Frame work for Sustainable Rainwater Harvesting for Urban Areas - A Case study of Guntur, Andhra Pradesh, India

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Abstract - In our changing environment, rainwater harvesting is one of the sustainable development goals. Rainwater harvesting systems are being used all over the world to supplement household water supplies and reduce urban water stress. According to the Sustainable Development Goals of the United Nations, the majority of the world's population is still lacking access to drinking water and other domestic usages. The motivation of the research is to integrate systems of municipal supply and harvested rainwater where both are critical and crucial for meeting the required or optimal requirements of domestic water demand in terms of supply, maintenance, frequency, and adequacy. Critical and crucial factors that have been considered in working out harvested rainwater [HRW] are climate, hydrology, terrain, type of development, and density. It could play a role in motivating people to create a research area where sustainable harvested rainwater can reduce the stress on a town's water supply. A case study in Guntur town revealed 29% of the local body's stress due to demand and supply. Analysis has been done to address the global water crisis, with an emphasis on meeting demand, efficiency, acceptability, applicable technical know-how, sustainability, and at the community level. The Karl Pearson's linear correlation method has been adopted among the 8 study pockets to verify the consistency of applying town-level harvested rain water. As per a study of literature indicated, 20 to 25% of the demand can be met from rainwater, which can be stored, distributed, and supplied to fulfil the water requirements of towns with similar meteorological conditions. i.e., 200–300 people per hectare, 10–15% slope of terrain, predominantly black cotton soil, and an annual precipitation range of 800–950 mm.

Keywords: Harvested Rain Water, Correlation Analysis, Chi Square Test, AHP and framework

I. INTRODUCTION

Population growth, urbanisation, industrialization, and increased levels of human activity place a continuous strain on existing water supplies, and water resources are inadequately managed to meet current demands and achieve long-term sustainability.

The world's population has increased from approximately 2.5 billion in 1950 to 7.35 billion in 2015. According to the United Nation's Sustainable Development Water Goals, the majority of the people are lacking access to drinking water and suffering from having sufficient water for daily domestic activities. An action plan has been framed to handle the water situation across the globe in a decade period, i.e., during 2018–28 to ensure availability and sustainable management of water for all. On July 9, 2020, the United Nations announced a new framework to speed up the progress towards attaining the SDG 6 – Water goals, making water available to all (United Nations, 2015, 2018 & 2020). Because water is essential for human survival, the demand for fresh water has more than doubled. It is noted that nearly 10% of freshwater is used for sanitation and health, while 70% and 20% are used for industry and agriculture, respectively (Machiwal and Jha, 2012). Rainwater harvesting (RWH) is an important method for utilising the seasonal monsoon and associated runoff. It is generally defined as the collection, storage, and distribution of water to meet the per capita water requirement in dwelling units (Fetaw et al., 2002; Gould, 1999; Stott et al., 2001). There are three types of RWH: 1. in situ RWH, 2. micro-catchment systems, and 3. a large-scale catchment system (Mbilinyi et al., 2005; Oweis et al., 2012; Gowing et al., 2015). The first two are applicable to a town's residential neighbourhoods. Rainwater harvesting is an alternative source of water for bridging the gap between water demand and supply in residential neighbourhoods.

II. AIM & OBJECTIVES

The Aim and Objectives are the goals of the research programme that will guide the entire research process. The research work is defined by the aim, and the objectives are the stages by which the aim is achieved.
The aim of the research is to develop a Sustainable Rainwater Harvesting Framework for Urban Areas: A Case Study of Guntur Town.

1. To develop a framework to utilise rainwater in reducing the gap between demand and supply of water by Guntur Municipal Corporation.
2. A critical review of existing RWH technologies available nationally and internationally, with the aim of identifying a sustainable consideration for Guntur town.
3. Identification and assessment of an approach to enhance the RWH at the micro-level to macro-level, considering neighbourhood scale as a unit.
4. Validation of the application of RWH in Guntur through secondary data and primary survey/questionnaire.

The literature review indicates that there are studies related to RWH in urban and rural settlements to recharge the underground aquifer broadly, Parnas F, Abdulla E, Muthanna T, in 2021, Krishna R, Mishra J, Ighalo J, 2020, emphasized on annual water demand has increased globally for a variety of reasons. Tamasan C F et al, 2007, contends that water was an essential for human survival, which explains why the right to water is gaining international and national recognition. Zabadi H et al 2020 emphasises that though the water stress exists, practice of rainwater harvesting is the best solution to overcome the stress through Roof harvesting system (RHS) and Pond harvesting system (PHS). Besides, it was further emphasizing that the rainwater harvesting is the process of augmenting natural infiltration of rainwater or surface runoff into the ground through the use of artificial methods. The method generally used for recharge was pits, trenches, and bore well shafts by directly diverting runoff water into existing or disused wells or conserving rainwater by artificially storing and using it for human use (Janmejoy et al, 2021). but no specific study related to the quantum of reduction in municipal water supply or through a framework by using harvested rainwater to residential dwellings at different levels such as plots of varying sizes and neighbourhoods, thereby reducing the load on municipal water supply.
How can harvested rainwater runoff reduce the load on municipal water supply to residential neighbourhoods?

- To explore the potential of rainwater harvesting in Guntur town, Municipal corporation area.
- To work out demand and supply and also to reduce the gap by working out sustainable rainwater harvesting frame work to Guntur Municipal corporation area.

