A Comparative Analysis of Estimating an Optimum Tank Size for RWH using Decision Support System and Unsupervised Classification Approach

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Abstract— Water is the matchless gift of the living being and it is the basic necessity of life. The universal atmosphere is fluctuating day to day, due to the high indulgence and negligence of human being with nature. As a result of that the water resources/reservoirs are draining gradually and People across the world is facing severe drought condition. In India, one-third of the region is claimed to be drought-prone and several thousand regions do not have drinking water due to the unpredictable climatic condition. Rainwater harvesting (RWH) is an effective approach to resolve the water scarcity in India. Setting up of an RWH plant is easy, but it requires proper understanding, suitable methods, as well as suitable to everyone. This paper, expresses a general way for selecting suitable rooftop rainwater harvesting sites and to construct an efficient harvesting plant with proper decision support system using QGIS tool and Google Earth Pro software. It also assesses rooftop runoff harvesting with geospatial techniques using an unsupervised classification approach to build a reservoir/tank size to increase the ground water level and to calculate tank capacity. A comparative analysis of two methods helps to understand the more efficient and accurate way of designing the rainwater harvesting plant and in calculating the tank capacity.

Keywords: RWH, Cluster analysis method, Geo browsers, Classification algorithm, tank capacity, Google Earth Pro, Quantum GIS (QGIS)

I. INTRODUCTION

Past few years due to unpredictable climatic changes and weather conditions, many parts of the world have been struggling to meet water demand. In India, drought is one of the most frequently occurring disasters. Because of its increased frequency and expanded coverage one third of the country is either drought prone or considered to desert areas. This leads to the downfall in agriculture as well affects the overall economic growth. Especially in the city like Chennai of India, operational land Imager on LandSat 8 reported that, one of the four main reservoirs Puzhal lake, serves the city with the water capacity of 0.2%. It leads to critical drought conditions and water shortages. In RWH, the rain water storage tanks are the most essential factor. It initiates the volume and time reliability of a RWHS. It is very difficult to estimate the optimum tank sizes in a particular area, as rainfall intensity vary widely. This paper approaches the estimation of optimum tank size and to assess its reliability for three different regions in and around three districts of Chennai. Here, two different techniques are used such as constructing a efficient harvesting plant with proper decision support system using QGIS tool and Google Earth Pro and estimation of optimum tank size using unsupervised classification methodology based on average rainfall patterns, rooftop catchment size and runoff coefficient.

II. LITERATURE SURVEY

Garima and Pratishtha (2016), assessed on Rooftop Rainwater harvesting (RRWH) in the cities of Rajasthan, India and computed the amount of rainfall with a runoff coefficient, that's used to recharge the ground water reservoirs, with the help of the factors like minimum, average and maximum rainfall of the study area. They also considered the intersected measurements of the area for placing containers that help in collecting the rainwater with Google earth and Quantum GIS tools. The satellite images of three cities were collected by the GIS tools and a vector layer was created for calculating the area of the individual and overall rooftops in the study area. The average rainfall with the tank capacity of the overall rooftops was estimated and as a result, one of the three cities was highly fitted best for the implementation of the Rainwater harvesting plant because of the high rainfall and wide-area (1500-200 m2).

Durgasrilakshmi Hari et al. (2017), the study area undergoes basic factors such as population, households, climate, rainfall, and temperature. GIS technique is used to calculate the area and type catchment exist. The annual rainfall in the study area are 820 mm. The satellite images of the study area have been downloaded and digitized with the help of Google and the digitized files are saved at Google earth pro with kml/kmz formats. The same is exported to ArcGIS software. ArcGIS is used to convert the Google earth pro files to shape file formats and calculates the area of each rooftop, after that the total rainwater harvesting potential was analyzed. The water demand of a particular area is also calculated and it is found that the amount of water collected using RWH from the rooftop and potential runoff is highly good and helps to mitigate the drinking water scarcity in the study area. The total quantity of water collected in the study area is around 436708288.17 liters, the water harvested is more than enough and it is quite sufficient and results that RWH is the best alternative to solve the water demand issues.

