IOP Conference Series: Materials Science and Engineering

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To cite this article: Durgasrilakshmi Hari *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **330** 012119

IOP Conf. Series: Materials Science and Engineering **330** (2018) 012119 doi:10.1088/1757-899X/330/1/012119

Assessment of rainwater harvesting potential using GIS

Durgasrilakshmi Hari[1,*], K Ramamohan Reddy[2,] Kola Vikas[3], N Srinivas[3] and G Vikas[3]

[1*] Vardhaman College of Engineering, Hyderabad, India.
[2] CWR, IST, JNTUH, Hyderabad, India.
[3] Vardhaman College of Engineering, Hyderabad, India.

Corresponding author E-mail: harisrilakshmi@gmail.com

Abstract: Rainwater harvesting (RWH) is one of the best practices to overcome the scarcity of water. Rainwater harvesting involves collection and storage of rainwater locally through different technologies, for future use. It is also useful for livestock, groundwater recharge and for irrigation practices. Potential of rainwater harvesting refers to the capacity of an individual catchment that harnesses the water falling on the catchment during a particular year considering all rainy days. The present study deals with the identification of the study area boundary and marking it as a Polygon in Google Earth Pro Later, Rooftops of various house entities and roads were digitized using the Polygon command in Google Earth Pro. GIS technique is employed for locating boundaries of the study area and for calculating the areas of various types of rooftops and roads. With the application of GIS, it is possible to assess the total potential of water that can be harvested. The present study will enable us to identify the suitable type of water harvesting structure along with the number of structures required. It is extremely an ideal and effective solution to overcome the water crisis through water conservation in the study area.

1. Introduction

1.1 Rainwater Harvesting (RWH)

Rainwater Harvesting and Conservation involve the direct collection of rainwater and storing it for direct use or can be re-charged into the Groundwater. The aim of it is to maximize water storage and minimize the runoff through drains/nallahas or to the rivers without making any use of it. Groundwater levels are depleting continuously due to ever growing demand for water. Thus, Rainwater Harvesting and Conservation aim at the optimum utilization of the rainwater.

1.2 Objectives of Rainwater Harvesting

The main objectives of rainwater harvesting are to

- Cater to the ever growing demand for water
- Prevent blockage of drains
- Check for inundation of roads
- Recharge groundwater
- Minimize the groundwater pollution due to leachate action
- Promote soil conservation
- Meet additional domestic water demands

1.3 Rain Water Harvesting Methods

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1.3.1. Surface runoff harvesting
Surface runoff due to rain is diverted into ponds, lakes and reservoirs. The runoff harvesting is a better solution to water scarcity, flood inundation and drainage problems. It also promotes groundwater recharge.

1.3.2. Rooftop Rainwater Harvesting (RRWH)
Rainwater falling on rooftops is captured, conveyed and stored either in surface water bodies for direct use or subsurface for groundwater recharge. Capturing rooftop rainwater is a simple and cost-effective approach that promotes sustainable water management.

2. Study area description
The study area comprises of Almasguda located in Saroornagar Mandal, Ranga Reddy district, Telangana. It is located at 17° 18′ 41.19″ N, 78° 32′ 5.47″ E coordinates. It covers an area of 2.74 km^2, having 1,490 households and with a population of 6356. Study area map is shown in Figure 1.