A global water model is used to investigate the effects of climate change and socioeconomic driving forces (derived from the IPCC's A2 and B2 scenarios) on future global water stress (Alcamo J et al., 2006). Water is essential for human survival, which explains why the right to water is gaining international and national recognition (Tamasan, C. F. et al., 2007). It is essential and crucial to address the water crisis so as to provide adequate water, which is the prime and essential service to the settlements. So, the research study area of Guntur town in Andhra Pradesh, India has been considered to understand the nature of the town, problems and potentialities of the water sources and its supply in order to explore the sustainable practises of utilising the harvestable rain water.

III. SIGNIFICANCE OF THE TOWN - GUNTUR

Guntur municipal corporation covers an area of 168.41 km^2. According to the CENSUS 2011, it has a land area of 159.46 km^2 and a population of 74,354 people. The summer season has the highest temperatures, but it is followed by monsoon rains from July to November, with August being the wettest month. The average annual temperature is 28.50 degrees Celsius, and the winter season, which lasts from November to February, has a pleasant climate. Guntur's soil is divided into two types: red soil and black cotton soil, with the former predominating. The town's population was 514461 in 2001 and has since increased to 743354. The town's population was 514461 in 2001 and 743354 in 2011, representing a 44.49 percent increase over the previous decade. Guntur is well connected by road, and nearby towns include Narasaraopet, Chilakaluripet, Mangalagiri, Tenali, Ponnur, and Sattenapalli. All of these nearby towns are well connected by road, with the road transport corporation's headquarters in Guntur.
(www.guntur.ap.gov.in, Census-India).

Eight study pockets with specific delineation criteria were chosen within the limits of Guntur municipal corporation for understanding the domestic water supply. The eight study pockets such as Ashok Nagar, Vengalarao Nagar, Brodipet, Nehru Nagar, Arundalpet, Sakethapuram, Old Guntur Extension, and Ankamma Nagar have been considered to appreciate the piped water supply of Gutur Municipal Corporation. Ankamma Nagar, Old Guntur extension, and Sakethapuram are three of the eight pockets with significant open spaces. The delineation criteria were discussed in section 4.8 below. All of the delineated pockets have been studied in terms of plot sizes ranging from less than 100 square metres to more than 800 square metres. As well as the existing land use map and foot print of the built form in varying plot sizes have been verified with the ground situation to workout paved/ non paved areas. The occupancy/ density/ population of each pocket has been arrived according to Andhra Pradesh building bye laws, plots of 100 to 300 square metres can have up to three floors and three kitchens. As a result, this has been used as a starting point to determine the number of dwelling units. On average, plot sizes ranging from 300sqm to 400sqm can accommodate six dwelling units. Similarly, all plot sizes have been analysed in accordance with building bye laws (APGO119) to determine the number of dwelling units and related occupancy based on published demographic data for a family size of 4.1.
In Guntur town, water is supplied from three major sources, i.e., 1. infiltration gallery at Vengalayapalem, 2. comprehensive water supply scheme from Kammamur canal at Sangam Jagarlamudi, and 3. Guntur canal from Krishna River at Thakallapadu village. This entire water supply management is being governed by the Guntur municipal corporation.

3.2 ANNUAL AVERAGE RAINFALL OF GUNTUR

The average annual rainfall in Guntur is 961 mm, with the maximum rain fall experiences during the months of July, August, September, and October. For effective and efficient distribution to the inhabitants, the two decadal averages of monthly precipitation for these four months, namely 139.71mm (14.53 percent), 152.53mm (15.8 percent), 149.82mm (15.59 percent), and 123.24mm (12.80 percent), have been considered. The precipitation over the course of four months accounts for 58.72 percent of the total annual rainfall. The precipitation in the remaining months is insignificant and may not result in runoff so it has not been considered for the analysis.

3.3 DEMAND & SUPPLY OF MUNICIPAL WATER

The Guntur municipal corporation provides 96 LPCD of water, whereas Indian standards require 135 LPCD. As a result, the demand and supply gap have been calculated based on the study pocket population, allowing the percentage of the contribution from harvestable rainwater to be determined.
The day-to-day water stress for all eight of the selected study pockets has been evaluated and tabulated based on the population of the eight pockets. The calculated water stress is a figure that falls between 25% and 35% of the total water demand. During the rainy season and subsequent immediate months, the gap can be addressed, even after considering evaporation and other water loss etc as 57% of the total annual rainfall amounts during these months i.e., July to October.

Consequent to the broad understanding with reconnization survey, and review of various models / methods yielded to analyse using appropriate methods such as Rational Method and SCS-CN Method to determine the amount of harvestable rainwater in each pocket of the study area. The Ashok nagar study pocket has a daily demand of 417.42 CuM, a daily supply of 293.83 CuM, a daily gap of 123.59 CuM, and a monthly stress of 3710.4 CuM from municipal supply. Similarly, the month-by-month water stress has been calculated for all of the study pockets based on the average monthly precipitation over the last two decades.

3.4 DELINEATION OF STUDY AREA CRITERIA

It is essential to understand the macro level considerations related to the rain water harvesting potential in terms of its demand, supply, availability, efficiency, intensity of rain water, runoff, surface absorptions, storage system and distribution at town level.
The delineated study areas have been considered to understand the broad perspective of the rainwater considerations. The criteria are as mentioned below:

1. Density of population: 220 -300 Persons Per Hectare
2. Areas having of municipal pipe water network and water drainage system
3. Predominantly residential land use with varying plot sizes
4. Topography, runoff considerations, having up to 15% of slope

According to the above-mentioned study criteria, eight pockets were identified in various locations throughout Guntur town to assess the harvestable rainwater potential. Vengalaraonagar, Ashoknagar, Brodipet, Arundalpet, Nehru Nagar, Ankamma Nagar, Old Guntur Extension, and Sakethapuram are among the pockets.

