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Groundwater Recharge through Rainwater Harvesting Structures in Parts of Chittoor District, Andhra Pradesh

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Abstract: **India is blessed with good rainfall but however large of it lost through runoff and it can be impounded on the surface at suitable sites for surface storage. In recent decades groundwater is also threatened by over exploitation, contamination etc. The exploitation of groundwater resources more than its annual replenishment has caused continuous decline of water level, declined well yields, dry of shallow wells deterioration of groundwater quality and increase in cost of energy require to lift water from greater depth this scenario is seen in many pockets of over exploited groundwater regions in Andhra Pradesh. Chittoor district has no exception to it. In order to overcome the situation and increase the groundwater levels, the present study has been carried out to identify Water Harvesting Structures (WHS) in parts of Chittoor district, Andhra Pradesh. This study includes collection of rainfall data, cropping particulars, irrigation particulars and identification of existing water harvesting structures (WHS) and proposal of new WHS etc. to recharge and raise the groundwater levels in Karvetinagaram mandal. Twenty four harvesting structures (WHS) have been proposed with an estimated cost with 56.lakhs. The estimated storage capacity from both existing and proposed WHS is 174.52 ha. m. It is found that percolation tanks (PT) have more storage with 122.4 ha.m followed by check walls with 19.0 ha.m, check dams with 16.2 ha, mini-percolation tanks (MPT) with 11.8 ha.m, and staggered trenches with 5.04 ha.m.**

Keywords: **Rainfall, Groundwater recharge, water harvesting structures, groundwater levels, Chittoor district.**

I. INTRODUCTION

Millions of people throughout the world do not have access to clean water for domestic purposes. One of the biggest challenges of the 21st century is to overcome the growing water shortage. Water harvesting Structures (WHS) has thus regained its importance as a valuable alternative or supplementary water resource, along with more conventional water supply technologies. Much actual or potential water shortages can be relieved if rainwater harvesting is practiced more widely.

Need for Water harvesting Structures (WHS)

Due to pollution of both groundwater and surface waters, and the overall increased demand for water resources due to population growth, many communities all over the world are approaching the limits of their traditional water resources. Therefore they have to turn to alternative or ‘new’ resources like Water harvesting Structures (WHS). Rainwater harvesting has regained importance as a valuable alternative or supplementary water resource. Utilization of rainwater is now an option along with more ‘conventional’ water supply technologies, particularly in rural areas, but increasingly in urban areas as well. WHS has proven to be of great value for arid and semi-arid countries or regions, small coral and volcanic islands, and remote and scattered human settlements.

II. LITERATURE REVIEW

Many researchers given importance for artificial recharge structures / water harvesting structures in the world. Assessment of Groundwater Recharge by Water Harvesting Structures Using Remote Sensing and GIS, A Study of Jamka Village- Prajit C Patel and Sharad R Gajera- 2013 (Volume 2, issue 4, April 2013 - PARIPEX - Indian Journal of Research). In Saurashtra region of Gujarat state, problem of groundwater depletion has arisen due to high withdrawal rate of replenishment of groundwater. The water harvesting and groundwater recharge activities played an important role in increasing the groundwater resource and also improved the quality of groundwater and decreased rate of seawater intrusion in the region. In present study, groundwater recharge created through water harvesting structures in Jamka micro watershed had been estimated and efficient utilisation of groundwater available in study area was suggested using remote sensing and GIS.

Percolation Ponds in Coimbatore District, Tamil Nadu:
The water Technology Centre, Tamil Nadu Agricultural University has studied existing 10 percolation tanks in Coimbatore district of Tamil Nadu State for economic evaluation. Eight percolation tanks in Coimbatore taluk and two in Avinashi taluk of Coimbatore district were selected and studied. The study indicates that the total number of wells benefitting from percolation ponds during 1988-89 was 36 out of the 258 wells (14%). The total area benefitted due to these 36 wells was only about 14.4 ha.

Artificial recharge to ground water in Channian and Kalasinghian, Jalandhar and Kapurthala Districts, Punjab:
The village Channian and village Kalasinghian is located in Nakodar block of Jalandhar district and Kapurthala block of Kapurthala district respectively. The water levels are declining at a rate of 0.2 m/year. The spare canal water and surface runoff generated during monsoon, accumulated in the village ponds will be recharged. Annual water available for recharge is estimated to be around 0.28 m.cm.

