ROOFTOP RAINWATER HARVESTING AN ALTERNATE WATER RESOURCE FOR THE BENGALURU CITY

Ananthakrishnaswamy D.S.,* Ashok D Hanjagi**

Research Scholar, Dept. of Geography, Bengalore University Bangalore, Karnataka, India.
Professor, Dept. of Geography, Bengalore University Bangalore, Karnataka, India.

Abstract

Bangalore City doesn't have nearby dependable perennial water source; therefore, the City is dependent on Cauvery River for drinking water which is at a distance of about 100 Km. The growing population and amalgamation of 7 CMCs and Kengeri TMC along 110 villages around the Bangalore City has increased the water needs considerably, thereby exerting more thrust on better management of treated water in the distribution system. The present population of the City is around 10 million and expected to increase to 20 million by 2030 as per BDA's Comprehensive Development Plan. As the population is growing and the water needs of city is increasing the water demand and expected supply projections indicate a gap in supply-demand. It is expected that more than 600 Mld of water will be the shortfall for the year 2021 and it may go up to 1050 Mld during the year 2036 which is based on the present availability of water from Cauvery river. The number of lakes in Bangalore has reduced from nearly 285 (1970's; spatial extent of Bangalore is 161 sq.km) to 194 (2016; spatial extent is 741 sq.km). During the last four decades there has been 79% reduction in water bodies and the number of lakes in Bangalore. During 1800, the storage capacity of Bangalore was 35 TMC. In 1970's, lakes covered an area of nearly 3180 hectares and now the spatial extent of lakes cover an area of 2792 hectares. The current capacity of lakes is about 5 TMC and due to siltation, the current storage capacity of the lakes is just about 1.2 TMC, i.e., nearly 387 hectares of water bodies lost apart from reduction in the storage capacity by 60%.

Keywords: *Rainwater Harvesting, Rooftop, Urban Water Supply, Water Resource ,Demographic growth.*

Introduction

Bangalore being located on the ridges, forms three watersheds – Koramangala Challagatta valley, Vrishbhavathi valley and Hebbal Nagavara valley. Earlier rulers of the region, created interconnected lake systems taking advantage of undulating terrain. Number of lakes in Koramangala Challaghatta valley is about 81, followed by the Vrishabhavathi valley (56) and the Hebbal Nagavara valley (46). In order to enhance the water retaining capability in the catchment, it is essential to harvest rain water. Lakes are the optimal means of rainwater harvesting at community level.

Rainwater Harvesting- Advantages

Environment – friendly option Easy and simple means of meeting the water requirements for vanity of uses Drinking. Washing, Gardening etc., Mitigates the effects of droughtEnhances groundwater – both in quantity and quality.Reduces water run-off, that could otherwise result in flooding of storm water drains.Reduces flooding of roads and low-lying areas.Easy maintenance and low-cost methods Results in considerable savings in water and electricity costs.

Rainwater harvesting anyone can do it anywhere: Opportunities to harvest rainwater viz. Rooftops of Houses, Public buildings, Institutions, Hospitals, Hotels and shopping malls, with wide open area. Farmlands, Public parks Playgrounds etc., Paved and unpaved areas of layouts, cities towns and villagesfor example, in Bangalore (average annual rain fall 39.37 inch/1000 mm) about 2,23,000 liters of rainwater can be harvested in an area of 2,400 sq.ft. (40ft x 60ft site). The harvest yield depends on the rainfall received the catchment area and the collection efficiency.

Rainwater Harvesting is a community based programme and its success largely depends on the collective participation of Government bodies NGOs, builder's architects, house owners and individuals.

Table 1. Rainwater Harvesting Connections

Year	Rain Water Harvesting Connections
2001-02	20081
2003-04	7602
2005-06	8
2007-08	832
2009-10	18207
2011-12	16846
2013-14	8374
2015-16	15134
2017-18	25229

Study Area

ThestudyareaBengaluru city lies in the southeast of the South Indian state of Karnataka. It is in the heart of the Mysore Plateau (a region of the larger Precambrian Deccan Plateau) at an average elevation of 920 m (3,020 ft). It is positioned at12.97°N 77.56°E and covers an area of 800 km². The City Government was called Bangalore MahanagaraPalike (BMP), with 100 wards in 1986. It was renamed as Bruhath Bangalore MahanagaraPalike (BBMP) in 2007 (147 wards). Presently there are 198 wards in BBMP according to 2011 Census. The population has 9.588910. With sex-ratio of 908 female/1000 males and its density were 4,378 people per square km in 2011 census. There are seven City Municipality Councils and one Town ship (Kengeri), 110 villages, four taluks (Bangalore North, Bangalore South, Bangalore East, Anekal), all together can be called BBMP or Bangalore Urban District. The study is limited to BBMP.

