Progress Report

Improving Livelihoods through Integrated Watershed Management Approach at UltraTech (APCW) – ICRISAT watershed

February 2019 to March 2021

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INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

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1. Introduction

UltraTech Cements Limited (Andhra Pradesh Cement Works, APCW) has adopted an integrated watershed management program to address water scarcity, land degradation and crop productivity to improve rural livelihoods with the help of ICRISAT Development Centre (IDC), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). In February 2019, the watershed project was started with an MoU for two villages (CSR villages of UltraTech cements) named as Patnikota (latitude 15° 085′ N and longitude 78° 063′ E) of Kolimigundla mandal, Kurnool district and Ankireddypalli (later changed to Ayyavaripalli, latitude 15° 024′ N and longitude 78° 004′ E) of Tadipatri mandal, Anantapur district of Andhra Pradesh State (Figure 1).

The Patnikota village is located about 25 km (North-East) upstream to UltraTech cement plant. Patnikota village has a population of 2700 and 630 households. Farmers grow Castor, Pigeonpea, Cotton and Pulses (black gram and green gram) in the rainfed areas and Sweet orange, Papaya and Pomegranate in the irrigated areas of the village. The hydrological watershed area that rainfall contributes towards Patnikota village is around 3500 ha, which is named as UltraTech-ICRISAT Watershed (Figure 2). The average annual rainfall in the watershed area is around 615 mm. The watershed area is characterized by undulated topography with more than 20.0% slope. The major soils in the watershed are sandy gravel (40%), alfisol (redsoil-30%) and vertisol (black-30%) with medium to low water-holding capacity. Of the total watershed area, 40% is under agricultural use and the rest is wastelands and non-agricultural use. Of the total agricultural area, 50% is under rainfed condition and 50% is irrigated.

The Ayyavaripalli village is located 5 km downstream (South-West) to UltraTech cement plant. Ayyavaripalli village has a population of 1000 and 250 households. Farmers grow pigeon pea, cotton and black gram in the rainfed areas and paddy and groundnut in the irrigated areas of the village. The hydrological watershed area that rainfall contributes towards Patnikota village is around 2750 ha, which is named as Ayyavaripalli Watershed (Figure 2). The Ayyavaripalli watershed area is characterized by plain topography with less than 2.0% slope. The major soils in the watershed are black with medium to high water-holding capacity. Of the total watershed area, 70% is under agricultural use and the rest is wastelands and non-agricultural use. Of the total agricultural area, 50% is rainfed and 50% irrigated.

However, there are two watersheds identified for the watershed activities, Patnikota watershed has been selected for an integrated watershed management approach and Ayyavaripalli watershed has been selected for only productivity enhancement demonstrations.

Figure 1. MoU between UltraTech Cements (APCW-Plant Head; Mr. MSRK Prasad) and ICRISAT (Director General – Dr. Peter Carberry) for Integrated Watershed Management Approach in February 2019.

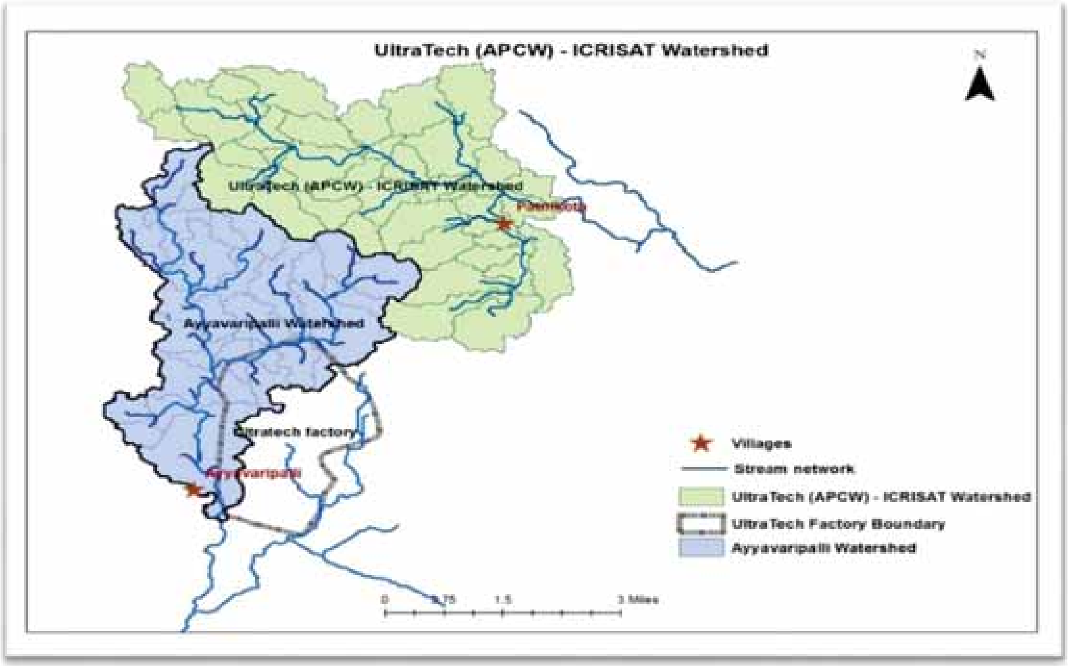


Figure 2. The map of two watersheds near to UltraTech Cements plant, Tadipatri mandal, Anantapur district of Andhra Pradesh.

