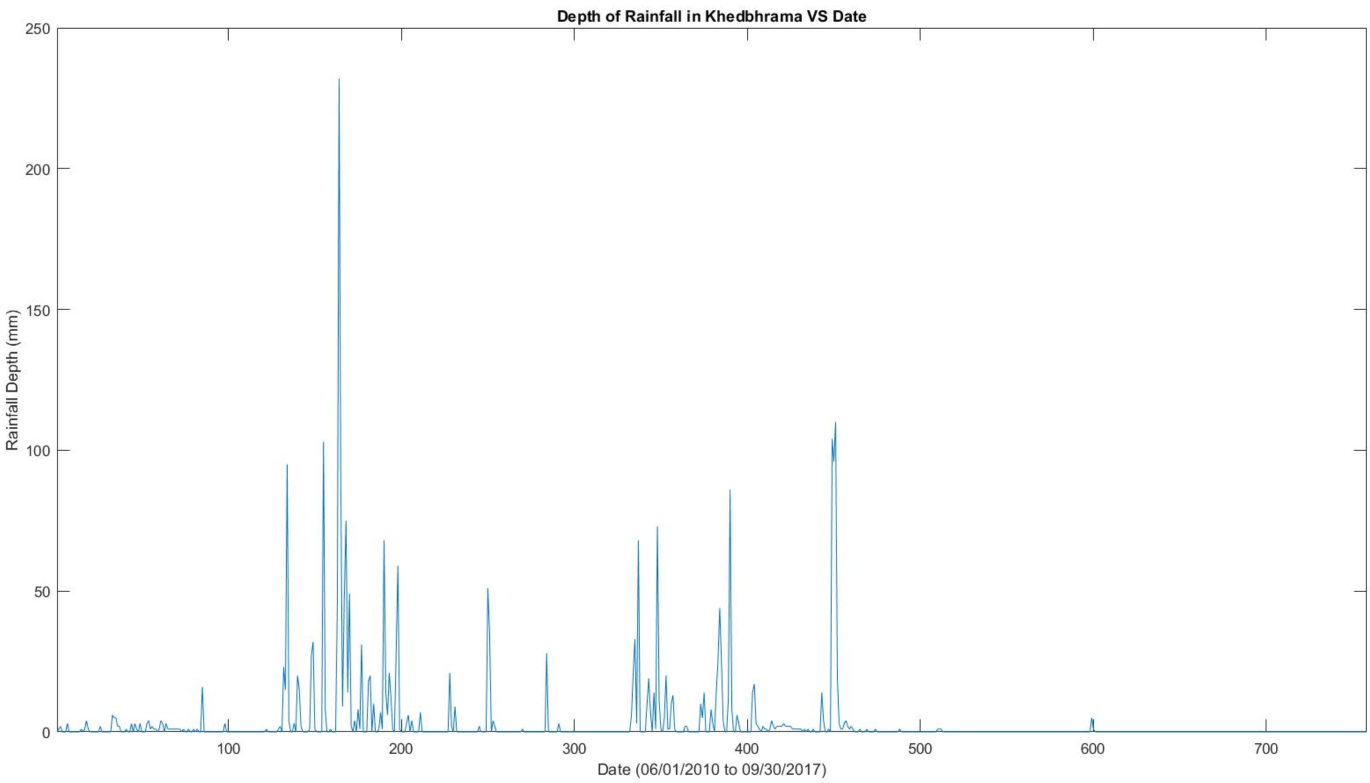
Sector 1	Ahmedabad	Shrubbery, Pavement, Roads, Impervious (All LTs, Faculty Block1, RC B block, DA-IICT Power Supply), Complete Lab, Lotus Point, Lawns (While entering the Campus, Outside LTs)
Sector 2	Sanand	Impervious (All hostels, A block of RC, SAC1, SAC2, OAT, CEP, Faculty Block 2,4, NAAC, Basketball court, Admin Block), Cafeteria, Playground (Lawn), Shrubbery, roads, pavements
Sector 3	Khedbrahma	Campus Residency, Roads, Shrubbery, Bridge of RC

4) For each day, there are variable number of samples of rainfall taken. All the data we obtained, represented cumulative rainfall and since we needed a daily time step, i.e., a time interval of 1 day, the difference of the precipitation values of the first and last samples of the day were taken. The above for June, July, August and September, thereby yielding 122 data points on average. Doing the same for 10 years, gave us 1220 data points, for each measuring station, thus a total of 3 plots. This data therefore represents the history of rainfall at DA-IICT, in its corresponding zone as mentioned above.