The annual mean air temperature is around 22°C with May is the hottest month having maximum temperature of 38°C and December is the coldest month having minimum temperature of 13°C. The study area has a semi-arid subtropical climate with mild summers and cold winters. The average annual rainfall in the study area is about 950 mm. The major portion (i.e., around 55%) of the rainfall is received during the south-western monsoon period (June to September); and, the pattern of rainfall in the city shows an increasing trend with wide variation.

In the present study we have used mainly two types of data. These are topographic map and remote sensing data.

The Topographic maps (57/G 5, 6, 7, 8, 10, 11, 12, 13 and 57/G 14, and on a scale 1: 50,000) obtained from survey of Indiaare scanned and imported into the digital image processing software. First of all, the topographic maps rectified using a geometrically corrected image with the ArcGIS10.1 software. The Indian Remote Sensing Satellite data QuickBird multi-spectral image acquired on 27th Feb 2018 used is with the resolution of 2.4mwere obtained and employed in this study.

The images are analyzed by using data images processing techniques in ERDAS Imagine© 10.0 and ArcGIS10.4 software. Built-up area is classified according to the NRSA (national State Remote Sensing Agency). Furthermore, the image analysis results are confirmed by the field research. Besides, a number of geospatial data including municipal boundaries, road networks, geomorphic units and elevation units have been constructed as GIS layers from diverse source.

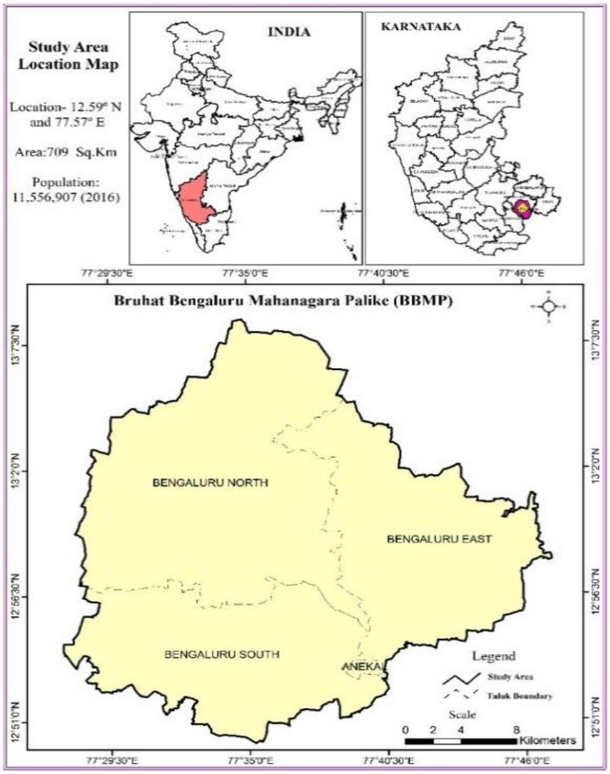


Figure 1. Location Map of the Study Area

Data and Methodology

Image classification method

Image classification methods [1-6] are very useful in identifying different features from the given image. Features like built-up, water, vegetation and barren land can be used for exploring in order to understand the multi-temporal variations. Multi-temporal satellite images [3-17] provide excellent temporal variations which can be used for urban growth analysis. Different combinations of bands [13-16] are generated in order to identify built-up,

vegetation, water and barren land signatures from the satellite images (signatures means similar spectral values). The supervised classification methods are used for pattern

classification [12]. Supervised classification [16] identifies class information in the satellite images and similar pixels are used as ‘training samples’ (signature values). The classifier system is used to determine the statistical characterization of reflectance for each information class and this stage is called ‘Signature analyses’. Signature analyses involve statistical characterization of the range of reflectance on each band. The statistical characterization has been achieved for each information class. Then the image is classified by examining the reflectance for each pixel and making a decision about which of the signature it resembles accurately [4-13].
The band combinations for each image are shown below which are used to collect signatures or training samples from the given datasets:
Post classification comparison was found to be the most accurate procedure and presented the advantage of indicating the nature of the changes [9].An automated object-oriented for an extraction of detached houses, of main street infrastructure, of vegetation areas, of bare soil and of water areas.
The land use maps pertaining of four different periods were used for postclassification comparison, which facilitated the estimation of changes in the land use category and dynamism with the changes. Postclassification comparison is the most commonly used quantitative method of change detection [5-14] with fairly good results. Postclassification comparison is sometimes referred to as “delta classification” [10]. It involves independently produced spectral classification results from different data sets, followed by a pixel-bypixel or segment-by-segment comparison to detect changes in the classes.