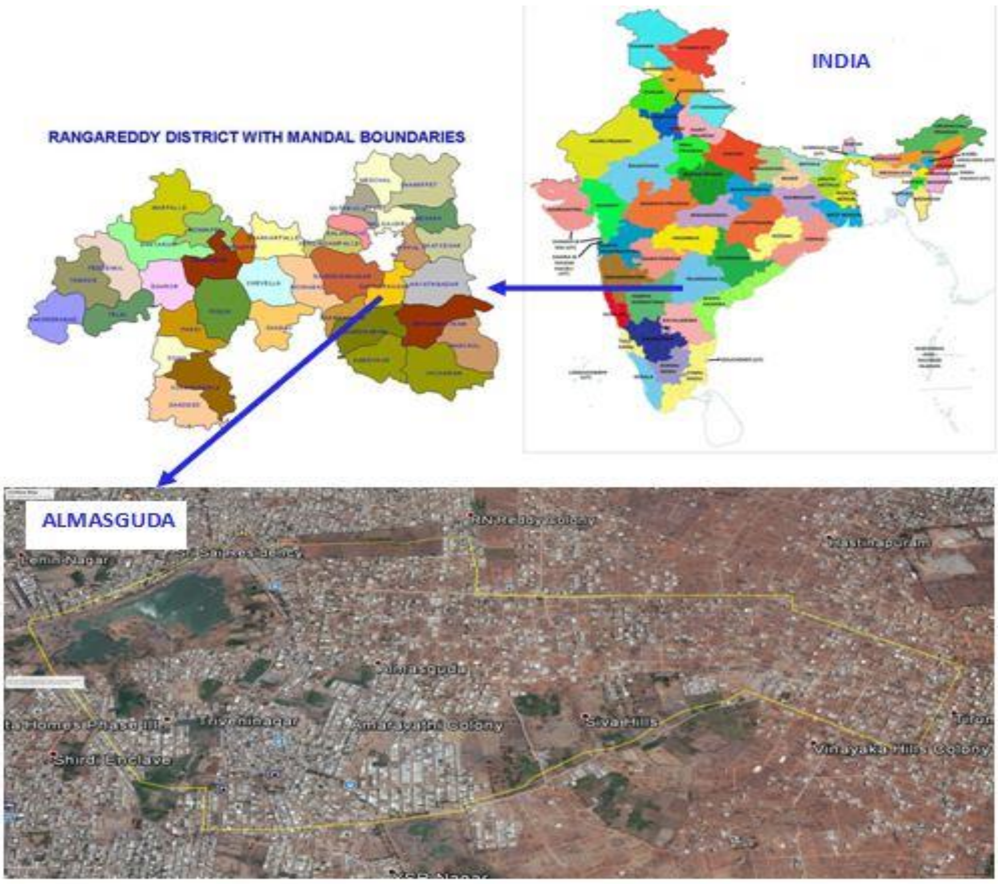


Figure 1. Study Area

Almasguda has a dry and tropical wet climate surrounding on a hot semi-arid climate. Average Annual temperature is 27°C. Almasguda has an average altitude of about 505 m (1,657feet) above Sea level; vignanapuri colony has the highest point in the study area of 552 m (1,811 feet). Most of the soil covered in the study area is red Soil. There are two Source of water in the study area one is Krishna

River water supply and the other is groundwater. Domestic water supply in this village is done especially by means of tube wells and dug wells. Drinking water is supplied to study area once in seven days in non-lean seasons and once in ten days in the lean season. The water demand is increasing to a greater extent because of increasing population. This situation, in turn, led to the digging of more number of bore wells. Consequently, ground water table is depleted to 360-400 meters below the ground and contaminating the groundwater in the study area.

2.1 Objectives of the proposed study

- To create geospatial database regarding the rainwater harvesting potential of the study area.
- To estimate the quantity of rainwater harvested.

3. Methodology

3.1 Data Collection

The data pertaining to population, households, climate, rainfall, temperature were collected from the departments concerned. It is very tedious work to calculate the area and type of catchment existing for the purpose of rainwater harvesting and hence, GIS approach was adopted. Google satellite image has been downloaded and different types of roof catchments and roads were digitized. Average annual rainfall data is considered for the assessment of potential rooftop runoff. The average annual rainfall in the study area is 820 mm.

3.2 Assessment of rainwater harvesting potential

The research methodology for the Assessment of rainwater harvesting potential of study area is presented in Figure 2.

The digitized files in Google Earth Pro are saved in kml/kmz file format and the same has exported to ArcGIS. In GIS kml/kmz files are converted into the shape file format and calculated the area of each type of roof available in the study area in order to find out the total rainwater harvesting potential of the study area. Collection efficiency differs with the type and size of the roof. Rande’s collection efficiency method for various types of a roof has been taken into consideration for calculating the coefficient of runoff. Gould and Nissen formula (1999) were utilized to calculate roof rainwater harvesting potential in the study area. Further that, the economic value of water which would be harnessed has been assessed.