Daily rainfall plots for the three sectors



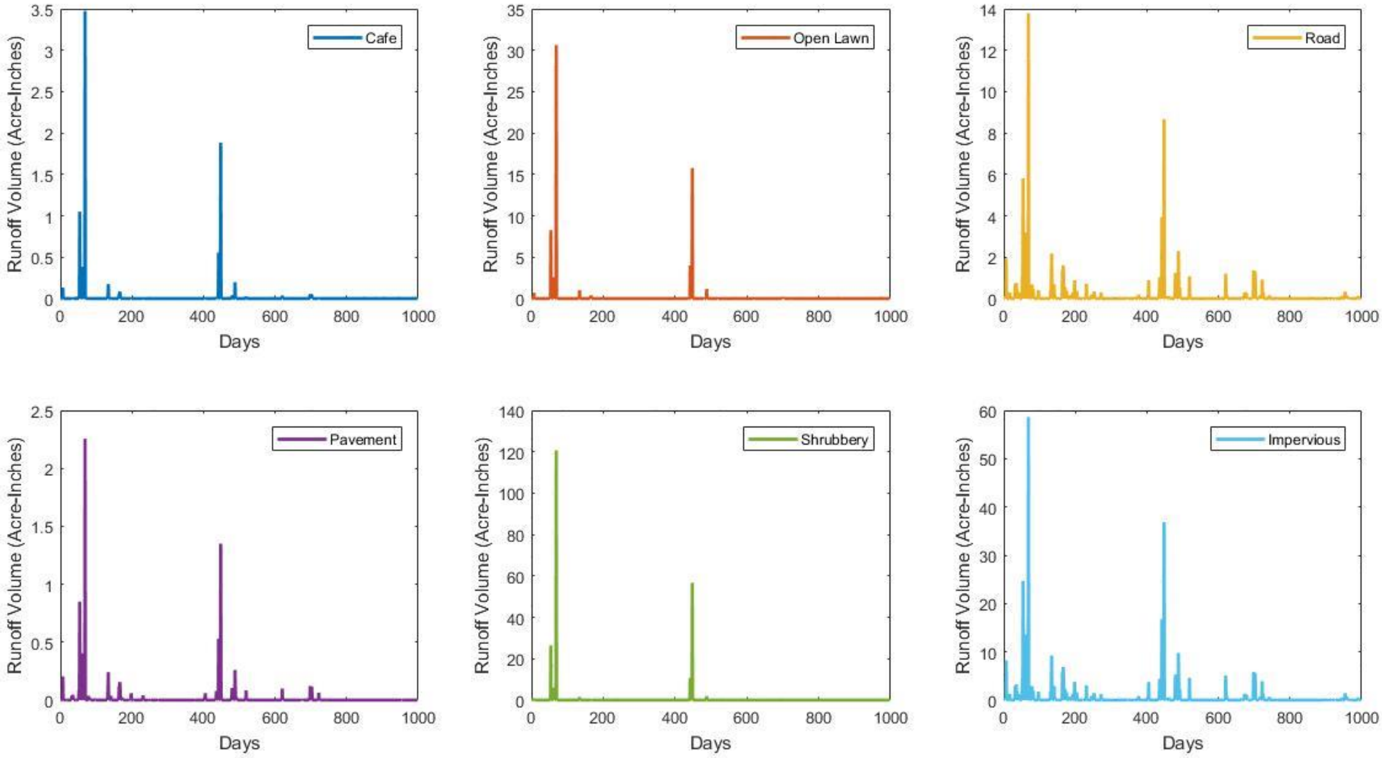

Depth of Rainfall in Ahmedabad VS Date
Rainfall Depth (mm)
Date(06/01/2009 to 09/30/2018)
X: 543
Y: 79
0
20
40
60
80
100
120
140
160
180
100
200
300
400
500
600
700
800
900
1000


Depth of Rainfall in Khedbhrama VS Date
Rainfall Depth (mm)
Date (06/01/2010 to 09/30/2017)
0
50
100
150
200
250
100
200
300
400
500
600
700

5) Now, the Terrain of DA-IICT has been divided into the following categories:

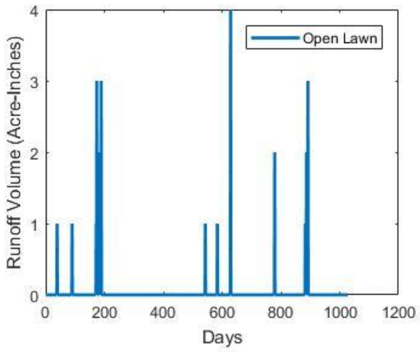
Index Alotted	Kind of terrain	Hydrologic Soil Group	Curve Numbers (CN-II)[2]
1	Café (Outer)	A	74
2	Open Lawns	B | C	67.5
3	Roads	B	98
4	Pavements	C	89
5	Shrubbery	B	58
6	Impervious	A | B | C | D	98

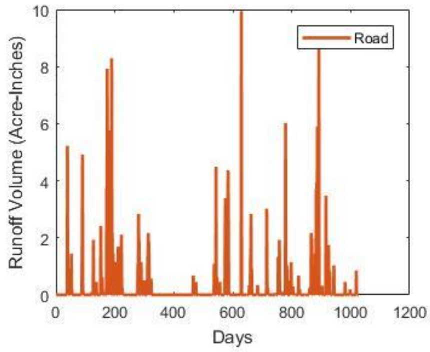
6) Using the data of rainfall for each of the 3 sectors and the corresponding topographical features, we computed Runoff volume for each kind of terrain in each sector, by multiplying the runoff depth with corresponding areas, i.e.:
   - **a.** Sanand Sector: Has values valid for all the kinds of terrains at DA-IICT
   - **b.** Ahmedabad Sector: Has values valid for all kinds of terrains except Cafeteria.
   - **c.** KhedBrahma Sector: Khedbrahma, only comrprises Shrubbery, Roads and Impervious establishments and hence runoff is for the same.

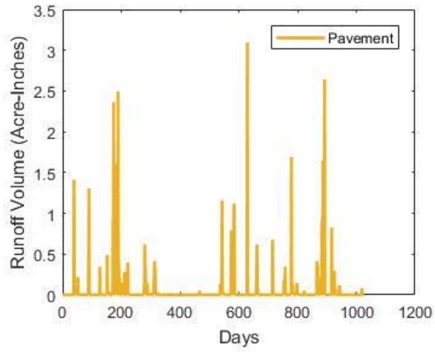


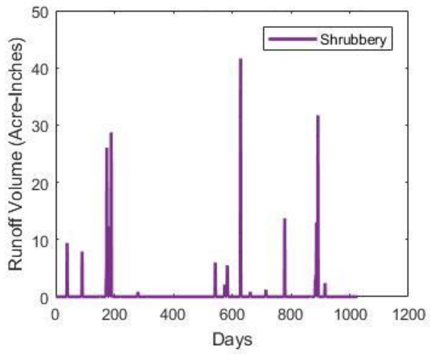
2 https://en.wikipedia.org/wiki/Runoff_curve_number