Sadhashiv Pradhan et al., (2013), proposed a scheme for computing the rooftop rainwater runoff from satellite images using land cover classification for rainwater harvesting. K-mean clustering is used to segments the satellite images of the study areas and classify them using. The k-mean clustering algorithm makes use of Euclidean distance metric to classify the images as water, grass, soil, and buildup region. It has been proven, that K-means clustering algorithm yields a precise output. The region under each cluster is computed with the count and percent of pixels of an image and total image areas are calculated with the length and breadth. It is computed that the water runoff is 0.04 cubic metric/seconds using MATLAB and Google earth images using water runoff. This technique can be used for calculating the water runoff that helps in development of RWHS.

Hao Zheng et al., (2018), identifies the suitable sites for Rainwater Harvesting (RWH) with an assumption of 12 heavy rains per year, annual wetness degree of 0.5 - 0.8 degrees and an annual evaporation of about 1600 - 2500 mm. However, the area has a persistent water shortage because of erratic monsoons, population's increase, and they found that the total water consumption of study areas is $2.403*10^9\ m^3$ whereas the water supply is only $299*10^6 m^2$. To reduce the water demand, they found suitable sites to establish RWH plants in semi-arid areas using the parameters such as rainfall, terrain, soil type, land to use, runoff characteristics and other indicators. A Digital elevation model (DEM) of 30-mm pixels was used to determine the elevation, slope and aspect accounted gentle slope of 33.64%, relatively steep and steep the slope was of 9.94% and 1.59%. The SCS-CN models used for estimations of runoff and handling water resources and a stepwise calculation was used to measure the surface runoff using ArcCN-Runoff tool. According to their model the yearly runoff average was 246.50 mm with the standard deviation of 34.3, verifies that 24.90% of the study area is highly suitable for RWH. The model also found that 57% of the area has a low risk of soil erosion and only 1% of moderate risk of erosion, helps in establishing healthy RWH plant.

C. W. Maina et al., (2016) uses remote sensing and geospatial techniques such as ArcGIS projected WGS_1984 UTM Zone36s to establish the Rainwater harvesting sites and to digitize it. The average rainfall in the study area are 1020 mm per annum, the river catchment is approximately $150km^2$ and lies down at the altitude of 3060 meters above the sea level. The Landsat images, Digital Elevation Model (DEM) were used to generate the land use, lineament delineation and slope generation. SCS-CN method is to predict the volume of direct surface runoff with the key factors like curve numbers, hydrologic soil groups, land cover type, antecedent soil moisture and hydro-logic conditions. The vital parameters land use, soil and slopes was used for sensitivity analysis. The calculated area covers 39.452% of forest and water body of about 0.54%, results forest is highly suitable for the Rainwater harvesting leads to the progress of agriculture regions of about 36.52%. Three different soils such as B, C and D such as sandy loam, clay loam, and sandy clay loam types of soil were found in the study area, out of them soil type D has remarkably low infiltration and excessive runoff useful in surface water harvesting and generates runoff. As a result, it's been observed, that 50% of the catchment area is to be suitable for RWH, implies great potential for RWH within the catchment of the study area.

V.S. Pawar Patil et al.(2013), assess the potential of roof rainwater harvesting based on primary as well as secondary data sources such as day-to-day, periodic and cumulative requirement and scarcity of water. The data like population, households, weather, rainfall, temperature were also collected from relative departments. Rooftops catchment approach with respect to GIS was utilized to calculate the area of various types of roofs in the study area. The study area comprises an average rainfall of 1025 mm and the village is spread over 279 hectares with a total population of 1893 reside in about 378 households. Rande's coefficient of runoff index is used to find the various roofs and Gould and Nissen formula (1999) benefits in the calculation of the potential of RRWH.

III. Methodology of the Proposed Work

This section proposes the two different methods of estimating the optimum tank size to build the rainwater harvesting system (RWH) with decision support system and unsupervised classification approach.

A. Estimating the Tank Capacity using Decision Support System

First, the images of the study area are captured with Google Earth Pro software in jpeg/jpg file formats, as the second step it is digitized and converted into tiff file format as raster images, then with the polygon tools of QGIS its been transformed into vector images. The area of individual rooftops is estimated along with average annual rainfall are used to estimate the water availability and that is used to measure the tank/reservoir capacity. The flow of the proposed approach is as in fig.1.