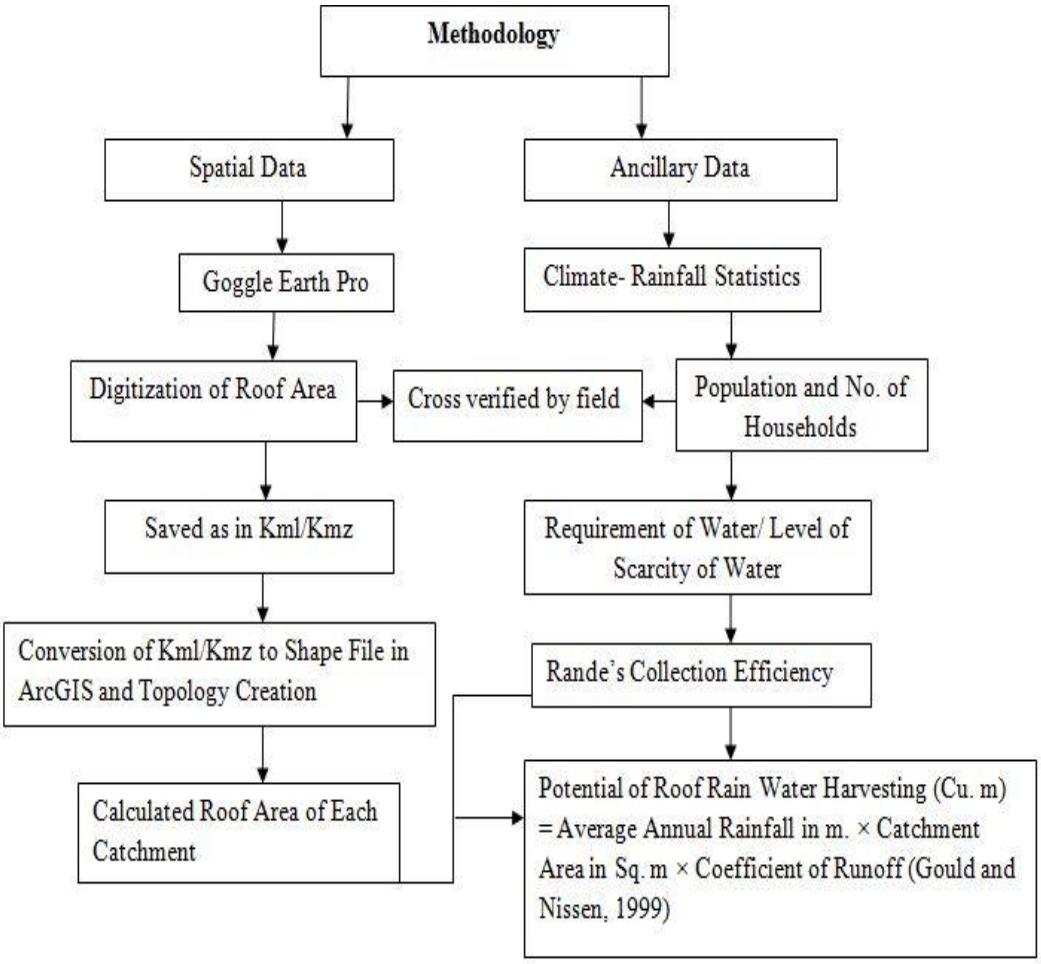


Figure 2. Flow chart of Research Methodology

4. Results & Discussion

4.1 Digitization and Assigning of Attributes

In the present study, satellite images covering the study area are acquired from Google Earth pro. Satellite images are digitized covering all the buildings rooftops and roads in the study area. This resulted in digitized maps with 1665 of concrete roof boundaries, 36 Asbestos rooftops, 29 PVC (Polyvinyl Chloride) sheet roofs that have been saved as KMZ file. Tracing of different types of road networks (Bitumen 9 and Concrete 92) present in the study area are digitized in Google Earth Pro with different colour notations for understanding purpose and saved as KMZ file which is exported to ArcGIS to obtain the capacity of potential runoff generated. Fig.3 is the final digitized map indicating different types rooftops and road network present in the study area, Almasguda.