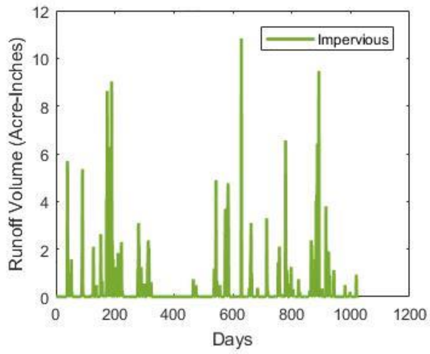
Runoff for Sanand Sector



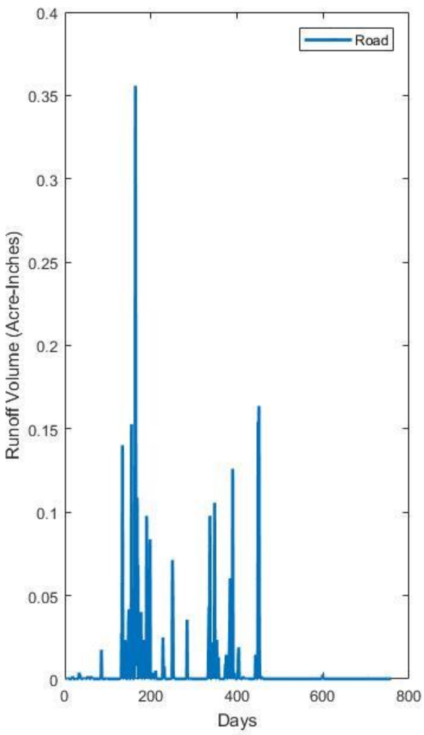


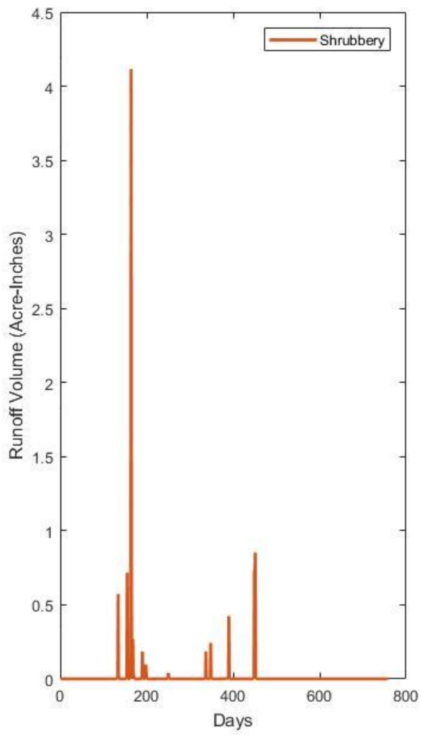


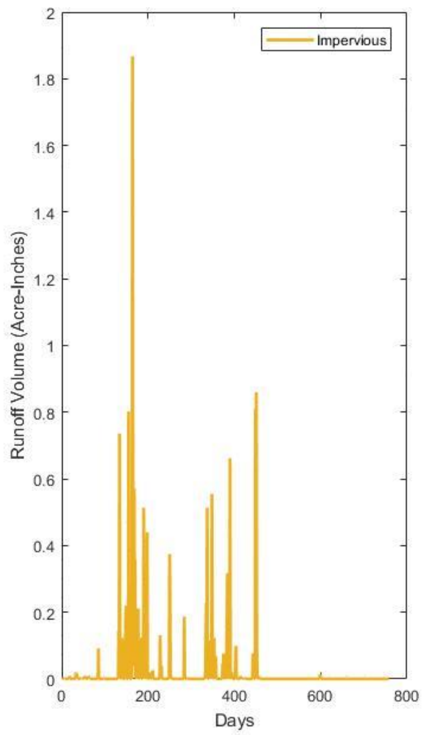




Runoff for Ahmedabad Sector







Runoff for Khedbrahma Sector

7) Till now, the analysis involved calculation of runoff, from the procured values of rainfall and obtaibed/estimated values of other parameters. Now, in order to find the rainfall for this year, keeping in find, the three requirements:
   - **a.** How much rainfall occurs.
   - **b.** What time it occurs
   - **c.** Which place it occurs in.

   Now, the above was predicted, using time-scale prediction techniques of Machine Learning, namely LSTM. The basic algorithm of LSTM is as follows:

LSTM: Long Short-Term Memory[3]

Long Short-Term Memory (LSTM) networks are an extension for recurrent neural networks, which basically extends their memory. Therefore, it is well suited to learn from important experiences that have very long-time lags in between.

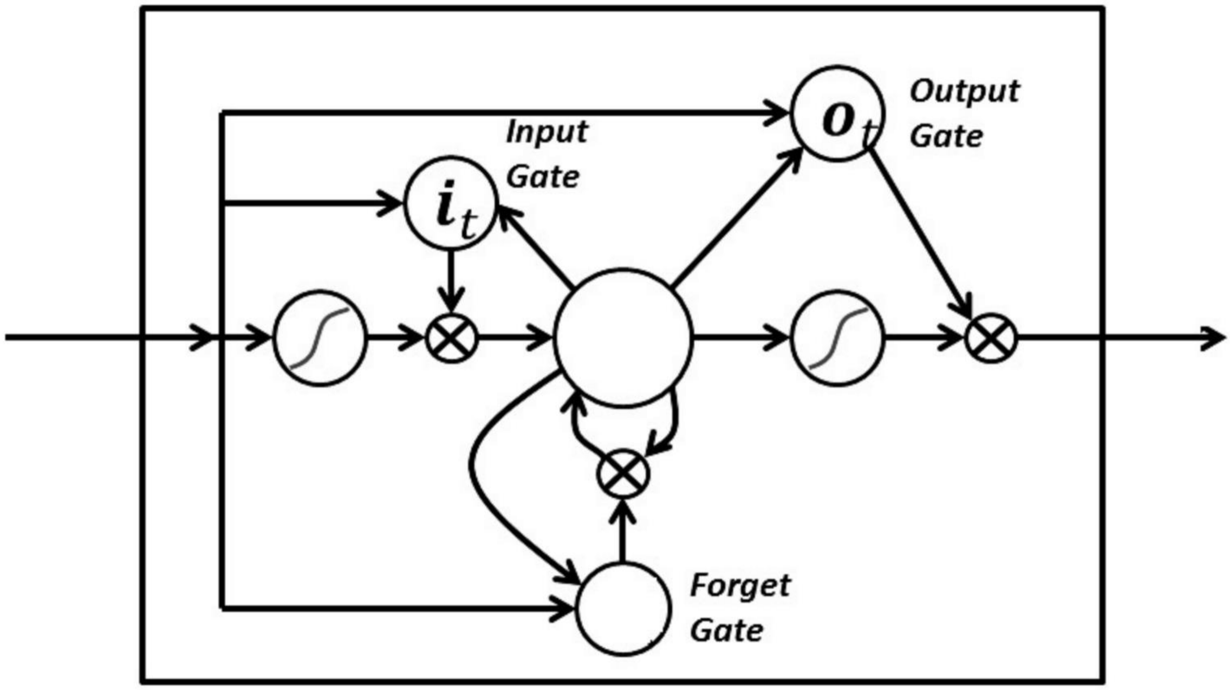
The units of an LSTM are used as building units for the layers of an RNN, which is then often called an LSTM network.