Result and Discussion

Urban growth is a global phenomenon that comes with the land use change, population growth and economic development. Urbanization is an important factor for the Bangalore city where rate of urban expansion has occurred very fast in the recent time. The city landscape is likely to expand at a very rapid rate. It is a growing city which increases its population nearly five-fold in last five decade. City offers many employment opportunities and amenities to its residents that are not always available in rural areas.

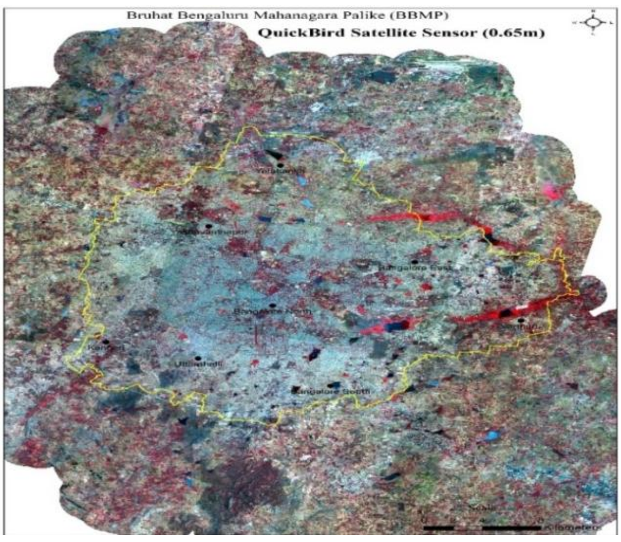
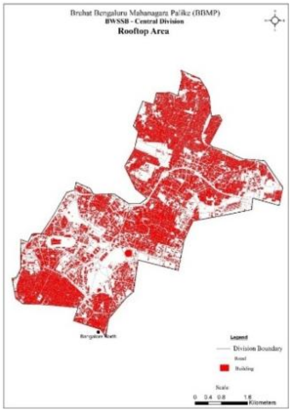
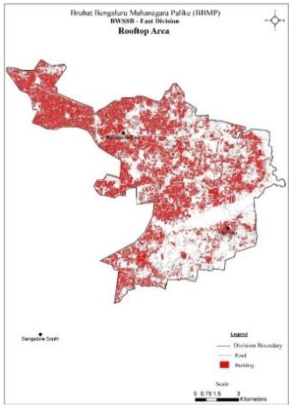


Figure 2. QuickBird multi-spectral Satellite Image of the Study Area



(a)



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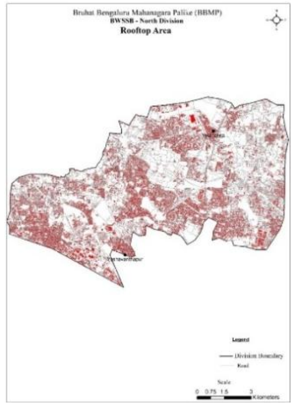

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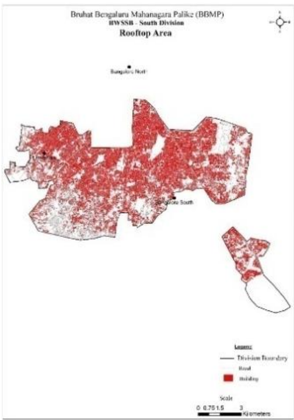

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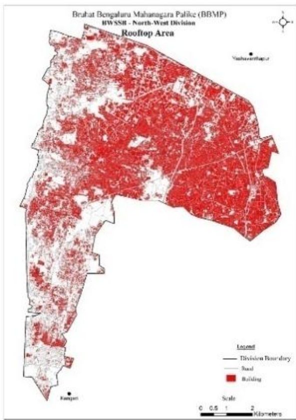

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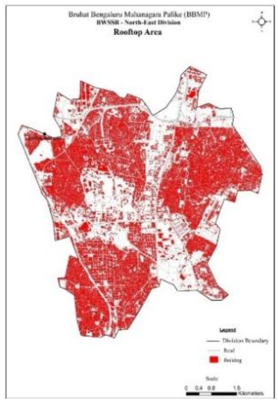

(f)

Figure 3. Division wise Rooftop Rainwater harvesting area (a,b,c,d,e, and f)