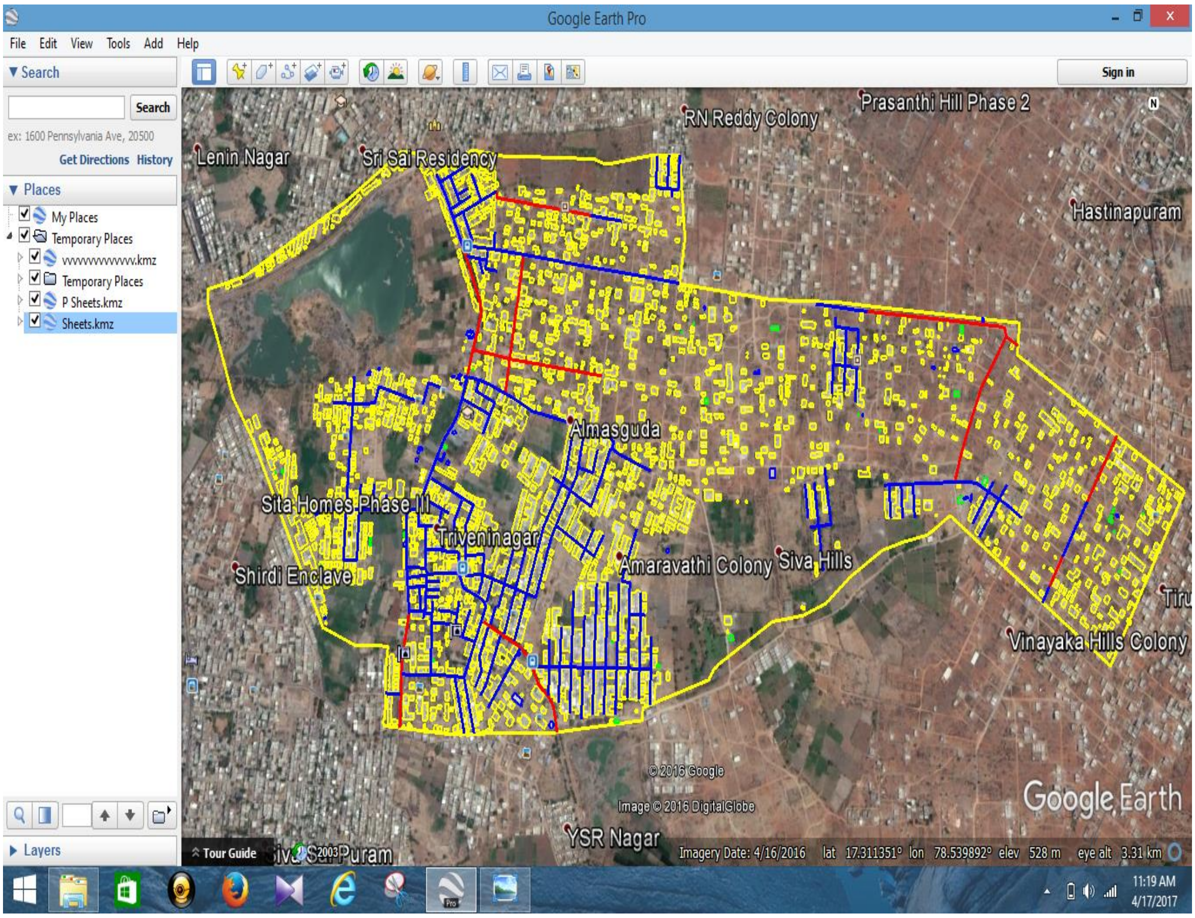


Figure 3. Digitized map with different types rooftops and road network in Google Earth Pro

4.2 Roof Area Calculation Using ArcGIS

In the present study, georeferencing and digitization abilities of ArcGIS are used. Digitized Kmz/kml files from Google Earth were exported to ArcGIS software. Here the kml files were converted to Shapefile (file format required for GIS software's.). the type of rooftop material was identified using satellite images, Google maps. The each shape file is projected to Change the coordinate system of georeferenced images from geographic coordinate system EPSG: 4326 - WGS 84 to projected coordinate system EPSG: 32644 - WGS 84 / UTM zone 44N to obtain the areas of digitized features by using the geometry calculation tool available in ArcGIS model (Figure: 4 and 5).