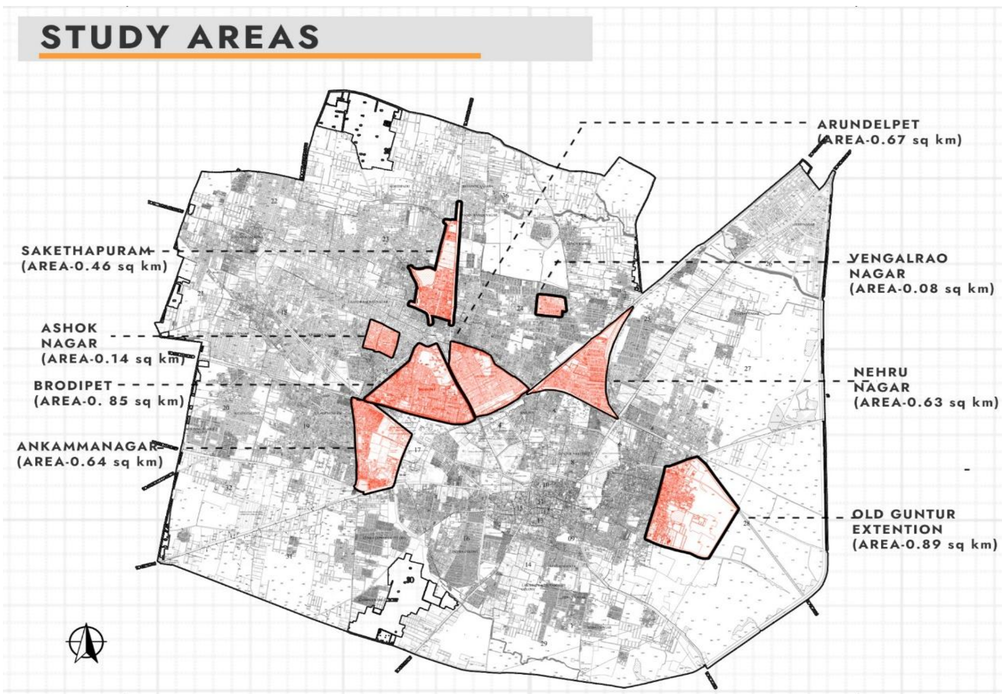

Figure1: The Guntur municipal limit and delineated pockets

The calculations of runoff quantities are influenced by a variety of parameters. Because most rainwater surface types in urban areas are restricted to roofs, the level of actual runoff is influenced by the type of surface material, surface wetting, ponding in depressions, absorption, and evaporation. The SCS – CN method and the Rationale method were chosen for calculations among various methods of assessing harvestable rainwater. In order to assess the harvestable rainwater using these two methods, the area covered by these study pockets has been divided into two categories: plotted areas and community areas.

The plotted area includes both built-up and unbuilt plots. The community area includes all types of roads, parks, public areas, additional paved areas, and non-paved areas that have been identified for assessing harvestable rainwater. The month-by-month harvestable rain water has been calculated based on the two-decadal annual rainfall, after deducting the loss due to evaporation and other factors using the PAN evaporation method. The study pocket of Ashok nagar has been shown in figure 2

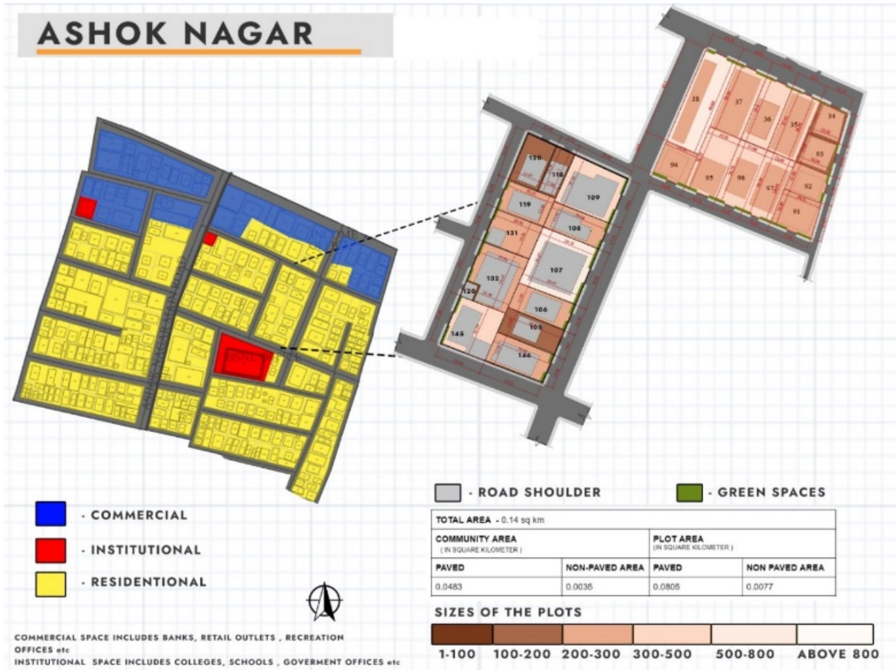

Figure 2: Study Pocket – Ashok Nagar, Total Area Details
Source: 1. Guntur Municipal Corporation, 2. Guntur master plan 2021.