2. Goals and objectives

The overall goal of the initiative is to increase water resources availability and improve agricultural productivity to improve the livelihoods of the rural poor in the watersheds on a sustainable basis by enhancing the impact of interventions through an integrated watershed management approach.

The initiative's specific objectives are:

- To enhance water availability in the watershed through rainwater harvesting and recharging of wells, to demonstrate that science-based interventions can increase water availability;
- To enhance agricultural productivity through Good Agricultural Practices (GAP);
- To establish a model village that demonstrates increased productivity and improved livelihoods; and
- To build the capacity of farmers, women and youth in the watershed.

3. Participatory Rural Appraisal

Participatory Rural Appraisal (PRA) is an integral component of watershed management. PRA is a process of understanding people, their resources, their socio-economic conditions. It is also a process of exploring their problems, their aspirations, and potentials in partnership within people. PRA is an important approach for decentralizing decision making and to create ownness among the farming communities (primary stakeholders). It provides opportunities for analyzing the resource base, problems, developmental opportunities, primary stakeholders rich experience and expertise of technical experts (service providers) in joint meetings. Triangulation further provides opportunities to improve in the initial development plan and create interest among primary stakeholders. PRA has been carried out in the Patnikota village and the key observations made during PRA are as follows (Figure 3):

i. Agriculture based Livelihoods: Agriculture is the major source of income followed by mining and factory workers in both villages. Agriculture is predominantly rainfed and subsistence in nature in both the watersheds. The major crops grown in the watershed and their average productivity levels are very low and need attention (Table 1). The agriculture can provide 50 person-days of working per family in both the villages and the average wage rate per head is 300-350 per male and 200-300 per female based upon the activity.

Table 1. Major crops and their yields (farmers survey) in the watersheds

UltraTech–ICRISAT watershed (Patnikota)		Ayyavaripalli Watershed	
Crop	**Yield (q/acre)**	**Crop**	**Yield (q/acre)**
Paddy	10-12	Paddy	20-25
Cotton	8-10	Cotton	5-6
Castor	4	Vegetables	4-5 (tones)
Pigeonpea (intercropping)	2-3	Pigeonpea (intercropping)	2-3
Sorghum (fodder)	100		
Pomegranate	3-4 (Tones)		
Chickpea (rabi)	5		
Sweet Orange	3-4 tones (below 5yrs) 6-8 tones (above 5yrs)		

ii. Industry based Livelihoods: in both the villages it is observed that, many men and women works as employees in UltraTech cement factory. In addition to factory employment, Patnikota village is dominated with slab stone mining area and consists of nearly 50 Slab/polishing industries (47 are owned by individual owners and 3 owned by Scheduled castes). The major issue with the polishing industries is interrupted electricity supply and labour shortages. Nearly, 300 hh in Petinikota village participate in loading and unloading activities at slab industry and mining sites. About 50 tractors are operating for mining industry giving livelihoods to nearly 100 hh in the village. Other than tractors, 20 lorries are operating in the village giving livelihood for 10 per lorry for 200 days.

iii. Livestock: Nearly 20 households (hh) in Patnikota village are having small ranging from 50-100 per hh. Availability of fodder is a major constraint in Patnikota village for livestock development. The dry fodder (paddy straw) costs around Rs 15000 – 40000 per lorry depending upon the season. Open grazing is the major source of fodder. Majority of the farmers in Ayyavaripalli village are having buffalo's as milch animals. The average milk yield per animal is 5-6 liters per day.

iv. Limitations: During PRA, farmers identified ten important issues/problems in the villages and prioritized in a sequential order those need to be addressed (Table 2). The biggest problem identified was water scarcity during the post-monsoon season. The dug wells are found drying as soon as monsoon recedes and groundwater levels in bore wells are declining year by year. All the farmers strongly agreed for developing water resources that supports drinking water and supplemental irrigation to the crops during no-monsoon season.

Table 2. Major problems in the village and farmers ranking to them

Sl. No.	Problems	Rank
1.	Acute water scarcity	I
2.	Low productivity of crops	II
3.	Acute shortage of fodder	III
4.	Low fertility of soil	IV
5.	Soil erosion and runoff	V
6.	Insect pest and disease attacks on crops	VI
7.	Lack of marketing facilities	VII
8.	Limited electricity for polishing industries	VIII
9.	Unemployment of landless people	IX
10.	Lack of expertise in allied enterprises	X

Figure 3. Conducting PRA at Patnikota village by DR.D.Mosses, Visiting Scientist, IDC, ICRISAT.

v. SWOT Analysis: SWOT (Strength, Weakness, Opportunities and Threats) analysis is framework used to evaluate village position and develop strategic planning. The analysis assesses internal and external key issues, as well as and current and future potentials (Table 3).