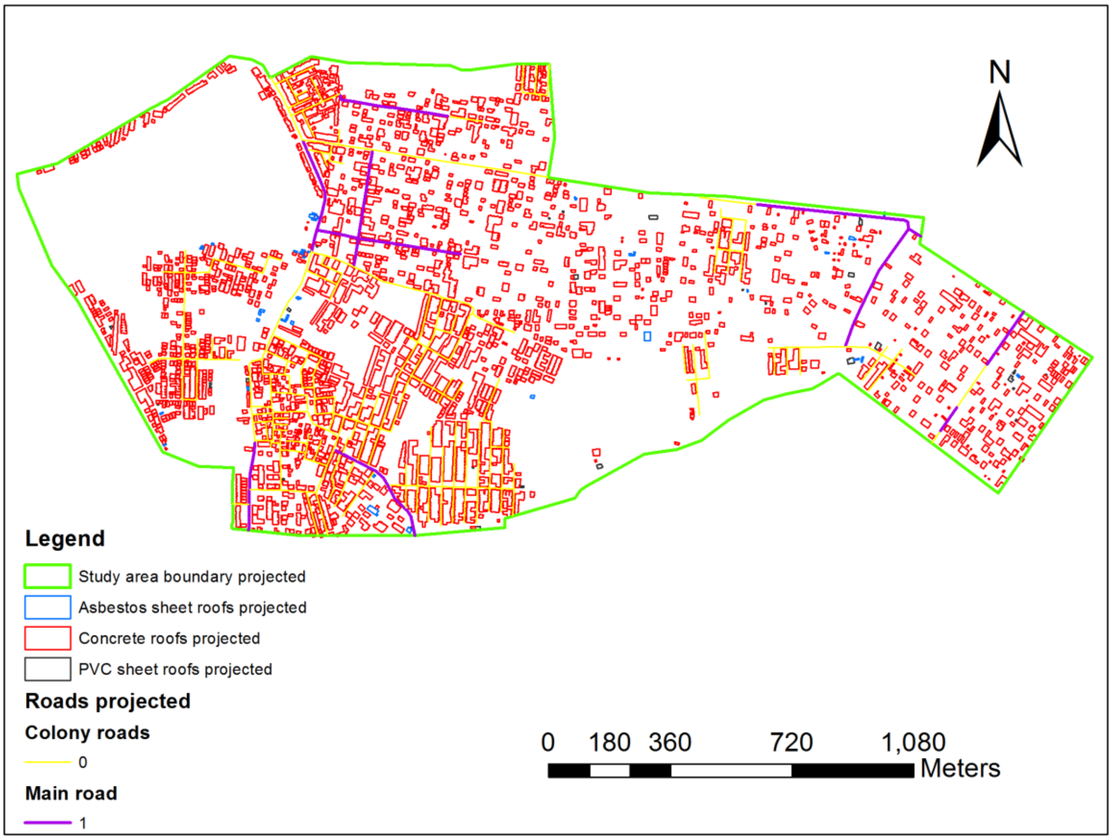
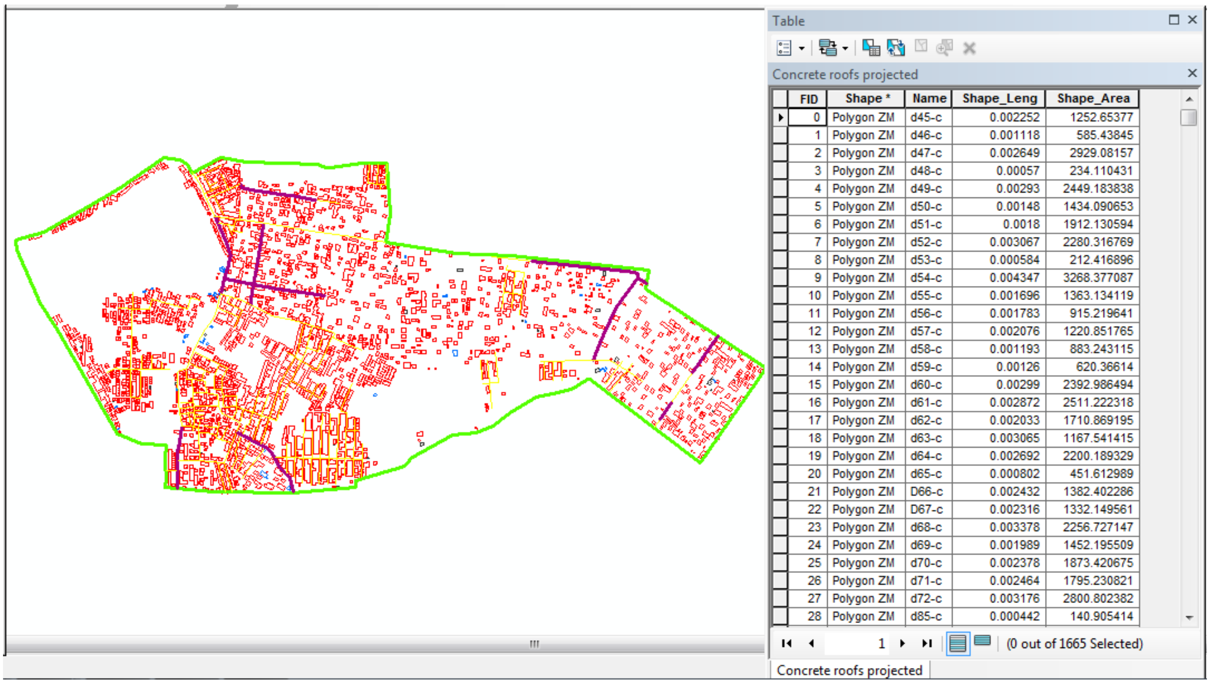