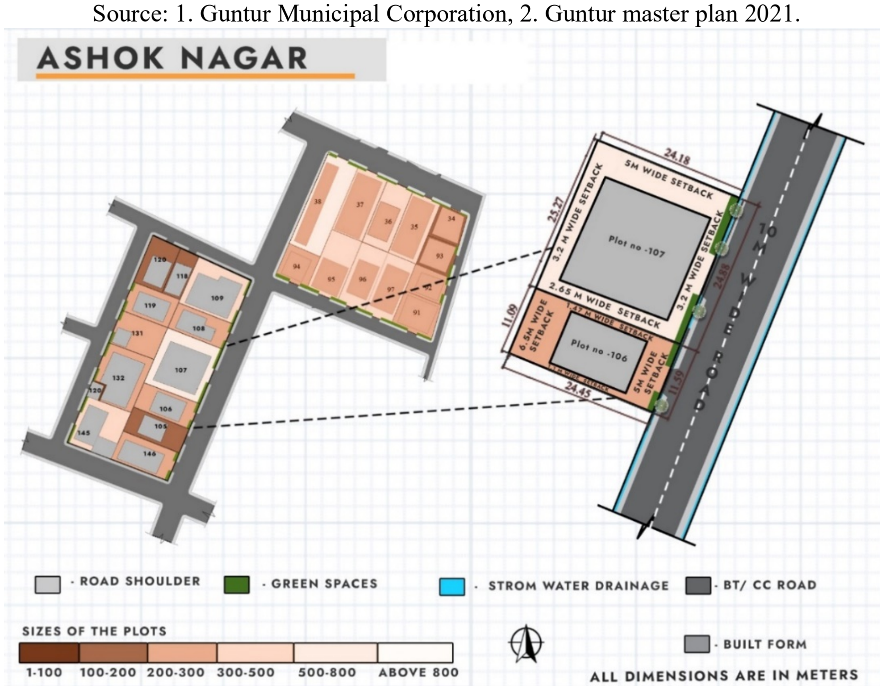

Figure : 3 part plan the Paved and non-paved areas in Ashoknagar

Source: 1. Guntur Municipal Corporation, 2. Guntur master plan 2021.
The land use of the ashok nagar related plot sizes been collected from the secondary and primary sources. Further paved and non-paved areas have been calculated as shown in figure 3 to analyse the runoff of rainwater taking in to the consideration of the building foot print to work out the runoff from terrace and from the setbacks.
Though harvestable rainwater has been assessed month by month, the peak rainfall period, i.e July, August, September, and October, has been taken into account for the assessment. The harvested water, after deducting the loss, was grouped according to plot area and from the community area and was worked out to a comparable unit of LPCD- litres per capita per day (LPCD).

3.5 QUNATITATIVE & QUALITATIVE SURVEYS

Research work have been carried with quantitative & qualitative surveys using Karl Pearson's linear correlation, Chi Square test and Analytical Hierarchy process for working out a correlation among the study pockets, deriving the consistence of expected to analysed LPCDs and establishing the parametric weightages for frame work respectively.As per the literature review and best practices identified in assessing the harvestable rainwater two methods given below.

- Rationale method
- SCS- CN Method

The Rationale method was considered for plotted areas of micro level considerations where the scope of the assessment involved is limited to plotted units. For community areas where the scope of the assessment involved is greater extent in a neighborhood level covering roads and supporting facilities/ uses other than residential plots where Curve Number method has been considered. Areas of paved and non-paved areas from plotted areas, as well as community areas, were analyzed for eight study pockets as delineated in Guntur town with respect to the existing land use from the base maps and the primary survey.

3.5.1 LINEAR CORRELATION – KARL PEARSON'S CORRELATION METHOD

To determine the relationship among the study pockets in terms of runoff quantities , occupancy , supply & demand compared and found that there is a strong correlation identified through the linear correlation by Karl Pearson method. The results established the similarity and consistency so as to derive a workable strategy for town level sustainable harvested rainwater to reduce the gap between the supply and demand. Further to elaborate that the method was used by grouping and analysing the plots based on varying areas within the eight study pockets.

Karl Pearson's linear correlation coefficient, denoted by "R," defines the degree of relationship between two variables. It is also known as the Cross-correlation coefficient because it predicts the relationship between two variables. If the R^2 value is 0.3, it is considered a None or Very weak effect size; if the R^2 value is 0.5, it is considered a weak or low effect size; and if the R^2 value is > 0.7, it is considered a strong effect on each other.

3.5.1.1 Correlation of plots with 1 to 100 sqm area with plots having 100-200, 300-500 & 500 800 sqm area among all study pockets.