LSTM's enable RNN's to remember their inputs over a long period of time. This is because LSTM's contain their information in a memory, that is much like the memory of a computer because the LSTM can read, write and delete information from its memory.

This memory can be seen as a gated cell, where gated means that the cell decides whether or not to store or delete information (e.g if it opens the gates or not), based on the importance it assigns to the information. The assigning of importance happens through weights, which are also learned by the algorithm. This simply means that it learns over time which information is important and which not.

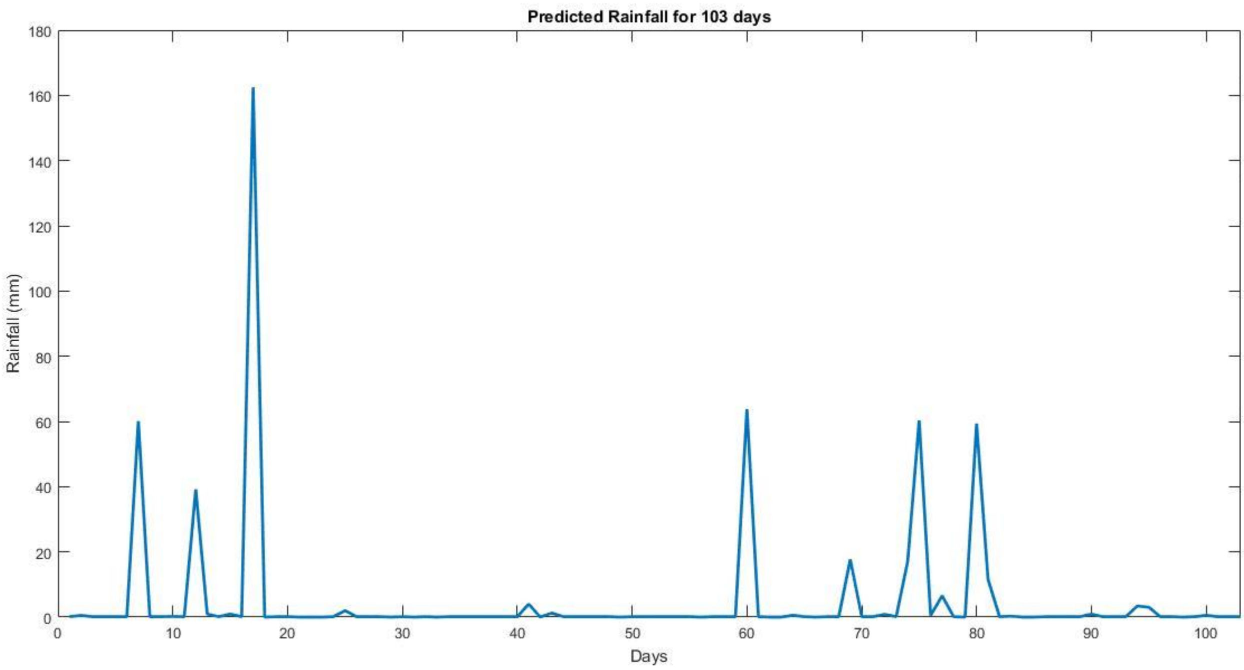
In an LSTM you have three gates: input, forget and output gate. These gates determine whether or not to let new input in (input gate), delete the information because it isn't important (forget gate) or to let it impact the output at the current time step (output gate). You can see an illustration of a RNN with its three gates below:

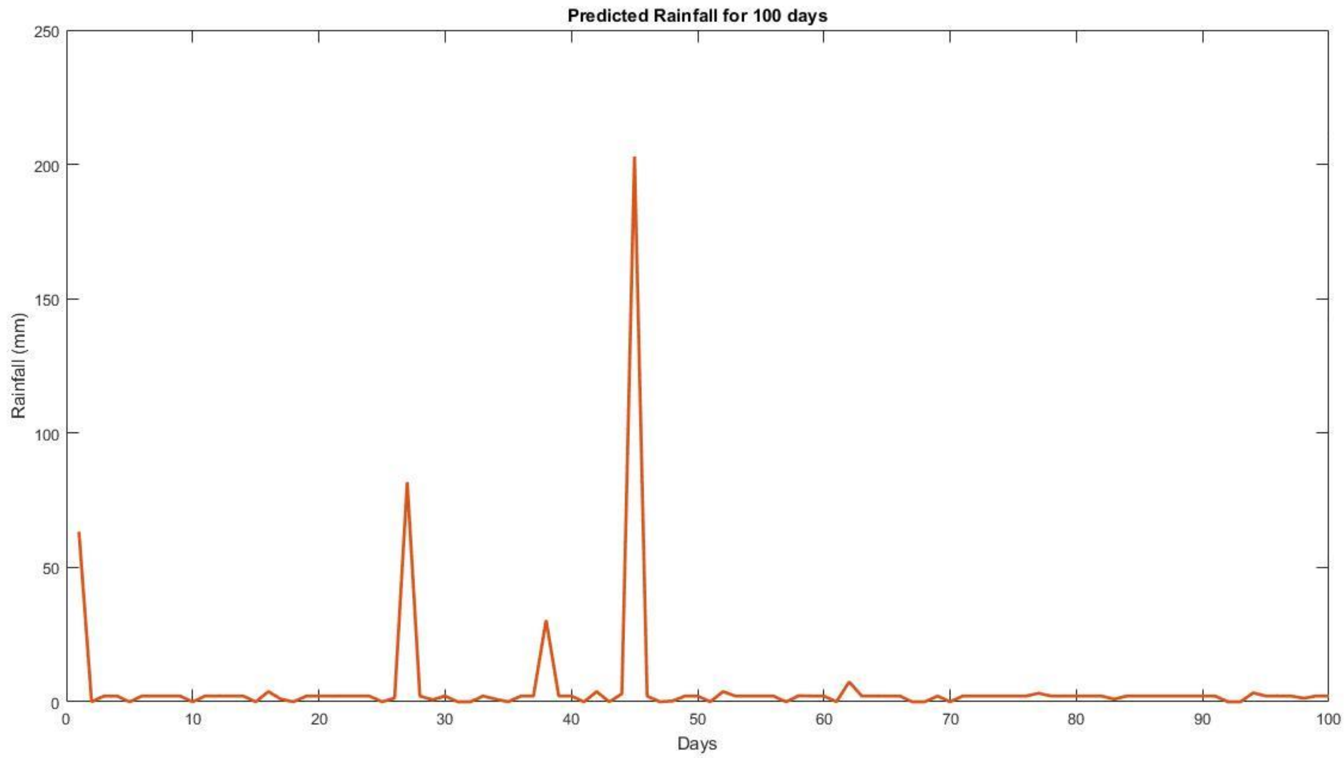
[3] https://towardsdatascience.com/recurrent-neural-networks-and-lstm-4b601dd822a5