Table 3. Major SWOT parameters in the village

Strength (S)	**Weakness (W)**
Awareness of farmers about Watershed management program.	Undulating topography in hilly terrains
Active participation by the farmers	High intensity rainfall during rainy season causes soil erosion
Diverse income sources	Deforestation and fragile geology.
Early adopters	Resource-poor farmers.
Opportunities (O)	**Threats (T)**
Potential for crop diversification.	Mining zone reason for poor soil health
Scope of runoff water harvesting and management	Migration to urban by youth
Existence of a drain system for water harvesting structures	Poor water retention due to fragile soils

4. Base line survey

Based on the understandings from PRA analysis a detailed baseline survey has been initiated to study major socioeconomic and biophysical constraints to sustainable crop production and livelihoods of the villagers in the watershed. The baseline information helps to identify, test and scaling-up of any intervention in the watershed. The detailed objectives of baseline survey are as follows.

- To capture the present demographic and socio-economic profile of the watershed area;
- To capture the existing cropping pattern, various agricultural practices and fertilizer utilization pattern in the watershed area;
- To analyze the consumption pattern of food grains.

The baseline survey has been planned as per small, medium, large, and landless farmers in the Patnikota village. The survey findings would be useful for identifying suitable interventions, monitoring and evaluation during the project period. The baseline survey also acts as base for impact assessment study upon its completion. Total 45 samples are planned, 10 from each farming category and 15 from landless farming category. In September 2019, the baseline survey has been conducted with 90 farmers (respondents) in both Patnikota and Ayyavaripalli villages.

The data collected from sample respondents were coded and presented in the form of tables. Various need-based statistical tools were used for data analysis. The inferences were drawn considering the results obtained in view of project objectives. Various indicators are developed for the research for future monitoring and evaluation and prioritization:

I. Demographic Profile

The demographic characteristics of pilot villages are presented in Table 4. The age and education levels of the Patnikota farmers are almost equal same. In Ayyavaripalli, the average age of the respondents is above 50 years and majority of respondent have completed 6th class. The average number of family members per family is five and four in respective villages, highest family members are found in households of large farmers (6/HH) in Patnikota and in households of medium farmers (5/HH) in Ayyavaripalli. The average number of working members in a family is two, highest working members are in marginal farmers houses in Patnikota and the lowest working members are in small farmers houses in Ayyavaripalli.

Table 4: Family size, the extent of literacy and participation in the labor market

	Pat	Ayy	Pat	Ayy	Pat	Ayy	Pat	Ayy	Pat	Ayy
Farmer Type	Age		Education		Total no of Family Members		No. of working members		No. of working Male	
Large	51	-	6		6		2		2	
Medium	47	52	7	5	4	5	2	1	1	1
Small	51	57	7	6	5	4	2	2	2	2
Marginal	59	57	7	6	5	4	3	1	2	1
Average	50	57	7	6	5	4	2	2	2	1

II. Landholding pattern

The average land holding size of Patnikota farmers is 6.53 ha, as 60% of the farmers in the village are large farmers. The average land holding size of Ayyavaripalli farmers is 1.19 ha, as 77% of the farmers are small and marginal farmers in the village.

Table 5. Land holding size of different type of farmers in both Patnikota and Ayyavaripalli villages.

	Patnikota		Ayyavaripalli	
Farmer Type	Share (%)	Average Land	Share (%)	Average Land
Large	60	8.57		
Medium	26	3.27	23	2.53
Small	12	1.22	55	1.74
Marginal	2	0.82	22	0.51
Average	100	6.53	100	1.19

III. Cropping Pattern

Patnikota village: In Patnikota village, the area under different crops and fallow/barren land is 56% and 44% of the total geographical area of the village respectively. The geo-climatic, socio-cultural, economic, historical and political factors influences the cropping pattern of a region (Nalawade et al., 2010)1. The cropping pattern denotes the distribution of crop areas under different crops in different seasons. The major kharif crops (Table 6) are pigeonpea (27.67%), castor (9.00%) cotton (9.79%) and the major rabi crops are chickpea and occupies (24.23%) in the village. Pomegranate (0.39%) and sweet orange (4.74%) are the major annual crops and occupy 5.6% of the net cropped area. The current fallows in the rainy season is 44.02 percent and the post rainy season is 75.77 percent and this implicates the need for major water harvesting structures for sustained agricultural income vis-à-vis the growth.

Table 6. Cropping pattern details of Patnikota village.

Kharif		Rabi		Annual	
Crop Name	% share	Crop Name	% share	Crop Name	% share
Pigeonpea	27.67	Chickpea	24.23	Pomegranate	0.39
Cotton	9.79	Fallow	75.77	Sweet Orange	4.74
Castor	9.00				
Sorghum	6.26				
Vegetables	2.51				
Paddy	1.41				
Fallow	44.02				

Ayyavaripalli: The major kharif crops grown in Ayyavaripalli are (Table 7) are paddy (60.21%) sorghum (21.44%), cotton (9.33%) and pigeonpea (5.2%). Paddy is the major rabi crop but occupies only 4 per cent of kharif cropped area. Water melon (2.85%) and banana (0.95%) are the major annual crops occupying nearly 4 per cent of net cropped area.