Table 1: Varying plot sizes for harvestable rainwater in case study pockets

S.NO	**Name of the study pocket**	**Total harvestable water from paved and non- paved areas (LPCD)**			
		Plot areas in sqm			
		1-100	**100-200**	**300-500**	**500-800**
1	Ashok nagar	17.40	23.96	20.00	25.00
2	Vengalarao nagar	20.00	27.43	30.05	32.56
3	Brodipet	18.00	26.46	27.00	29.00
4	Nehru Nagar	12.06	19.58	21.00	22.00
5	Sakethapuram	15.00	18.90	20.00	26.73
6	Arundalpet	11.95	14.72	20.32	22.16
7	Old Guntur extension	18.78	25.90	25.00	31.00
8	Ankamma nagar	9.00	4.83	18.00	19.46

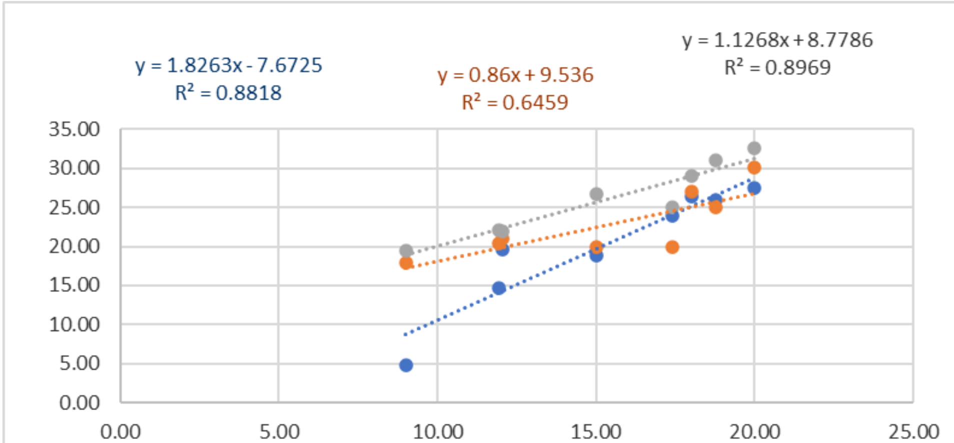

Figure 4: Correlation of plots having an area of 1 to 100 sqm through varying other plot sizes (100-200, 300-500 & 500-800sqm)

The correlation coefficient carried for study pockets as shown in table 1 and found that LPCD of (1-100) has correlation to other study pockets related LPCD's of (100-200) sqm, (300-500) sqm and (500-800) sqm Plots and found strong relation as shown in figure 4 with the 'R^2' values are 0.88, 0.65 and 0.90 respectively.

3.5.1.2 Correlation of plots with 100 to 200 sqm area with plots having 200-300, 300-500 & above 800 sqm area

Table 2: Varying plot sizes for harvestable rainwater in case study pockets

S.NO	Name of the study pocket	Total harvestable water from paved and non- paved areas (LPCD)			
		Plot areas in sqm			
		100-200	200-300	300-500	Above 800
1	Ashok nagar	23.96	19.00	20.00	30.00
2	Vengalarao nagar	27.43	27.00	30.05	34.00
3	Brodipet	26.46	24.00	27.00	30.00
4	Nehru Nagar	19.58	15.00	21.00	24.00
5	Sakethapuram	18.90	17.00	20.00	27.00
6	Arundalpet	14.72	19.11	20.32	24.00
7	Old Guntur extension	25.90	21.00	25.00	32.00
8	Ankamma nagar	4.83	10.00	18.00	21.00

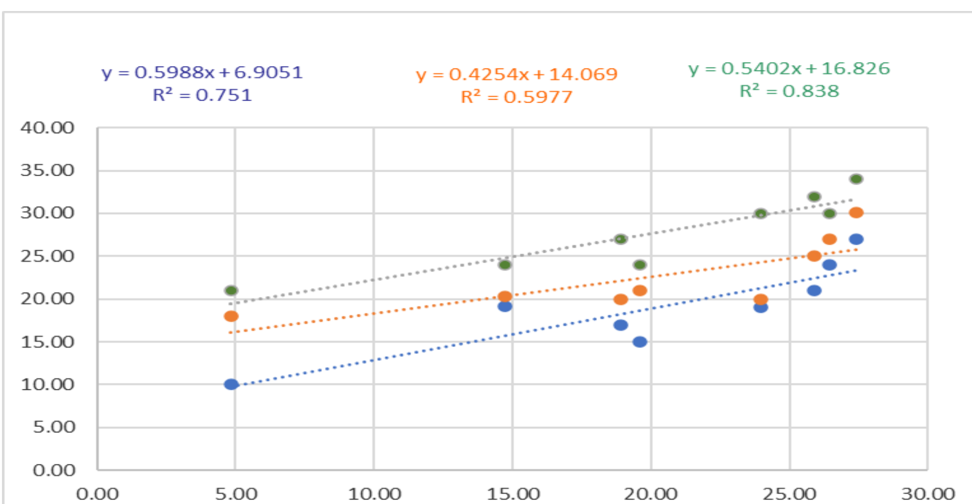

Figure 5: Correlation of plots having an area of 100 to 200 sqm through varying other plot sizes (200-300, 300-500 & above 800sqm).

S.No	Category of plots based on Area, sqm	Required LPCD	Municipal supply	GAP LPCD	[Oi] Analysed/ Calculated HRW in LPCD	[e_i] Expected reduction on Municipal supply LPCD	$\sum_{i=1}^{6}\frac{(o_i-e_i)^2}{e_i}$
1	below 100	135	96	39	15.27	19.52	0.93
2	100-200	135	96	39	20.22	19.52	0.03
3	200-300	135	96	39	19.01	19.52	0.01
4	300-500	135	96	39	22.67	19.52	0.51
5	500-800	135	96	39	25.99	19.52	2.14
6	Above 800	135	96	39	25.13	19.52	1.61
							5.23

The correlation coefficient carried for study pockets as shown in table 2 and found that LPCD of (100-200) has correlation to all eight study pockets related LPCD's of (200-300) sqm, (300-500) sqm and (above 800) sqm Plots and found strong relation as shown in figure 5 with the 'R^2' values are 0.88, 0.65 and 0.90 respectively.
The correlation analysis was applied to the remaining four study pockets with varying plot sizes as carried above and found similar relation among all, establishing the application of town level sustainable harvestable frame work.