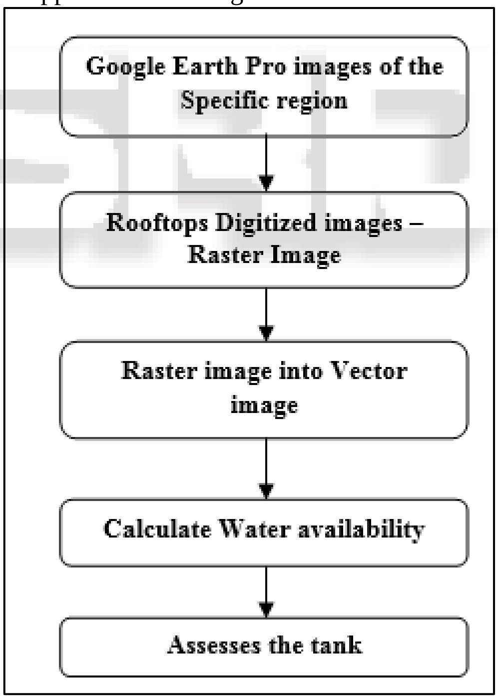


Fig. 1: Flow diagram of RRWH

1) Data Acquisition

a) Satellite Images

The satellite images of all the domiciliary areas, the rooftops of constructions and road surface can be digitized with the help of Google Earth Pro software. This software helps in capturing the geographical data with premium high resolution of full 1080p HD resolution and doesn't involve very complex techniques. In this paper, the study area of the three different district of North-Tamilnadu was retrieved from Google Earth Pro software in jpeg/jpg formats as in Fig. 2

(a)

(b)

(c)

(d)

Fig. 2: Google Earth Pro - Satellite Image
a) Thiruverkadu b) Tambaram c) Royapuram d) Sholinganallur

b) Rainfall Data Collection

The Rainfall data onto each region frequently varies from place to place. The Rainfall datasets were obtained from the websites. The Rainfall data for the period of 25 years from the year 1993 to 2018 were considered to measure the water availability from the rooftops using unsupervised clustering.

Year	Annual Rainfall	Year	Annual Rainfall
1993-1994	900.5	2006-2007	704.5
1994-1995	895.5	2007-2008	658.4
1995-1996	359.3	2008-2009	839.8
1996-1997	907.6	2009-2010	839.80
1997-1998	1051.4	2010-2011	744.8
1998-1999	602.4	2011-2012	821.1
1999-2000	574.4	2012-2013	546.3
2000-2001	484.9	2013-2014	315.4
2001-2002	602.4	2014-2015	641.8
2002-2003	526.2	2015-2016	1879.7
2003-2004	410.6	2016-2017	459.1
2004-2005	451.8	2017-2018	672.6
2005-2006	1471.0		

Table 1: The Annual Rainfall Data of Kanchipuram District
Source: http://www.kanchi.nic.in/district_profile_pro.html

c) Coefficient of Rooftop

"The ratios between volumes of water that runs off and that of a total volume of rain that fall on the Rooftop" is defined as the Coefficient of rooftop (Cr). The table 2 shows the runoff coefficients for the different roofs.

S.No	Type of rooftop	Rooftop Coefficient
1.	Galvanized sheets	0.90
2.	Asbestos	0.80
3.	Tiled	0.75
4.	Concrete	0.70

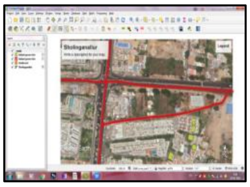
Table 2: Rooftop Coefficient for Roofs
Source: *www.ijcset.com › docs ›IJCSET16-07-04-054*

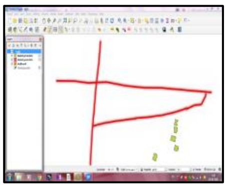
In this paper the roof areas are assumed to be Concrete, thus the Runoff coefficient is considered as 0.70.

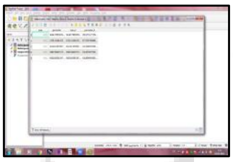
2) Data Preprocessing

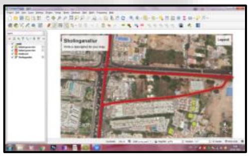
a) Digitizing and Calculation of the rooftop

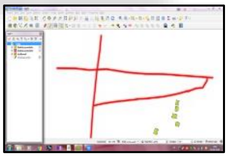
The Satellite Images retrieved from Google Earth Pro is exported to QGIS, the image will be converted and saved as kml/kmz file formats, that supports both raster and vector layers. The rooftop area is measured with the help of the polygon tool for each building of with the help of the image as in the following figures.