Table 7: Cropping pattern details of Ayyavaripalli village.

Kharif		Rabi		Annual	
Crop Name	% share	Crop Name	% share	Crop Name	% share
Paddy	60.21	Paddy	4.08	Watermelon	2.85
Sorghum	21.44	Fallow	95.79	Banana	0.95
Cotton	9.33				
Pigeonpea	5.20				

[1] Nalawade, D. B., Mohan, C. S., and Pawar, C. T., 2010, Spatio -Temporal Changes in Cropping Pattern of South Konkan of Maharashtra: A Geographical Analysis. The International Online Journal - Literature, Humanities & Communication Technol., 3(2): 74-81.

IV. Cropping Intensity

There is slight change in cropping intensity between villages. In Patnikota, the overall cropping intensity is low (90%) due to severe water shortage during the post rainy and summer seasons (Figure 4). In Ayyavaripalli, low second crop cultivation is observed despite the availability of water. This might due to soil health problem, which indicates the importance of interventions to improve soil health in the village. Overall, both villages have the potential to improve crop intensity with science-led interventions.

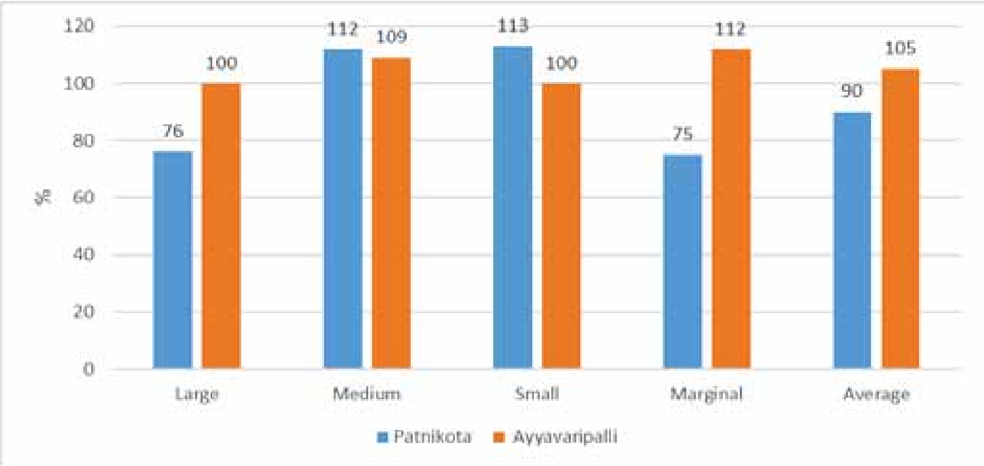


Figure 4. Details of cropping intensity in both the villages

V. Crop water productivity (CWP)

Due to water availability, the crop water productivity index in Ayyavaripalli is comparatively lower than that of Patnikota. Of all the major crops, castor crop is having highest crop water productivity index and Pigeonpea crop is having the lowest crop water productivity index in both the villages.

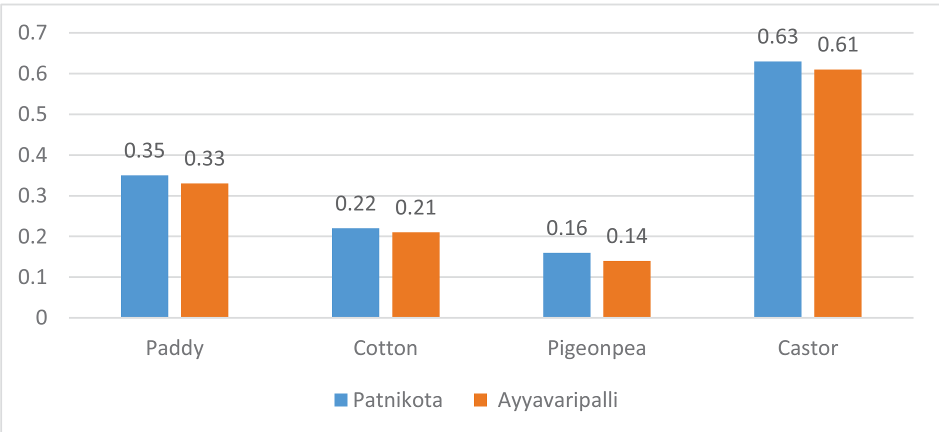


Figure 5. Details of crop water productivity in both the villages

VI. Benefit-Cost ration (BCR)

Cost-Benefit analysis is mostly used to assess adaptation approaches by farmers who are inclined towards beneficial technologies and helps the researchers to assess whether the technology has given expected results or not? Hence it is very much essential to document the base year technologies and their values for evaluating the profitability of the project. The BCR of all rainfed crops is less than 2 (except pigeonpea) and >2 for irrigated crops in watershed villages (Table 8). Among all the crops, it is observed that watermelon gives highest returns than other crops (1: 2.94, almost 3 rupees for 1 Rs of investment). The returns from chickpea found very low, possibly the reason for low cultivation of chickpea in the post-rainy season. Hence it is important to introduce drought-tolerant chickpea varieties or alternative cropping systems in the region for better management of current fallows during the *rabi* season.