3.6 CHI SQUARE TEST

The literature review and interview with municipal authority revealed the harvestable rain water of similar climatical, meteorological, topographical and population density of towns may support the harvestable rain water for domestic use and provide 20 to 25% of the domestic water requirement. The analysis of runoff for rainwater harvesting at macrolevel to micro level with due consideration to all datasets in all 8 study pockets derived to the basic level unit of LPCDs with respect to the paved and nonpaved, absorption of the runoff surfaces for varying plot sizes and community level to workout total contribution of HRW. So the analysed quantities and expected HRW According to the calculated harvestable rainwater at study pocket level has been derived with respect the occupants / density of population to LPCDs. The calculated/observed frequency was compared with the expected frequency has been tested using the Chi Square statistical analysis as shown in table 3.Table 3: the Calculated/ observed frequency compared with Expected Feequency
Chi Square test

$$\text{The Observed chi} - \text{square statistic} = \sum_{i=1}^{6}\frac{(o_i-e_i)^2}{e_i} = 5.23$$

The table Chi Square value with 5 degrees of freedom and a significance level of 0.05 at the right tail of the Chi Squared distribution is 11.07. Hence the expected level of LPCDs. The calculated Chi Square value (5.23) is less than the table Chi Squared value (11.07), indicating that it falls within the acceptable range.
As a result, it demonstrates that sustainable practises of harvested rainwater and related framework will reduce stress on municipal water supply and facilitate the reduction of the gap between demand and supply.

3.6.1 ANALYTICAL HIERARCHY PROCESS - DERIVING THE WEIGHTAGES FOR SUSTAINABLE PARAMETERS

The survey was conducted in the aforementioned study pockets.50 responses from residents were collected from each study pocket, averaged and analysed. The components are broadly categorised to work out a sustainable harvested rainwater frame work as: harvestable rain water, technical knowhow, monitoring, rainwater storage, institutional mechanism, and urban engineering considerations. To find the ranking of priorities and the Eigen-vector X, the normalisation of the matrix, the calculation of the consistency ratio and related weightages, and its procedure have been given below to apply to the sustainable components for rainwater harvesting to reduce supply and water stress on local bodies and to utilise rain water through natural means. If the consistency ratio is less than or equal to 10%, the inconsistency is accepted. The subjective judgments were revised if the consistency ratio was greater than 10%. The components have been categorised into 3x3 matrices of sub-components and parameters to derive the weightages for the development of frame work. The component of harvestable rain water has been analysed through sub components and its significance over other parameters has been derived as shown in table 4.

Table no:4: Significance level of component with respect to the subcomponent and related parameters for Harvestable rain water

1	Propose your significance for Rainwater runoff in terrace in comparison to runoff of setbacks in Harvestable rain water		
	EXTREMELY IMPORTANT	2	4.00%
	VERY IMPORTANT	8	16.00%
	NEUTRAL	10	20.00%
	LESS IMPORTANT	26	52.00%
	NOT AT ALL IMPORTANT	4	8.00%
2	Propose your significance for terrace runoff in comparison to community level runoff of rainwater for Harvesting		
	EXTREMELY IMPORTANT	3	6.00%
	VERY IMPORTANT	7	14.00%
	NEUTRAL	8	16.00%
	LESS IMPORTANT	29	58.00%
	NOT AT ALL IMPORTANT	3	6.00%
3	Propose your significance for setbacks in comparison to common spaces in HRW.		
	EXTREMELY IMPORTANT	5	10.00%
	VERY IMPORTANT	21	42.00%
	NEUTRAL	16	32.00%
	LESS IMPORTANT	5	10.00%
	NOT AT ALL IMPORTANT	2	4.00%
4	Propose your significance for quantity of water collected in comparison to quality, with in terrace runoff in Harvestable rainwater		
	EXTREMELY IMPORTANT	0	0.00%
	VERY IMPORTANT	2	4.00%
	NEUTRAL	6	12.00%
	LESS IMPORTANT	23	46.00%
	NOT AT ALL IMPORTANT	19	38.00%
5	Propose your significance for management in comparison to quality, with in terrace level runoff collection mechanism of rainwater for Harvesting		
	EXTREMELY IMPORTANT	0	0.00%
	VERY IMPORTANT	2	4.00%
	NEUTRAL	6	12.00%
	LESS IMPORTANT	34	68.00%
	NOT AT ALL IMPORTANT	8	16.00%
6	Propose your significance for quantity in comparison to management, with in terrace in HRW.		
	EXTREMELY IMPORTANT	9	18.00%