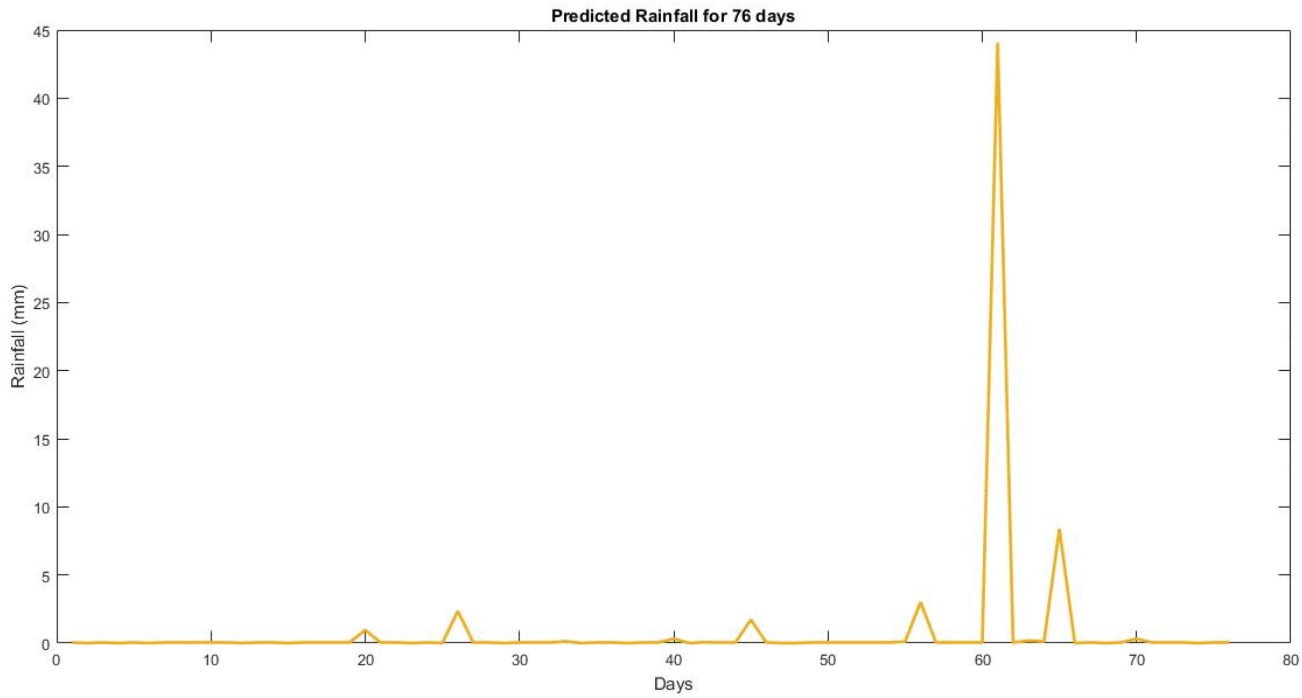


The gates in a LSTM are analog, in the form of sigmoids, meaning that they range from 0 to 1. The fact that they are analog, enables them to do backpropagation with it. The problematic issues of vanishing gradients is solved through LSTM because it keeps the gradients steep enough and therefore the training relatively short and the accuracy high.

8) Having applied LSTM technique, we found out the rainfall depth for June-Sept 2019, for **Ahmedabad, Sanand & Khedbrahma sectors respectively**, plotted them and thereby calculated the expected runoff volumes in DA-IICT, for each sector, for the different kinds of terrains.