Table 2. Rainwater Potential

Annual Rainfall		Annual Rainwater Potential (in Liters)			
		Plot sizes in Sq. feet			
in inch	in mm	600 (20' x 30')	1200 (30' x 40')	2400 (40' x 60')	4000 (50' x 80')
19.69	500	28,000	55,500	1,11,500	1,86,000
31.50	800	44,800	88,800	1,78,400	2,97,600
39.37	1000	56,000	1,11,000	2,23,000	3,72,000
47.24	1200	67,200	1,33,200	2,67,600	4,46,400
55.12	1400	78,400	1,55,400	3,12,200	5,20,800
157.48	4000	2,24,000	4,44,000	8,92,000	14,88,000

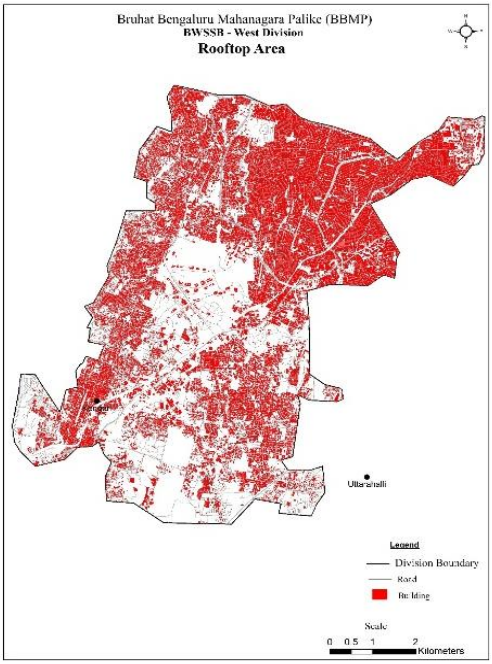

Figure 4. Division wise Rooftop Rainwater harvesting area

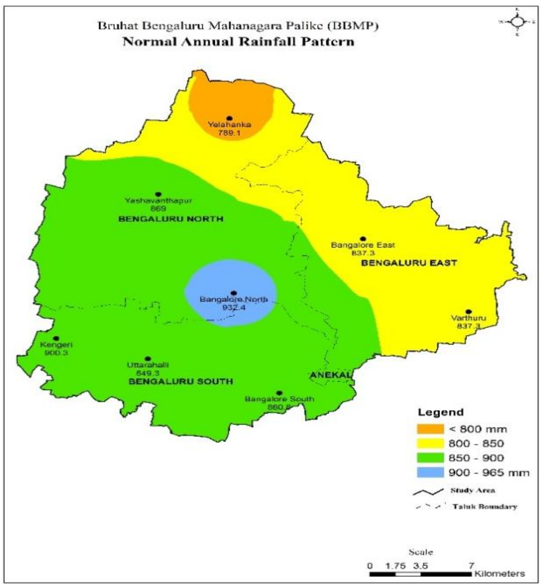

Figure 5. Annual Rainfall Pattern.

Rainfall

Rainfall or precipitation data was collected from 8 monitoring stations (Figure 4.1) maintained by Indian Meteorological Department (IMD) and Directorate of Economics and

Statistics – Karnataka between 1961 to 2018. 59 years average rainfall data was considered to understand the rainfall dynamics – spatio temporal variability, etc. in Greater Bangalore.
Spatial Analysis of rainfall indicates that the western portion of Bangalore receives higher rainfall than the east. Seasonal analysis of rainfall indicated that rainfall in Bangalore is spread across 7 months i.e., 86.9% of rainfall occurs between the months of May to November, September being the highest with average rainfall of 156 mm.
Annual rainfall pattern (Figure 6) indicates higher variability in rainfall with respect to mean. The trend line and the moving averages indicate increasing rainfall.

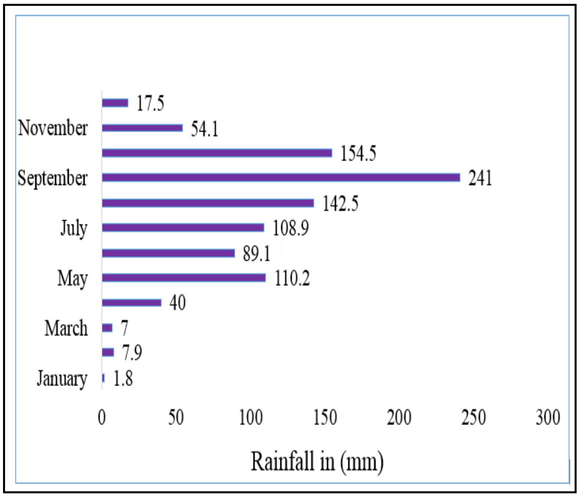

Figure 6. Monthly Rainfall Variability

Statistical analysis (Figure.6 Table 3) of annual rainfall indicates that average annual rainfall in Bangalore is 787 mm with 75% dependability and return period of 5 years. The coefficient of variation is 0.23 which indicates that there would be 23% variability in rainfall between consecutive years.