Artificial Recharge in Sikheri, Mandsaur Block, Mandsaur District, Madhya Pradesh:
In Mandsaur block, depletion of water levels is taking place due to over development of ground water. Water levels have declined in the range of 1.25- 4.60 m in last 20 years. Level of ground water development is about 119%. A percolation tank is proposed to be constructed.

Artificial Recharge To Ground Water Through Sub-Surface Dyke At Nallan Pillai Patral, Gingee Block, Gingee Taluk, Villupuram District, Tamil Nadu:
The project is located in a backward area having concentration of landless labour. Villupuram district is severely affected by drought every year. Due to nature of the terrain and gradient of land, depletion of storage of water occurs at a very rapid rate and the entire zone becomes dry during summer. It is proposed to tap ground water by constructing subsurface dyke. The length of dyke is expected to be about 100 m whereas depth is around 3.50 – 7.00 m. The construction of dyke will result in better availability of water in the dug wells for a longer period even during summer months.

Impacts of Rainwater Harvesting: A case study of rainwater harvesting for domestic, livestock, environmental and agricultural use in Kusa by Orodi J. Odhiambo., Alex R. Odour & Maimbo M. Malesu, 2005. (Technical Report No. 30. Nairobi, Kenya; Regional Land Management Unit (RELMA-in-ICRAF), Netherlands Ministry of Foreign Affairs and Swedish International Development Cooperation Agency (Sida), 48 p). It was written to document the experiences and success of the Kusa community in implementing a rainwater harvesting initiative. The publication is a chronology of what it took to get the people out of poverty to paths of development and prosperity, through harnessing rainwater as an entry point for community development.

Rainwater Harvesting Innovations in Response to Water Scarcity by Maimbi M. Malesu, Joseph K. Sang, Alex R. Oduor, Orodi J. Odhiambo & Meshack Nyabenge, 2006 (Technical Report No. 32. Nairobi, Kenya; Regional Land Management Unit (RELMA-in-ICRAF), Netherlands Ministry of Foreign Affairs and Swedish International Development Cooperation Agency (Sida), 41 p). This book highlights results of a technical study commissioned by RELMA-in-ICRAF focusing on the relationship between land use and the local hydrology. Field surveys and Quickbrid images were used to establish the impact of land use and land cover changes in Lare Division of Nakuru District in Kenya and how these have contributed to the adoption of rainwater harvesting mainly using ponds. It has also dwelt at length on the technical and socioeconomic aspects of the runoff harvesting ponds.

Rainwater Harvesting by a Maasai Community: An evaluation report on a project in Talek of Masai Mara, Kenya, 2006 by Tanguy De Bock, Maimbo M. Malesu, Bancy Mati & Alex R. Oduor (Technical Report No. 31. Nairobi, Kenya; Regional Land Management Unit (RELMA-in-ICRAF), Netherlands Ministry of Foreign Affairs and Swedish International Development Cooperation Agency (Sida), 47 p). In 1999, a tourist firm located in Talek-Masai Mara approached the Regional Land Management Unit-RELMA, for technical support towards providing safe drinking water for the Maasai community. RELMA reciprocated by training local artisans through field excursions to Kusa, along the Lake Victoria shores and organizing tank construction tutorials. Since then, institutional and individual tanks, wells, and dams have been constructed. The authors evaluated the relevance, effectiveness, efficiency and impact of the water supply project.

Mapping of Potential of Rainwater Harvesting Technologies in Africa: A GIS overview on development domains for the continent and ten selected countries by Bancy Mati, Tanguy De Bock, Maimbo Malesu, Elizabeth Khaka, Alex Oduor, Meshack Nyabenge and Vincent Oduor (Technical Manual No 6, Nairobi, Kenya: World Agro forestry Centre (ICRAF), Netherlands Ministry of Foreign Affairs. 116p). This publication, which is a joint effort between the World Agro forestry Centre (ICRAF) and united Nations Environment Programme (UNEP), aims at demonstrating in spatial domains, the huge potential for rainwater harvesting in Africa and ten selected African countries. GIS database of RWH technologies such as rooftops, surface runoff into ponds or pans, sub-surface dams and in situ harnessing has been developed and highlighted.

Rainwater Harvesting and the Millennium Development Goals by the Rainwater Partnership Secretariat, 2005 (published by UNEP and Regional land Management Unit (RELMA in ICRAF). The primary aim of this publication is to create awareness among governments, donors, UN agencies and other relevant stakeholders on the contribution of rainwater harvesting to improving the livelihood of people worldwide. It is envisaged that the information offered will encourage governments and donors to invest both financial and human resources towards promoting rainwater harvesting especially among resource poor people who are hardest hit by water scarcity. UNEP and RELMA-in-ICRAF prepared this publication in close consultation with an expert group and many contributions from individuals and organizations belonging to the Rainwater Partnership. The Partnership was established on 7th October 2004 in The Hague.