Table 8. Benefit-Cost analysis of major crops

Crop	Yield (kg/ha)	Price (Rs/Kg)	COC (Rs/ha)	Net Returns (Rs/ha)	BCR
Chickpea	554	45	23465	1446	0.15
Castor	675	29	12103	7472	1.52
Cotton	1042	58	20854	39562	1.90
Sorghum	1592	17	22156	4916	1.22
Paddy	5558	14	40755	34271	2.08
Pigeonpea	511	46	11980	11625	2.40
Pomegranate	6421	36	69795	162132	2.32
Sweet Orange	5900	25	77805	69695	2.21
Watermelon	58800	9	200000	388000	2.94
Banana	70 (bunches)	800	30000	26000	1.86

Overall, base line data indicates that the large and marginal farmers are equally affected by poor agricultural land utilization in both villages. Low cropping intensity, crop yields and crop water productivities are major concerns in both the project villages. The high benefit-cost ratio of irrigated crops shows the importance of water harvesting interventions in project villages. Delayed and untimely rainfall are the major risk factors effecting the crop productivity. Hence, strategies should be drawn to improve the crop yields with high yielding short duration varieties that can withstand to drought and need improve water resources in both villages for providing supplementary irrigations during critical stages of the crop.

5. Climate monitoring and awareness in the watershed

Daily rainfall data from 2009 to 2020 collected at UltraTech cement factory and in the watershed has been analyzed to understand temporal pattern of rainfall in and around the UltraTech watershed. The average annual rainfall in this area is 661 mm, with 388 mm as lowest and 1059 (2020) mm as highest annual rainfall. In the total rainfall, 84% of occurs during monsoon (June to October) season and the rest 16% occurs in the non-monsoon season. The annual rainfall found declined at the rate of 13 mm per year up to 2018 and found increasing since 2019 in the watershed (Figure 4). It is observed that, average number of rainfall events per year is 39. Since 5 years, the high rainfall events which creates floods are found increasing and low rainfall events found decreasing which are useful for crop growth in the watershed (Figure 5 & 6). In total rainfall events, 19% are low (below 10 mm), 44% are medium (10-30 mm) and 37% are high (> 30 mm) rainfall events (Figure 6). Based on the daily moisture availability, weekly soil moisture calendar has been created and displayed at prime locations of the village where formers gather for discussions at their free time (Figure 7&8).

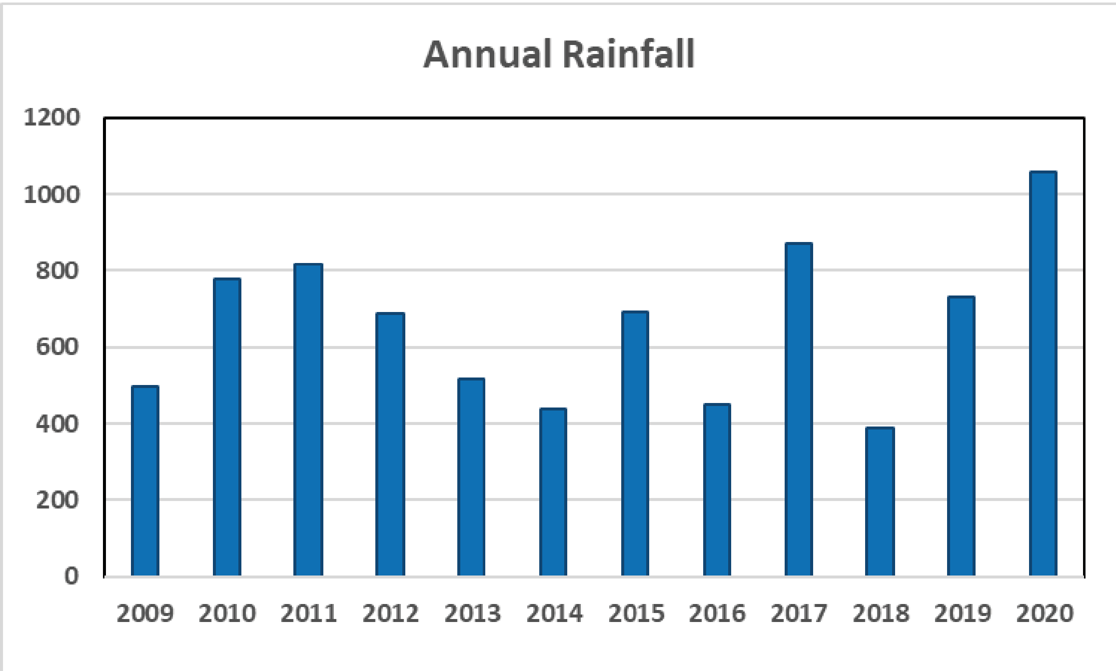


Figure 4. Trend of annual rainfall in the watershed.