	VERY IMPORTANT	29	58.00%
	NEUTRAL	6	12.00%
	LESS IMPORTANT	5	10.00%
	NOT AT ALL IMPORTANT	1	2.00%
7	Propose your significance for quantity of water in comparison to quality of water, with in setback runoff in Harvestable rainwater		
	EXTREMELY IMPORTANT	3	6.00%
	VERY IMPORTANT	6	12.00%
	NEUTRAL	33	66.00%
	LESS IMPORTANT	5	10.00%
	NOT AT ALL IMPORTANT	3	6.00%
8	Propose your significance for management in comparison to quality, with in setback in harvestable rainwater		
	EXTREMELY IMPORTANT	2	4.00%
	VERY IMPORTANT	5	10.00%
	NEUTRAL	7	14.00%
	LESS IMPORTANT	28	56.00%
	NOT AT ALL IMPORTANT	8	16.00%
9	Propose your significance for quantity in comparison to management, with in setbacks in HRW		
	EXTREMELY IMPORTANT	2	4.00%
	VERY IMPORTANT	6	12.00%
	NEUTRAL	7	14.00%
	LESS IMPORTANT	15	30.00%
	NOT AT ALL IMPORTANT	20	40.00%
10	Propose your significance for quantity in comparison to quality, with in community level collection of rainwater for Harvesting		
	EXTREMELY IMPORTANT	2	4.00%
	VERY IMPORTANT	4	8.00%
	NEUTRAL	7	14.00%
	LESS IMPORTANT	6	12.00%
	NOT AT ALL IMPORTANT	31	62.00%
11	Propose your significance for management in comparison to quality, with in common spaces / community level in harvestable rainwater		
	EXTREMELY IMPORTANT	2	4.00%
	VERY IMPORTANT	22	44.00%
	NEUTRAL	14	28.00%
	LESS IMPORTANT	10	20.00%
	NOT AT ALL IMPORTANT	2	4.00%
12	Propose your significance for quantity in comparison to management, with in common spaces in HRW.		
	EXTREMELY IMPORTANT	1	2.00%
	VERY IMPORTANT	5	10.00%

		NEUTRAL	6	12.00%
		LESS IMPORTANT	10	20.00%
		NOT AT ALL IMPORTANT	28	56.00%

Similarly, all other components have been analysed and drawn the weightages as compiled in table no:5.
Table:5 Assessment of Hierarchical considerations through AHP for framework for Sustainable Harvested Rainwater utilization

Components	Sub-Components	Parameters	Weightage	Received Priority
Harvestable rain water	Terrace runoff	Quantity	0.21	Management
	setbacks runoff	Quality	0.32	
	Community spaces runoff	Management	**0.47**	
Technical knowhow	NH level	Quantity	0.32	Quality
	Plot level	Quality	**0.44**	
	Town level	Management	0.24	
Monitoring	Plot level	Inspection	0.38	Quantity
	Street level	Review	0.18	
	NH level	Quantity	**0.45**	
HRW storage	Combined sump	Quantity	**0.47**	Quantity
	Separated sump	Quality	0.32	
	Connected sump	Management	0.21	
Institutional mechanism	residential District	Quantum of service	0.28	Management
	Town	Quality of service	0.21	
	Neighborhood	Management	**0.51**	
Urban engineering and Architecture	Town	Cost	0.38	time
	NH	Time	**0.47**	
	Plot	Quality	0.15	

All of the components were evaluated in terms of quality, quantity, and management, and it has been observed that the management of rainwater harvesting is 47 percent as compared to quality and quantity. The quality service of urban engineering and architectural thought is 47 percent, the maintenance and systematic monitoring of the urban local body and its institutional mechanism is 51 percent, the rainwater storage capacity is 47 percent, and the monitoring of the rainwater system to ensure that it operates effectively showed a 45 percent weightage, with a quality filtration system in the order of 44 percent for sustainable harvesting in the neighbourhood and at the dwelling unit level.
The importance, significance level, and pair-wise comparison have been carried out in relation to the questionnaire survey for all of the above components in terms of quality, quantity, and maintenance.

IV. RECOMMENDATION & FRAMEWORK

The sustainable framework has various tasks and challenges that are addressed sequentially in order to bring the feasible solution with respect to the macro level through the correlated appreciation of 8 study pockets of considered data sets to reduce water stress in terms of demand and supply.
Fig. 6 shows the broad framework covering the application of sustainable harvested rainwater through the components, sub-components, and related weightages. However, the framework diagram is not limited to the shown components as it is only an outline. The additional parameters of consideration are also elaborated upon below.

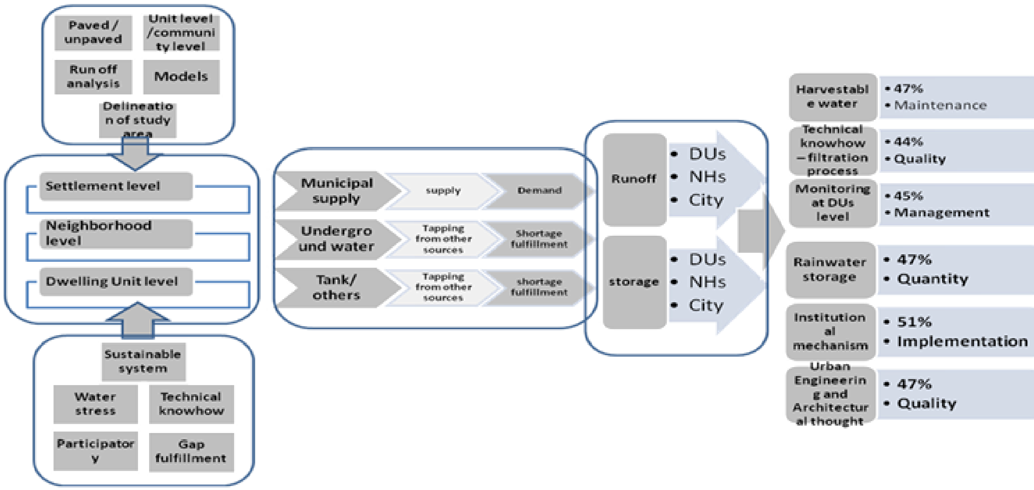

Fig6: Framework for sustainable Rainwater Harvesting.