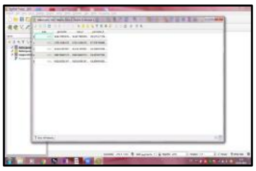

3(a)
Fig. 3(a): Digitized images of study area with selected rooftop: Royapuram


3(b)
Fig. 3(b): Vector image of study area with polygon rooftop: Royapuram.


3(c)
Fig. 3(c): Calculated areas of the selected roofs:Royapuram.


4(a)
Fig. 4(a): Digitized images of study area with selected rooftop: Sholinganallur


4(b)
Fig. 4(b): Vector image of study area with polygon rooftop: Sholinganallur.


4(c)
Fig. 4(c): Calculated areas of the selected roofs: Sholinganallur.

S.No	Areas of selected rooftops	Royapuram	Sholinganallur
1	House1	3824.17	2456.75
2	House2	10551.61	1847.13
3	House3	3621.61	2589.54
4	House4	2889.78	1749.94
5	House5	9282.82	1987.14

Table 3: Areas of the Selected Roofs

The formula for the calculation of water availability is given below:

$$W = TRA * AR * CR \quad (1.1)$$

Where,
W - Water availability from the rooftop,
TRA - Total Roof Area
AR - Average Rainfall and
CR - Coefficient of the Rooftop

3) *Classification of Criteria*

The water availability of the designated rooftop of Kanchipuram district is calculated for twenty-five years and is shown in Table.4.

House1	House2	House3	House4	House5
1548612.363	1164338.396	1103074.679	1252593.699	1632316.539
1540013.738	1157873.441	1096949.889	1245638.709	1623253.149
617897.1925	464571.6663	440127.4094	499785.5814	651295.2054
1560822.41	1173518.632	1111771.881	1262469.785	1645186.553
1808118.865	1359450.737	1287920.841	1462495.297	1905849.649
1035962.34	778897.7784	737914.6992	837937.1952	1091957.227
987810.04	742694.0304	703615.8752	798989.2512	1041202.243
833894.6525	626971.3359	593982.1342	674494.9302	878967.5622
1035962.34	778897.7784	737914.6992	837937.1952	1091957.227
904919.295	680371.8642	644572.8996	731943.1476	953831.1636
706119.085	530902.1046	502967.7548	571143.7788	744285.5868
776971.755	584173.3338	553436.0244	628452.8964	818967.9204
2529715.475	1901989.761	1801913.218	2046158.058	2666449.338
1211546.263	910912.1595	862982.911	979958.091	1277031.651
1132266.94	851305.2744	806512.3472	915833.0832	1193467.195
1444225.055	1085853.842	1028719.728	1168160.12	1522286.984
1444225.055	1085853.842	1028719.728	1168160.12	1522286.984
1280851.18	963019.6968	912348.7184	1036015.31	1350082.574
1412066.198	1061674.91	1005813.014	1142148.458	1488389.906
939485.7675	706360.9833	669194.5554	759902.2074	990265.9914
542401.265	407809.3614	386351.7532	438720.7692	571718.6412
1103719.505	829841.6238	786178.0444	892742.5164	1163376.74
3232567.083	2430435.183	2302553.553	2614658.941	3407290.837
789525.7475	593612.1681	562378.2178	638607.1818	832200.4698

Table 4: The Availability of Water in Individual Rooftops of Kanchipuram District

4) *Tank Capacity*

Tank capacity for Rainwater harvesting is computed using the average of water available from the roof (W) for the past twenty-five years (1993-2018), this computation can be used for assessing the storage size of the tank. The tanks can be placed under-grounded or can also be on the ground level too. The diameter and the height of the tank can be planned according to the collected water and beyond the collected water. The Table. 5 illustrates a proportional analysis for five individual buildings of kanchipuram district of Tamilnadu.

Rooftops	Average water available from the rooftops	Tank Capacity
House1	1263055.466	1270000
House 2	949639.826	950000
House 3	899672.9	900000
House 4	1021621.263	1030000
House 5	1331324.982	1340000

Table 5: Assessing Tank Size for Five Individual Building of Kanchipuram District

B. *Estimating The Amount Of Water K-Means Clustering – Water Availability*

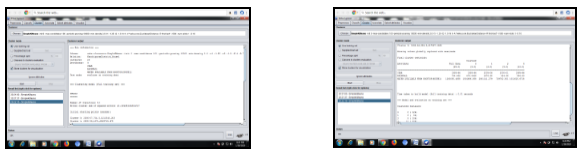
K-means is an unsupervised clustering method of classifying the given set of data onto multiple classes. The datasets are subdivided into k clusters, so that each object has its own location in space. After the process of clustering, the percentage of each cluster is calculated to determine the accuracy of the algorithm. K-mean clustering is represented as follows,

$$V_i = (1/C_i)\sum_{j=1}^{C_i} x_i \quad (1.2)$$

Where, 'c_i' is the number of data points in the i^{th} cluster.