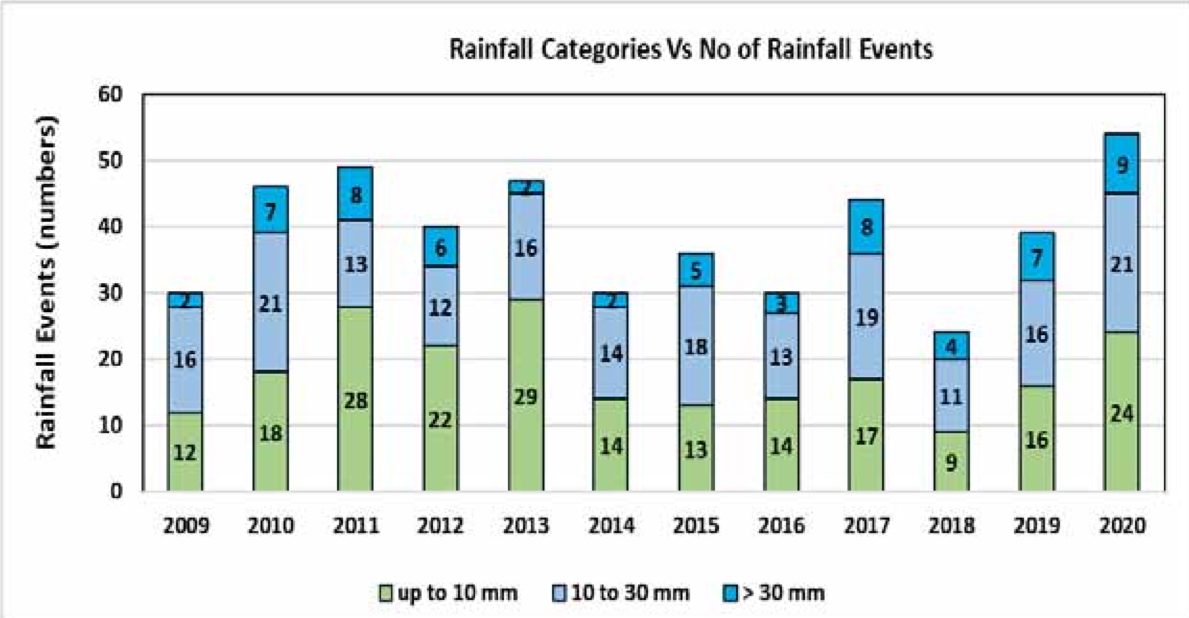


Figure 5. Rainfall Variability such as low, medium and high rainfall events in the watershed

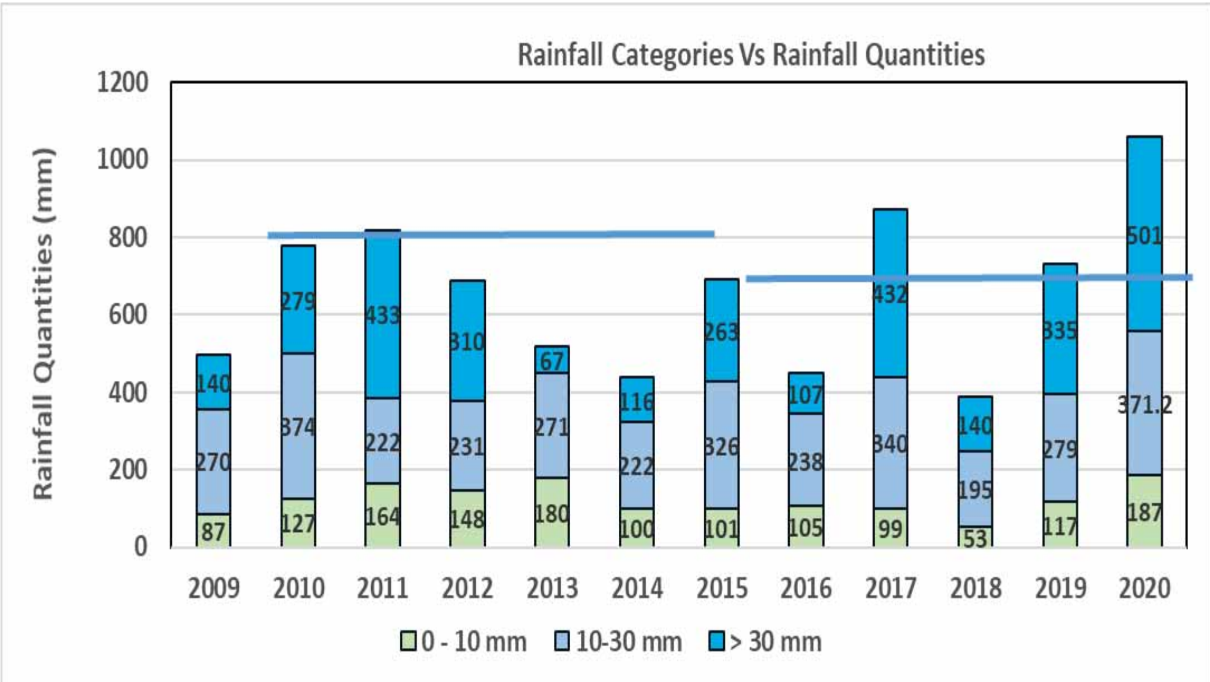


Figure 6. Proportions of low, medium and high rainfall events in annual rainfall in the watershed