Low–Cost Methods of Rainwater Storage: Results from field trials in Ethiopia and Kenya by Nega H, Kimeu PM (Technical Report Series 28, Nairobi, Kenya: Regional Land Management Unit (RELMA), Swedish International Development Cooperation Agency (Sida).

Many people in rural areas who would like to harvest rainwater lack the resources to do so. Conventional stone, brick or ferrocement tanks are costly, and therefore there is a great need for cheaper alternatives. This publication gives an account of two trials conducted in 1998/99 to investigate some such alternatives. In Ethiopia, five different methods of tank construction were tested in the suburbs of Nazareth town in Adama Woreda. In Kenya, six different methods were tested during the same period at various locations im Machakos and Makueni Districts. A main feature of the alternative tank designs is that they are built underground, which reduces the need for reinforcement materials.

The Texas Manual on Rainwater Harvesting, Texas Water Development Board in cooperation with Chris Brown Consulting, Jan Gerston Consulting, Stepen Colley/Architecture –Third Edition 2005, Austin, Texas. This Manual highlighted issues on Rainwater Harvesting System Components, Water Quality and Treatment, Rainwater Harvesting Guidelines, Financial and Other Incentives etc with case studies etc.

A Study on Ground Water Recharge in over exploited basin, Palavai basin in Anantapur District, Andhra Pradesh by Venkateswara Rao, S. (2011) Under Mahatma Gandhi Ground Water Recharge Project Implemented by Rural Development, Government of Andhra Pradesh (un-published report) and identified different Rain water harvesting and estimated possible groundwater recharge in the above basin.

III. STUDY AREA

Location: The study area Karvetinagaram basin situated on eastern part of Chittoor district at a distance of 50 km from district head quarters, Chittoor. The geographical area of Karvetinagaram mandal is **25328.3** ha, spread over 27 panchayats/villages. This area falls in part of Survey of India toposheet Nos. 57 0/7 lies between 13.4167°N 79.4500°E.

Physiography and Drainage: The Karvetinagaram part of the Peninsular Plateau and it is characterized by rugged topography formed by scattered hill ranges, streams and valleys. It has an average elevation of 266 meters (875 feet).This area is drained by local streams namely, Vepakonavanka, Boliguttavanka, Jedimanuvanka, Nagalaguntavanka, MukkaraVanka, etc.

Climate and Rainfall: The normal rainfall of this area is 963mm. Rainfall collected from 2001 to 2011. The summer temperature touches around 36º to 38°C and winter temperatures with 20°C to 22°.C.

Soils: A major portion of the area is covered by red soils. Red loamy soils constitute 57%, red sandy 34%, while the remaining is covered by black clay, black loamy, black sandy and red clay. Whereas as in the case of red soils the infiltration and percolation capacities are more the water holding capacity is very less as it contains high organic matter.

IV. METHODOLOGY

The methodology includes collection of rainfall data for ten years period (2001 to 2012), irrigation particulars and crop particulars from Mandal Revenue Office, Karvetinagaram, Chittoor district. Identification of suitable sites based on soil type, topography etc, for Water Harvesting Structures for surface storage to recharge and increase the groundwater levels with appropriate design of WHS and their cost. The rain fall pattern, irrigation particulars and crop particulars are shown in Table 1 and Fig. 1, Fig.2 and Fig. 3 respectively.