Figure 4. Projected shape files in ArcGIS



FID	Shape *	Name	Shape_Leng	Shape_Area
0	Polygon ZM	d45-c	0.002252	1252.65377
1	Polygon ZM	d46-c	0.001118	585.43845
2	Polygon ZM	d47-c	0.002649	2929.08157
3	Polygon ZM	d48-c	0.00057	234.110431
4	Polygon ZM	d49-c	0.00293	2449.183838
5	Polygon ZM	d50-c	0.00148	1434.090653
6	Polygon ZM	d51-c	0.0018	1912.130594
7	Polygon ZM	d52-c	0.003067	2280.316769
8	Polygon ZM	d53-c	0.000584	212.416896
9	Polygon ZM	d54-c	0.004347	3268.377087
10	Polygon ZM	d55-c	0.001696	1363.134119
11	Polygon ZM	d56-c	0.001783	915.219641
12	Polygon ZM	d57-c	0.002076	1220.851765
13	Polygon ZM	d58-c	0.001193	883.243115
14	Polygon ZM	d59-c	0.00126	620.36614
15	Polygon ZM	d60-c	0.00299	2392.986494
16	Polygon ZM	d61-c	0.002872	2511.222318
17	Polygon ZM	d62-c	0.002033	1710.869195
18	Polygon ZM	d63-c	0.003065	1167.541415
19	Polygon ZM	d64-c	0.002692	2200.189329
20	Polygon ZM	d65-c	0.000802	451.612989
21	Polygon ZM	D66-c	0.002432	1382.402286
22	Polygon ZM	D67-c	0.002316	1332.149561
23	Polygon ZM	d68-c	0.003378	2256.727147
24	Polygon ZM	d69-c	0.001989	1452.195509
25	Polygon ZM	d70-c	0.002378	1873.420675
26	Polygon ZM	d71-c	0.002464	1795.230821
27	Polygon ZM	d72-c	0.003176	2800.802382
28	Polygon ZM	d85-c	0.000442	140.905414

Figure 5. Rooftop catchments ‘map with Attribute Table

4.3 Assessment of rainwater harvesting potential
Roof top rainwater harvesting potential in the study area was assessed by using

Gould and Nissen Formula (1999): S = R*A*Cr

Where S = Roof top rainwater harvesting potential in cu. m.
R = Average annual rainfall in m.
A = Roof area in Sq. m.
Cr = Coefficient of Runoff.