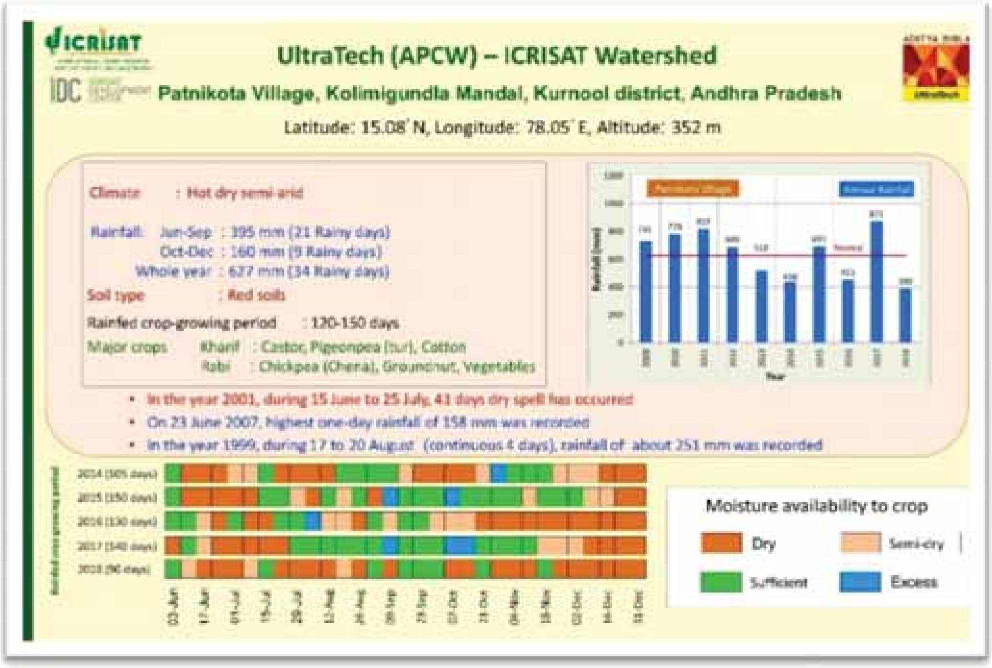


Figure 7. Information on annual rainfall and weekly soil moisture calendar in the watershed.

Figure 8. Wall writing template about climate variability and weekly soil moisture availability in the watershed.

An automatic weather station with a data logger was installed in the Patnikota primary school to collect daily rainfall and temperature data to understand daily temporal variation in the rainfall and temperatures in the watershed (Figure 9).

Figure 9. Rain gauge installation in the Patnikota watershed

6. Balanced Soil Health Management

Declining soil health is often cited as one of the reasons for stagnating or declining yields. Soil health management is a well-recognized practice all over the world which takes care of low, high or disproportionate applications of fertilizers or nutrients in the farmers' fields. The imbalanced and sole use of high NPK fertilizers and declining use of organic manures since few decades have resulted degradation in secondary, micronutrients and low carbon (C) levels. The deficiencies will further aggravate when we attempt increasing the crop productivity without resorting to proper soil fertility management practices. Soil testing is first step that addresses the judicious fertilizer use in the farmer's field. Fertilizers recommendations based on soil test will maintain the soil health and also reduce cost of cultivation to the farmer. The soil testing and soil health management programs are being given adequate importance in Indian agriculture for sustaining crop production and balanced fertilization. Plant nutrition along with other management practices viz. improved cultivar, pest and disease management, soil and moisture conservation, water management, weed control, inter-culture, cropping systems also has decisive effect on crop yields.

Soil samples collected from individual farmers' fields have been analyzed to understand the soil nutrients status in the UltraTech-ICRISAT watershed (Figure 10). The soils were analyzed in an international standard soil laboratory, ICRISAT, Hyderabad. The soil health condition in the Patnikota villages show multi-nutrient deficiencies of micro nutrients and secondary like Zinc, Sulphur, and organic carbon, along with nitrogen (N), phosphorus (P) and potassium (K). Based on the soil test results, fertilizer recommendation (Urea, DAP, Potash and Zinc) for major crops such as Castor, Pigeonpea, Cotton, Groundnut, Paddy, pulses and vegetables were given to all individual farmers who had contributed their soils for the soil analysis through soil health cards (Figures 11 & 12).