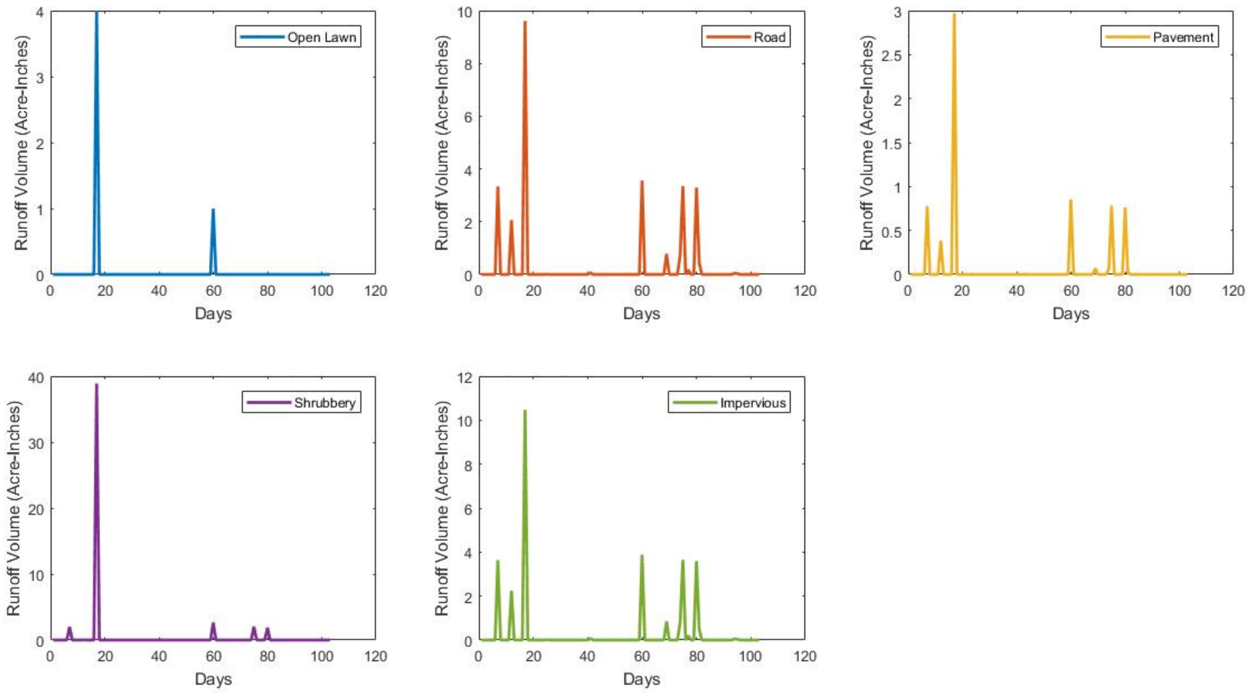


Root Mean Square Errors in prediction of Rainfall (Percentage)

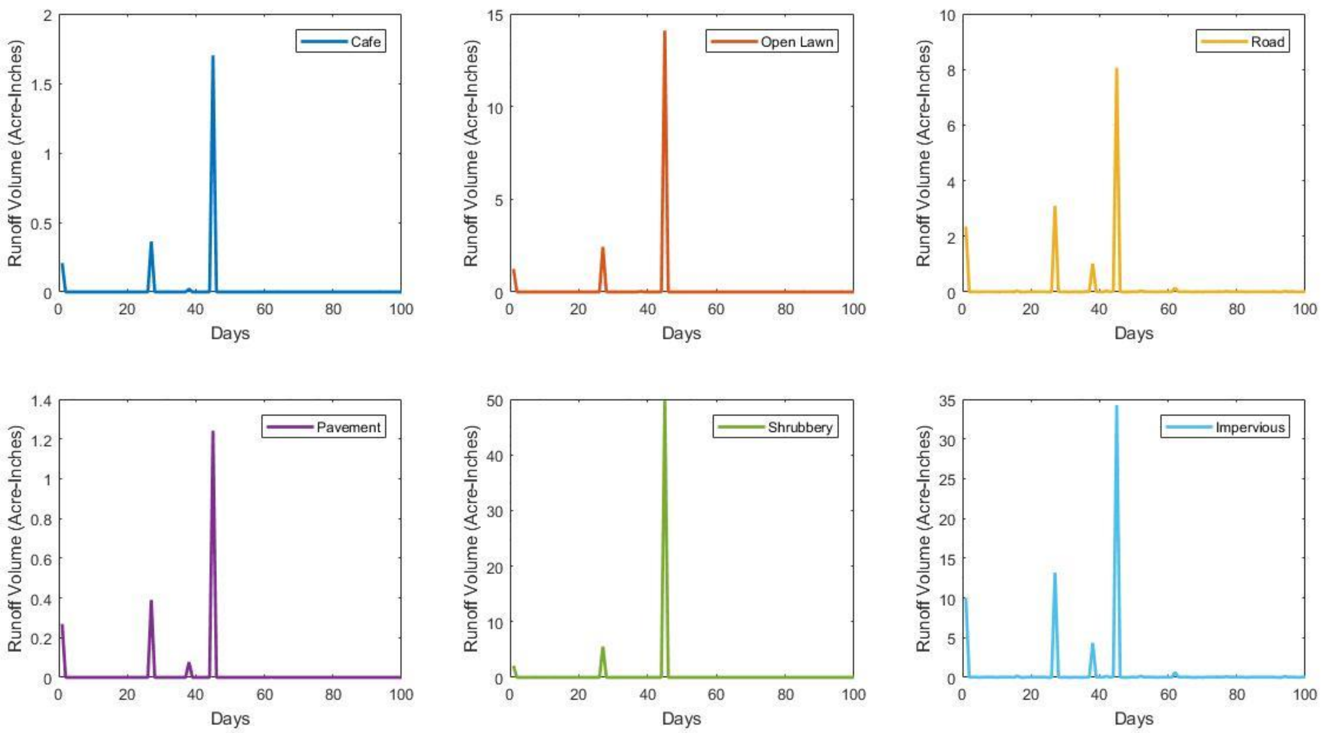
1) Ahmedabad – 11.401%
2) Sanand – 14.623%
3) Khedbrahma – 9.077%

The **predicted runoff volume in Acre-in,** in each of the above corresponding sectors, **for June-September, 2019,** for the above predicted values of rainfall:

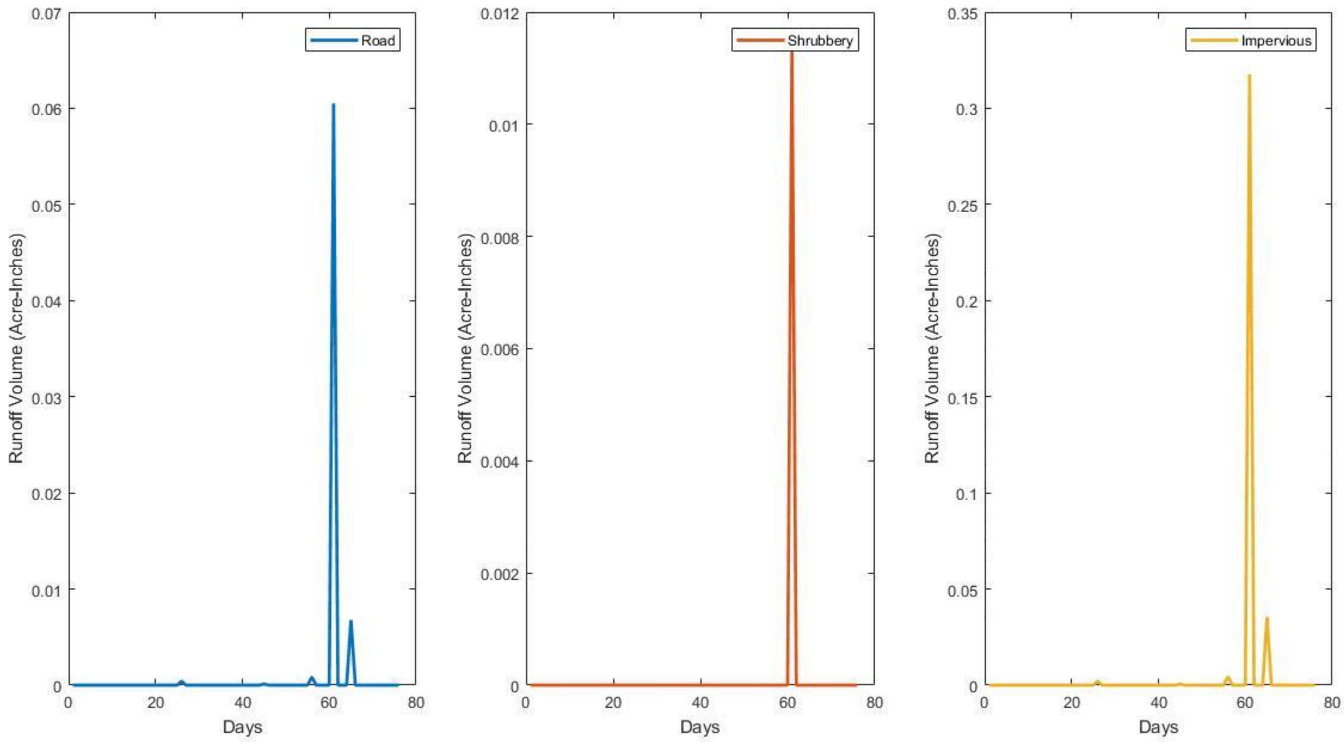
1) Ahmedabad Sector of DA-IICT:



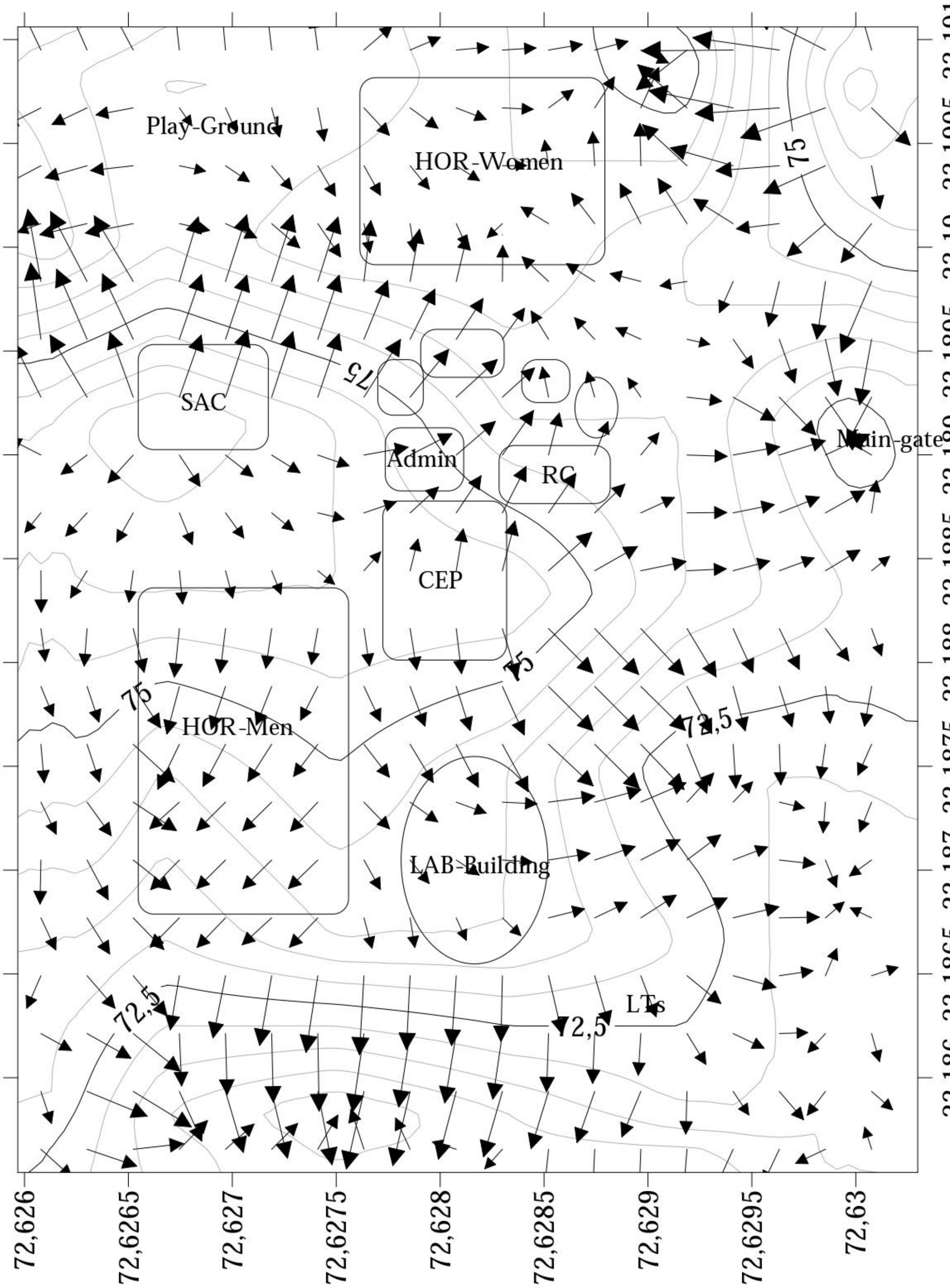
2) Sanand Sector of DA-IICT:



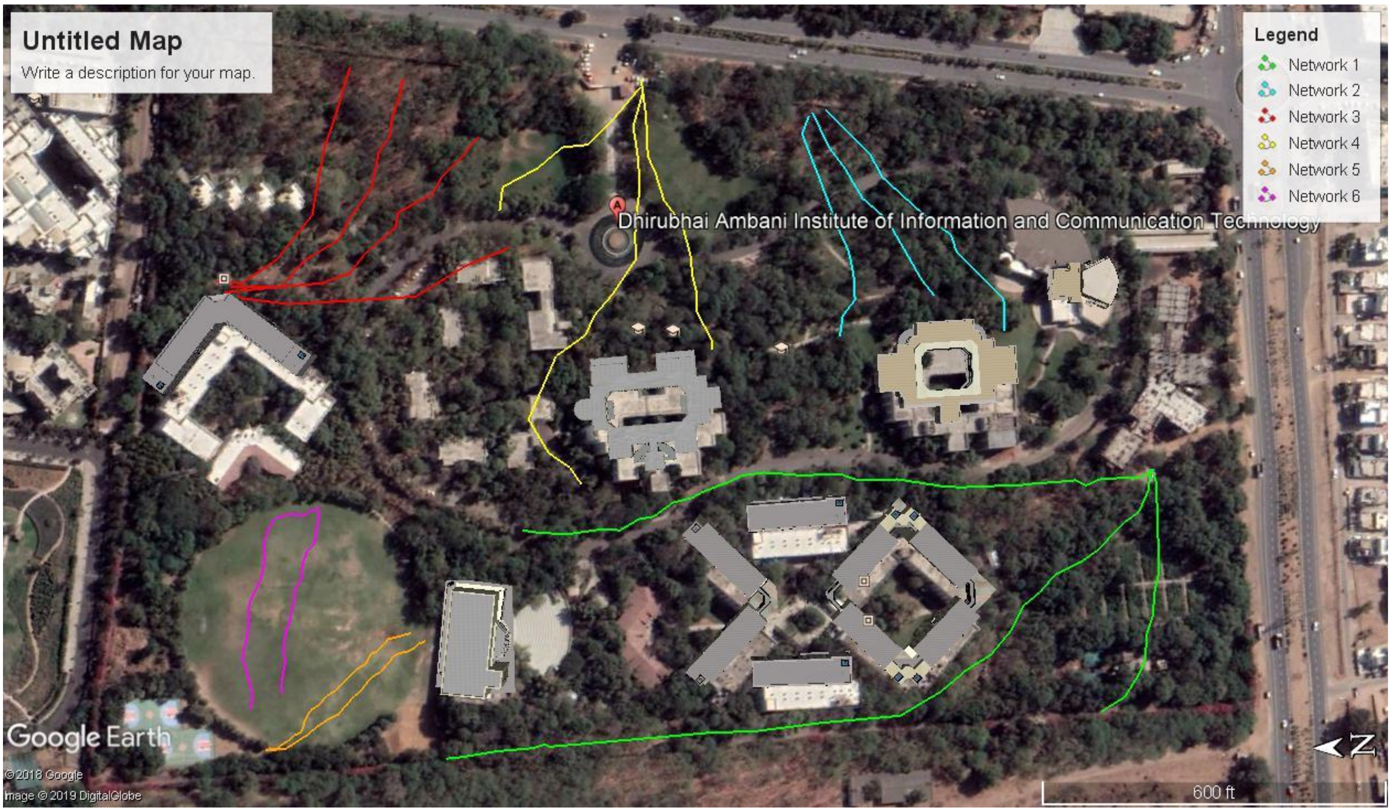
3) KhedBrahma Sector of DA-IICT:



9) Thus, we now have the volume of water, that is expected to go away in surface runoff. This water flows in the form of streams and forms a network. The contour plot of the campus, using the elevation profile, helps us to find the direction of flow of runoff streams.



10) Using this information, we finally obtain both the predicted amount of rainfall, accounting for both temporal and spatial variations, and from it the expected values of surface runoff as well. By deriving the path information of how this water flows, we can establish a system of conservation at the watersheds.



The Runoff stream-flow network in DA-IICT

Results and Conclusion

1) We found out that the rainfall can't be assumed uniform over even a relatively smaller area, such as a university campus and variation is thus, not just temporal, but spatial also.

2) Geostatic analysis techniques are used to estimate the rainfall in different zones on the campus. From the information about soil characteristics, we found out the Curve number values and thereby, from the rainfall data, successfully obtained runoff values for the past 10 years.

3) We predicted the rainfall for the monsoon season of 2019, using LSTM (time-scale machine learning prediction technique) and hence also predicted the runoff volume from different zones.

4) We found out that even though roads and pavements have high potential of runoff, because the lawns and shrubbery occupy the major portion, the volume of runoff is maximum.

5) We obtained the data from various sources, like Geospatial Lab of DA-IICT, Google Earth and Google Maps, extensively used MATLAB and Python and finally using Surfer software, produced the contour plot for elevation profile of DA-IICT. The vectors plotted, show the direction of flow of water and we see a stream network developing.

6) At the watershed regions, where the water from the streams gather, we can apply conservation practices, to check the runoff and thus, our goal of helping to give back to the society by harvesting rainwater, is accomplished.

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