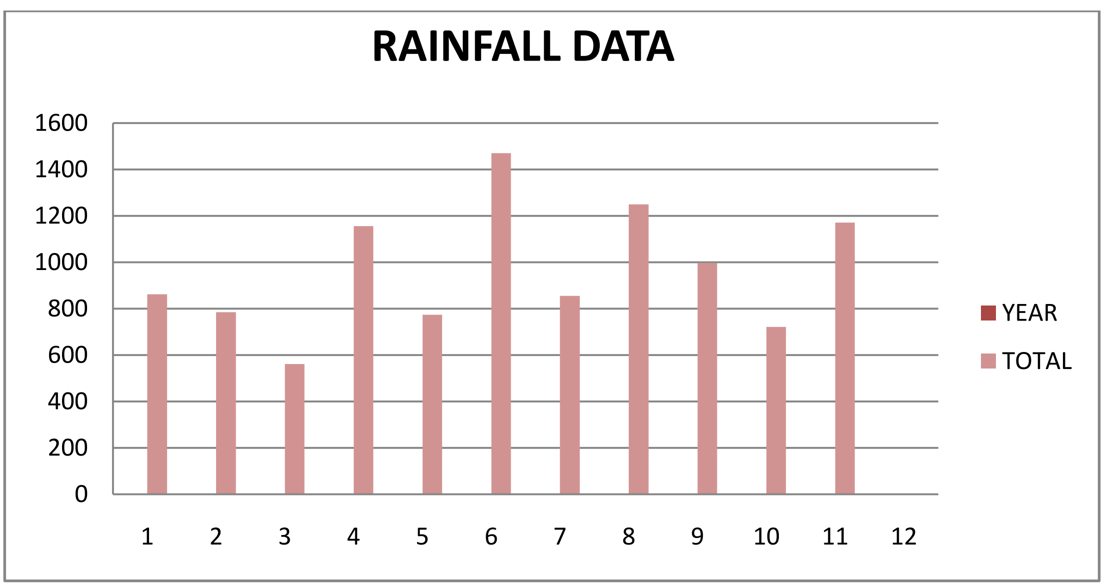

Fig: 1 Annual Rainfall Data of Karvetinagaram from 2001 to 2011(in mm)

Collection of Rainfall Data: The rainfall data collected from the Mandal Revenue Office of Karvetinagaram are shown in the following Table 1.

Table: 1 Annual Rainfall Data of Karvetinagaram from 2001 to 2011(in mm)

YEAR / MONTH	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	20011-12
JANUARY	0	3.2	0	0	0	0	0	14.4	0	50.4	3.6
FEBRUARY	0	0	0	0	0	0	11.8	0	0	0	16.4
MARCH	0	0	26.6	0	0	0	0	64.8	0	0	0
APRIL	0	131.2	0	61.4	64.6	0	46.1	22.4	0	7.6	0
MAY	25.6	40.6	0	207.5	112.8	71.1	36.6	52.2	83.6	117.2	0
JUNE	9.2	127.6	160.1	108.1	45.3	84.2	117.7	91.1	44.2	69	60
JULY	76.63	78.2	8.6	381.1	63.1	129	9.8	178	97.4	135	265
AUGUST	60.8	98.6	50.2	149	15.2	114.2	152	162.3	70	101	226
SEPTEMBER	207.4	110.2	89.8	101	300.8	252	220.7	218.9	100.2	31.2	135.4
OCTOBER	380.8	120.2	156	116.2	93	458	177.6	186	151	9.8	64.8
NOVEMBER	58.2	42	54.5	19.6	88.6	246	21	31.2	417	220.8	313.6
DECEMBER	43.2	33.2	14.6	5.4	0	228	61.4	228	32	78.6	86.4
TOTAL	861.8	785	560.7	1155	773.4	1470.5	854.9	1250	997	721.6	1171.2