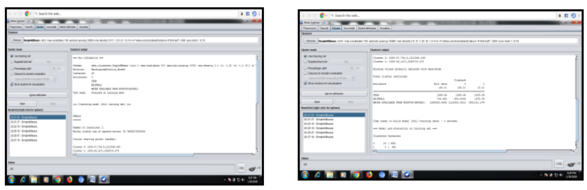
The K-mean clustering is used to measure and classify the capacity of rainwater harvesting systems. In order to accomplish this task, the rainfall data of the three different districts of North- Tamilnadu, like Chennai, Thiruvallu and Kanchipuram as the sample areas. Cluster analysis was applied to measure the distance similarity between the data provided. Each district rainfall data will have different scores of the long-term values that are being clustered by the same process, produces the results the efficiency of Rainwater harvesting system.

Here, simple k-mean clustering algorithm is used to measure the water availability of the houses to estimate the optimal size of the RWH tank. In particular, the calculated water availability data shown in table 4 for house-1 of Kanchipuram district is clustered based on the comparisons of twenty five years of data with four iterations. The following figure 6(a) and 6(b) depicts that five datasets were more similar, that concludes that 40% of data can be considered as an output of the overall cluster. The same technique is repeated for the datasets for house-2 as presented in the table 4 and found the five datasets are similar, it contributes that the output of 40% of data clustered and found in a positive similar state and is proven in the figure 7(a) and 6(b).



5(a) 5(b)

Fig. 6(a) and 5(b): Water availability clustered for House1



6(a) 6(b)

Fig. 7(a) and 5(b): Water availability clustered for House1

C. *Results of Comparitive Analysis*

Accumulating rainfall in storage tanks or earth ponds can be expensive and it's exposed to water losses due to leakage and vaporisation. Therefore, to overcome the failure of RWHS from the poor design, poor management, and poor communication between designers, this paper initiated an optimal strategy and guidelines that can be considered as the most applicable measure the tank size for effectiveness of a rainwater harvesting system. Fig. 7 shows the difference between basic DSS and Unsupervised clustering approach and indicates that K-Mean clustering estimate the tank size better than the other one.

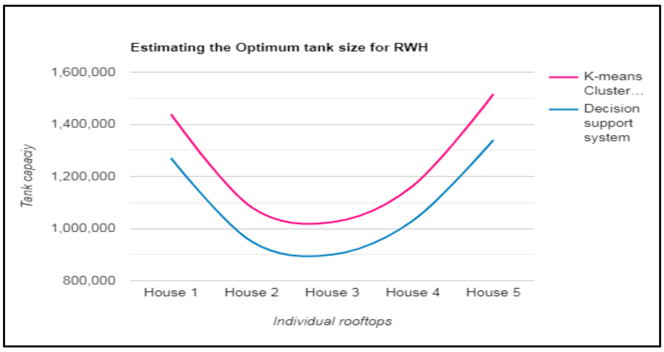


Fig. 7: Comparison Line graph of estimating the optimum tank size between Decision Support System and Unsupervised algorithm.

D. Conclusion and future work

Rainwater is a natural source of fresh water and it should be consumed in a proper manner, as there is an immense need for the proper utilization of water to increase the ground water level by means of RWH. There is no proper RWH mechanism available to build an efficient RWH plants. This paper is an attempt to design a methodology to estimate capacity of the tank/reservoir and install them. It also helps to evaluate the long-term water availability of the rooftops by describing the methods of decision support system and also by the ways of clusters with K-Mean's algorithm to classify the measurement of the storage area. In this paper, we compared the basic decision support system with unsupervised classification to estimate the size of the storage tank for the proper utilization of mismanaged usage of water. Further study is essential to understand other factors like rain depth, periodic distribution of rainfall, necessity of water and tank shape, etc., to tackle the water scarcity problem in rural areas.

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[37] https://www.rapidtables.com/tools/line- graph.html