Table 3. Rainfall Characteristics

Rainfall (mm)	Frequency	Probability of Occurrence	Dependability	Return Period (years)
500	3	0.9	100.00%	22
600	12	0.8	95.40%	7
700	10	0.6	81.50%	8
800	18	0.5	68.50%	5
900	20	0.55	46.30%	5
1000	14	0.15	25.00%	7
1100	5	0.05	10.20%	22
1200	2	0.03	5.60%	37
1500	2	0.01	2.80%	37
Minimum		475 mm	Maximum	1595 mm
Mean		937 mm	Median	951 mm
Standard Deviation		±229 mm	Coefficient of	**0.24**

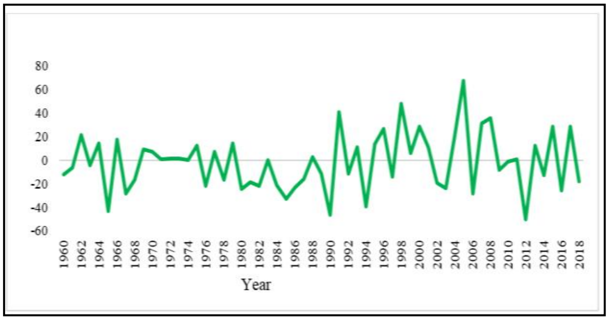

Figure7. Annual Rainfall Variations (Time Series)

Rainfall distribution as per the IMD classification of rainfall conditions nearly 67.7% of the time at least normal rainfall can be observed in Bangalore, 20.7% drought and 11.7% deficient rainfall conditions. The return period of normal rainfall is 3.5 years.

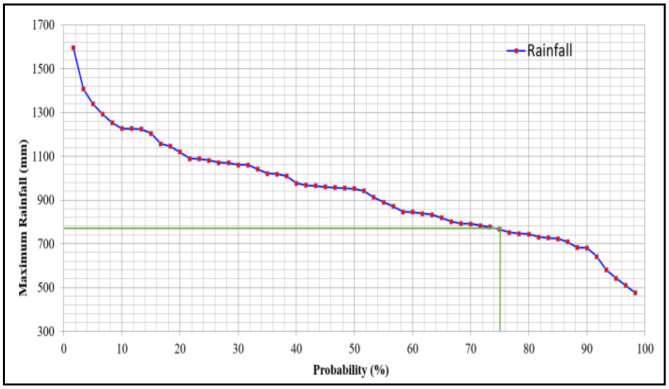

Figure 8. Rainfall Probability (%)

Table 4. Division wise Rainwater Harvesting in Volume

Sl.No.	BWSSB Division	Division Area (Sq. m)	Rooftop Area (Sq. m)	Volume in tmc
1	North	98807726	15597731	0.3
2	North-West	68144309	15229318	0.3
3	North-East	37787498	10119864	0.2
4	South	107680602	20873875	0.4
5	South-West	38383541	12931596	0.2
6	South-East	67057342	12530692	0.2
7	Central	26043431	7609362	0.1
8	East	132947917	21822567	0.4
9	West	58929131	12389991	0.2
		635781497	129104996	2.3

Runoff yield in Bangalore is calculated spatially based on the empirical equation (eq. 1) using GIS.

$Q = C*A*P/1000$ ….1 Where, Q = runoff in cubic meters; C = runoff coefficient (depends on land use of each pixel); C = 0.85 – 0.95 for paved surfaces (Built-up); C = 0.40 – 0.60 for open/agriculture and horticulture; A = area (pixel or catchment) in square meters; P = precipitation as mm.

Conclusion

Division wise rooftop yield analysis indicates that about 15% (2.3 TMC) for 500mm rainfall dependability. In the North division (0.3 TMC), North-West (0.3 TMC), North-East (0.3 TMC), South (0.2 TMC), South-West (0.4 TMC), South-East (0.2 TMC), Central (0.1 TMC), East (0.4 TMC), and West (0.2 TMC) and the total annual water yield is about 2.3 TMC.

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