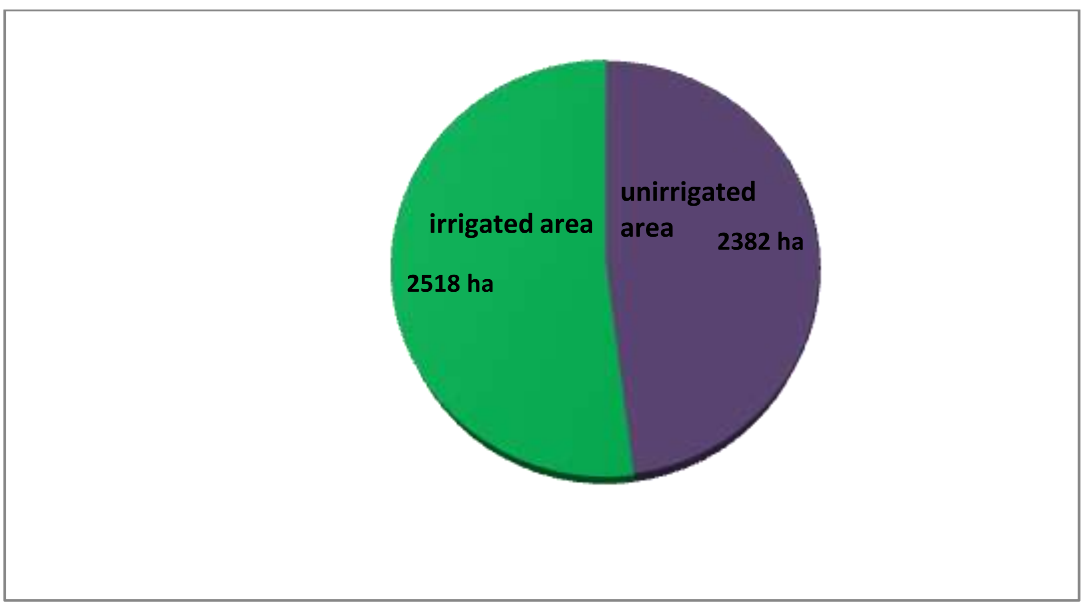

Fig:2 Irrigated and Un-irrigated Area (in ha) of Karvetinagaram.

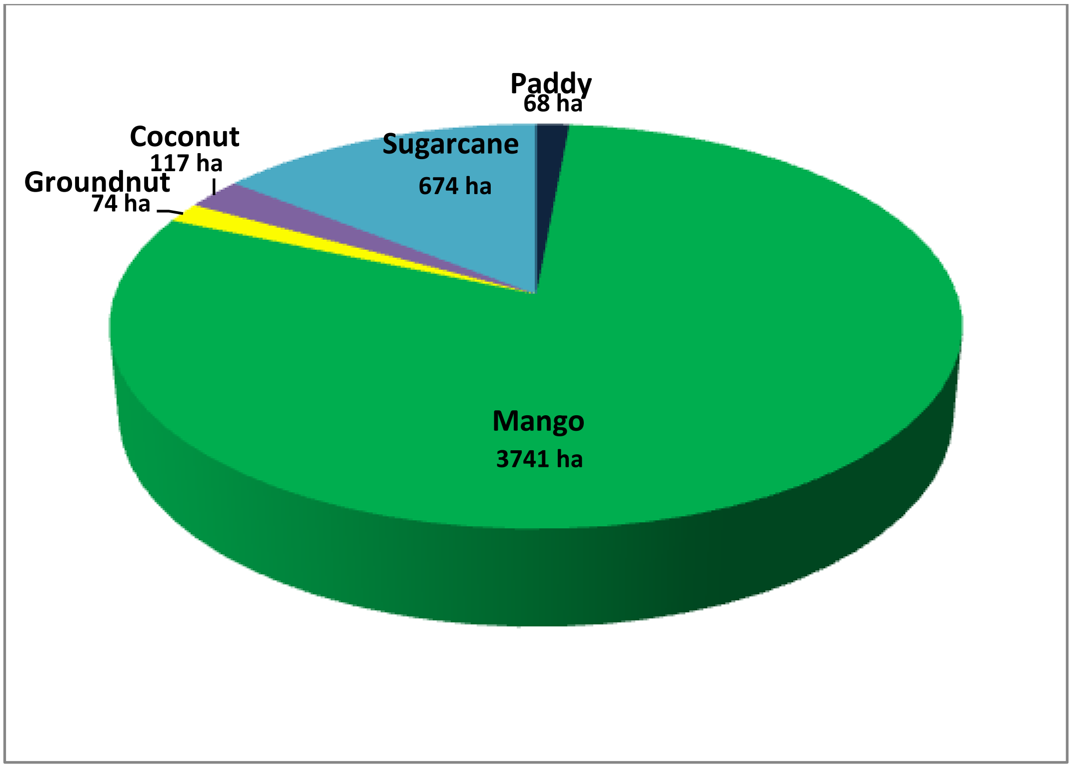

Fig 3: Major Crops Cultivated (in ha) in Karvetinagaram [2011-2012]

V. RESULT AND DISCUSSIONS

In Karvetinagaram systematic survey has been carried out and identified both existing and proposed WHS. The details of these WHS have been noted in the prescribed formats / annexure.

Surface Water Estimations

To assess the present surface water potential and to suggest new water harvesting structures to improve the ground water conditions, estimations of storage capacities have been arrived from the both existing as well as proposed WHS. The total available water for the village is estimated by taking the village geographical area (ha) and annual rainfall (m) for the last 10 years of the study area.

The water towards evopo-transpiration, ground water recharge, storage of surface water bodies and WHS is calculated. The balance available surface water is arrived by subtracting the water of the mentioned categories from the total available surface water of the village and is shown in Table: 2. The utilized surface water towards the construction of newly identified WHS is considered 20% of the above balance water.