4.3.1 Coefficient of rooftop
The Coefficient of rooftop (Cr) for any catchment is the ratio between volumes of water that runs off to the total volume of rain that falls on the Rooftop. Here, to assess the coefficient of runoff for different types of house roofs Rande's coefficient efficiency index were used as follows.

Table 1: Overall Almasguda Rainwater harvesting potential

S.no	**Type of Roof**	**Area (m^2)**	**Runoff Coefficients**	**Annual Rainfall in (mm)**	**(S=R*A*Cr) Runoff (cu. m)**	**(S=R*A*Cr) Runoff (litres)**
1	Asbestos Roof	2841.369326	0.85	820	1980.43442	1980434.42
2	Concrete Roof	472866.8905	0.95	820	368363.308	368363308.00
3	PVC Roof	2231.217356	0.98	820	1793.006267	1793006.26
4	Concrete Road	66119.44	0.95	820	51507.04	51507043.76
5	Bitumen Road	16770.8546	0.95	820	13064.4957	13064495.73
	Total	**560829.7718**			**436708.2841**	**436708288.17**

From the table.1 it is evident that the water collection efficiency changes with roof type. Concrete roof has maximum collection efficiency (368363.308 cu.m) followed by Asbestos Roof (4365.71 cu.m.) and PVC Roof (1793.006267cu. m.). In road catchments, the maximum yield of rain water could be harvested from Concrete Road (51507.04 cu.m) followed by Bitumen Road (13064.4957 cu.m). The total potential of water harvesting from roofs is 436708.2841cu. m.

4.4 Water Demand
It is assumed that in rural areas 20 litres of water/capita/ day is required to fulfil the basic domestic needs including hygiene and health (UNO, 1990). If we consider this UNO's minimum threshold of domestic water use, the cumulative annual demand of water for total population in Almasguda would be 46398800 litres.

"Water Demand = Per Capita Demand * Population * No. of Days"

Total annual demand of Water (@ 20 lpcd) is

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20 * 6356 (population) * 365 (yearly) = 46398800 litres.

Although as per Indian Standards (BIS):1172-1993, 135 litres/capita/day is the domestic water demand if we assume 10 litres/capita/day for both cooking and drinking the total cumulative annual demand for water in Almasguda, would be 23199400 litres.

Total annual demand of water (@ 10 lpcd) is

10 * 6356 (population) * 365 (yearly) = 23199400 litres.

Table 2: Domestic Water Requirement of the Study Area

Total Population (2011)	No. of Households (2011)	Total Annual RRWH Potential (in Litres)	Total LPCPD Annual Demand of Water (@ 20 Litres)	Total LPCPD Annual Demand of Water (@ 10 Litres)
6356	1490	436708288.17	46398800	23199400

Table.2 shows the amount of water that can be collected from the different types of rooftops and the total potential runoff which is high and good to establish rainwater harvesting systems to mitigate the drinking water scarcity in the Almasguda. From the study, it is evident that the rooftop rainwater harvesting technique can be effectively used to meet the complete domestic water demands. Furthermore, the excess water can be used for gardening and other purposes. Also if properly treated and filtered, the excess water left can be used for potable demands and thus the amount in rupees which will be saved can be calculated as

"Saving amount (Rs.) = Water volume from rooftop area (m^3)* Cost of one cubic meter of water

Rainwater harvesting is the best alternative to overcome water scarcity in the study area. The groundwater levels are depleting at an alarming rate. This problem can also be overcome through groundwater recharge techniques.

5. Conclusion

The present study has been carried out to assess the rainwater potential that can be harvested from the rooftop and through runoff. The geospatial techniques and domains like the Google™ earth, Bing® maps and software's like ArcGIS are helping tools in the works where the entities of varied characteristics and tedious field works are involved. It is evident that from table 1 that the amount of water that can be harvested from both rooftop and runoff is sufficient enough to overcome water scarcity in the study area. Rainwater harvesting system is a compelling method in the Almasguda region. The total quantity of rainwater can be collected in the study area is around 436708288.17 litres. For at least the domestic demands 46398800 litres the water harvested is more than enough and is quite sufficient if specific correction factors and losses are considered. Rainwater harvesting is the best alternative to address ever-growing water demand issues and concerns in Almasguda region.

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