4.1 The requirements for the design of the sustainable harvestable rainwater framework for towns were derived from the challenges observed in the various studies and analysis. This was on the understanding that these requirements could be used as measures or solutions to overcome water stress. Apart from the identified requirements from the results presented in eight delineated study pockets, Karl Pearson's linear correlation establishes the acute stress on municipal water supply by 30%.

4.2 The frame work has different phases, including assessment of the current status of water supply, elicitation requirements, refinement requirements, and implementation-related requirements.

4.3 The frame works are urged to always examine their existing strategies in order to harmonise them and overcome them with the most appropriate strategy for municipal authorities.

4.4 These requirements should then be refined through a rigorous process of additions and eliminations w.r.t context-specific conditions where various data analysis techniques and tools can come into the picture other than the rationale and the SCS CN method of calculating the runoff.

4.5 After the framework has been chosen, it can elicit requirements from the users, institutional mechanisms, urban engineering, monitoring and maintenance.

4.6 The framework has been further analysed with a diagram shown in fig.6 covering identified challenges, derived requirements, assessment of intensity of stress, analysed solutions, and adopted steps so as to get the desired output.

a) Challenges
b) Derived requirements
c) Assessment of intensity of stress
d) Analyzed solutions
e) Adopted steps

4.7 The significance of rainwater runoff through terraces has been compared with runoff collections from setbacks. Similarly, the quantity of water collected has been compared in terms of quality, quantity, and management.

4.8 Harvestable rainwater has been assessed from three distinct areas such as terraces, setbacks, and common spaces and related parameters such as quantity, quality, and management. (Further analysed and found that the management of harvestable rainwater amounts to 47% of the priority vector/weightage as compared to quality of water (32%), and quantity of water (21%).

4.9 The significance of technical know-how is essential and crucial for making the stored water available for effective utilization. So, the technical know-how at different levels, i.e., plot level, neighbourhood level, and town level, of harvested rainwater has been viewed to assess quality. Quantity and its management.

4.10 It is found that plot level technical know-how shows the priority vector/weightage of 61% as compared to neighbourhood level of 27% and 12% at town level. Further category wise weightages are also analysed at the neighbourhood level, plot level, and town level. At neighbourhood level, the management of technical knowhow is in the order of 59%. At plot level, 10% and at town level, 14% of weightage).

4.11 Monitoring of harvested rainwater at similar three levels is deemed necessary, and it is discovered that management of monitoring has received 45% of the weightage as compared to general inspections (11%) and reviews (18%). it is also analysed that the management of the system is found to gain more weightage at the plot level (63%), as compared to the neighbourhood level (16%) and street level (16%).
4.12 The storage configuration is one of the essential parameters in relation to the paved and non-paved areas and available spaces at ground level of varying plots as a sump, so as to filter and pump water to elevated tanks in order to distribute the water supply system to wet areas. It is found that the water storage system of the combined sump gained 57% of weightage as compared to separate sump (14%) to municipal water supply and to harvested rainwater and connected sump to both (29%). All these sumps were further analysed for quality, quantity, and management and it was found that the quantity of harvested rainwater has got more weightage of 56% as compared to quality and management for the combined sump.
4.13 The institutional mechanism is basically the supply of municipal water from source to users. It has an important role in fulfilling the water requirements of the town in terms of present and future projections with regards to demand and supply of water requirements. The institutional mechanism starts with the water and sanitation department of the municipal corporation, collecting water charges on a metre or slab basis. The mechanism also monitors residences, district wise, neighborhood, and town level, through piped connection and other means of supply at times of acute shortage, such as tankers, etc.
4.14 The institutional mechanism has been analysed and found that the residential district level mechanism, where a group of neighbourhoods monitored by a district level zonal office, gained 59% of weightage as compared to the town's 29% and the neighbourhood level's 16%, (further the matrix says the management at district level has shown more weightage as compared to quality and quantum of service).
4.15 Urban engineering has also been analysed by considering the opinion survey and found that the engineering and architectural thought processes are essential at plot level as they have gained 62% as compared to neighbourhood 14% and town level (24%).
4.16 Furthermore, to understand the same has been analysed in terms of cost, time, and quality and found the urban engineering and architectural services show more concern for cost and time factors for all levels of sustainable harvested rainwater practices. On the basis of the above items analysed through AHP, the broad framework which helps the sustainable practises of rainwater harvesting in Guntur is concluded below.

V. CONCLUSIONS & FURTHER STUDY

A thorough examination of its impact will shed more light on the RWH scenario and its implications in the future. As a result, the goal of this research was to develop a framework for assessing and fulfilling the demand-supply and develop a solution that took into account the potential of rainwater harvesting. The stated objectives of the study are to investigate plot and community level considerations in order to develop a framework to reduce water stress on municipal supplies while avoiding the use of ground water. Guntur's sustainable framework evolved as a result of deliberate direction, the collection, and the integration of rainwater-related parametric solutions. The same framework can be used for other towns with broadly similar conditions. The further scope of research may be extended to group development, high rise, and high-density compact development areas where harvestable quantities of rainwater and related paved or nonpaved areas have higher densities of population.

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