In this area 24 WHS have been proposed and surface water required to be 55.46 ha.m. After deducting this from 20% balance surface water runoff, this area would be further balance of surface water is 870.13 ha. m.

The details of volume of rainfall, evapo-transpiration, recharge to ground water, eligibility run-off (20% of total volume of rain fall), and surface flow in existing and proposed water harvesting structures, surface flow in tanks and balance runoff for future use are shown in Table 2.

Table: 2 Run off Estimations in the Study area

Name of the Mandal: Karvetinagaram					
Number of villages included: 05				Name of the District: Chittoor	
S.NO	DETAILS		FORMULA	QUANTITY	
1	Area of the GP(in Ha)		Acres x 0.41	5430.2	
2	Average rainfall Mandal (in meters)		10 Years average	0.963	
3	volume of rainfall (in ha.m)		Rainfall(m)xarea of the GP in Ha	5223.28	
4	Evapotranspiration of Rainfall (ha.m)		0.5xvolume of rainfall in ha. m	2614.5	
5	Surface flow of rainfall (in ha.m)		0.4xvolume of rainfall in ha. m	2089.05	
6	Rainfall converted as ground water		0.1xvolume of rainfall in ha. m	531.96	
7	Storage of surface flow in the tanks		Area of the tank in Ha x Average height of the water level	141.4	
8	Storage of surface flow in existing WHS				
	Name of the structure	Storage capacity in cum. m	No. of fillings	No. of structures	Total Quantity in ha. m (storage capacity x No. of fillings x No. of structures x.0001)
I	CHECK DAM	3000	3	13	11.7
II	CHECK WALL	2500	4	14	14
III	PERCOLATION TANK	12000	6	12	86.4
IV	MINI PERCOLATION TANK	2200	6	4	5.28
V	STAGGERED TRENCH	1400	6	2	1.68
	TOTAL			45	119.06
9	20% balance surface runoff in ha.m				1044.65
10	Particulars of proposed WHS				

S.NO	Name of the structure	Storage capacity in cum. m	No. of fillings	No. of structures	Total Quantity in ha. m (storage capacity x No. of fillings x No. of structures .0001)
I	CHECK DAM	3000	3	5	4.5
II	CHECK WALL	2500	4	5	5
III	PERCOLATION TANK	12000	6	5	36
IV	MINI PERCOLATION TANK	2200	6	5	6.6
V	STAGGERED TRENCH	1400	6	4	3.36
	TOTAL			24	55.46
11	Total storage capacity from the proposed WHS in				55.46
12	Balance surface runoff for future use(ha. m)				870.136

Cost Estimation for Water Harvesting Structures: Rs. 56 lakhs have been estimated for all the 24 new WHS. Structure wise details and estimated cost, expected impounding of ground water is shown in following Table 3.

Table: 3 Cost Estimation for Water Harvesting Structures

S.NO	TYPE OF STRUCTURE	NUMBER	ESTIMATED COST IN LAKHS	EXPECTED IMPOUNDING GROUND WATER
1	CHECK DAM	5	15	4.5
2	CHECK WALL	5	5	5
3	PERCOLATION TANK	5	25	36
4	MINI PERCOLATION TANK	5	10	6.6
5	STAGGERED TRENCH	4	1.0	3.36
TOTAL		24	56	55.46

VI. CONCLUSIONS

The study area is blessed with moderate rainfall but however large amount of it lost through runoff. Suitable sites have been identified and proposed to impound for surface through Water Harvesting Structures (WHS), viz., percolation tank, mini-percolation tank, check dam, check walls and staggered trenches to raise and increase the declined ground water levels in study area.

A total number of 24 WHS have been proposed in the study area with an estimated cost of 56 lakhs. It noticed that the storage capacity of all WHS is 55.46 ha. m. It is found that percolation tanks (PT) have more storage with 122.4 ha. m followed by check walls with 19.0 ha.m, check dams with 16.2 ha, mini-percolation tanks (MPT) with 11.8 ha.m, and staggered trenches with 5.04 ha.m.

VII. EXPECTED OUT COMES

The following affirmative impact is expected by execution of proposed water harvesting structures in the study area.
1. Improved ground water levels.
2. Additional area brought under the cultivation by ground water.
3. Increase in cropped area and crop yields.
4. Assured and potable drinking water supply to every house hold.
5. Quality improvement owing to dilution of ground water.
6. Failure of bore wells will be reduced.

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