A mean was calculated form the all soil collected and a separate fertilizer recommendation for major crops were given at watershed level (Figure 13). It is observed that soils (100%) in the watershed are alkaline, 71% of samples showed deficiency of Zinc, 67% of samples showed deficiency in Sulphur, 38% of samples showed deficiency in Organic Carbon and 29% soil of samples showed deficiency in Phosphorous and Iron. No deficiency of Potash, Calcium, Magnesium, Cupper and Manganese nutrients observed in soil samples (Figure 11). The village level fertilizer recommendation was written as wall writings in the village corner points, where farmers gather daily for their interactions (Figure 14). Farmers meetings were conducted to share the soil health information and fertilizers recommendations disseminated through wall writings in the village. Soil health cards program cards were distributed to the farmers under the chairmanship of Plant and HR heads of UltraTech Cements.

Figure 10. Soil samples collection from the farmers' fields in the Patnikota village

Figure 11. A copy of Soil Health Card (SHC, front page) printed for individual farmers.

Figure 12. A copy of Soil Health Card (SHC, back page) printed for individual farmers.

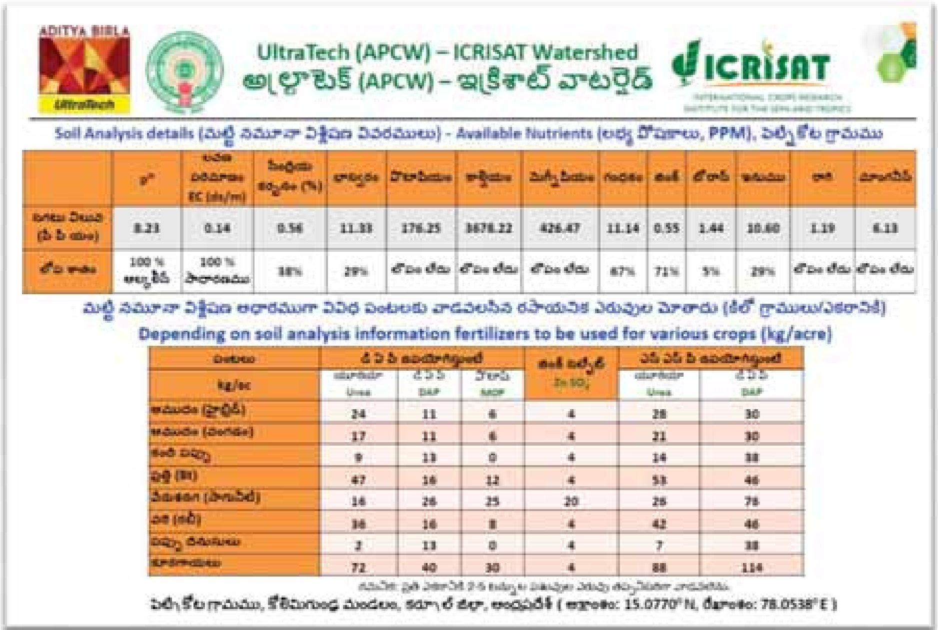


Figure 13. Mean soil health information calculated from the soil samples collected from the Patnikota village.

Figure 14. Mean data of soil health information dissemination through wall writings in the Patnikota village.

Figure 15. Farmers soil health cards unveiled by Shri. Keshav Nooguri (Unit head), Shri MSRK Prasad (FH-HR Head), Shri.Ch. Anjan Prakash (HoD, CSR) and Shri. G.S Ravikumar (HoD, ER) UltraTech Cements, Tadipatri, A.P.

Figure 16. Farmers soil health cards distribution by Shri. Papi reddy, president-Patnikota village.

7. Soil and water conservation measures

Managing water resources is considered as an effective method to reduce water stress in a watershed during non-monsoon season by recharging rainwater to groundwater storage during monsoon season. A watershed is defined as a hydrological area in which all rainwater water flows to a common point or outlet. Water travels from headwater to the downward location and meet with similar strength of streams in the downstream until it reaches to a bigger stream or river. A water balance approach accounts various hydrological components at watershed scale. Water balance components are described in a simplified form as:

$$P = Ro + GWR + Et + \Delta S \text{ – Equation (1)}$$

Where P is the precipitation (Rainfall), Ro is Runoff, GWR is groundwater recharge, Et is Evapotranspiration (Evaporation + Transpiration) and Δ S is change in storage. Rainfall shows the source of water in watershed, which will be partitioned into various hydrological components depending on topographic features, soil properties, land use cover and various land and water management practices as shown in Equation (1). Evaporation is non-productive water losses to atmosphere but water flow through transpiration of biomass. Thus ET component can be estimated inversely by balancing the above equation. But separating evaporation and transpiration component from ET is the most challenging task. Rainfall and runoff component could be measured by installing rain gauge and runoff recorder, respectively. Groundwater recharge could be measured by water table data in different wells. A rain gauge was installed already for measuring daily rainfall in the Patnikota watershed and a runoff gauging instrument will be installed at the earliest. The major groundwater dug and bore wells in the village and in farmer’s fields are mapped for monitoring the groundwater levels in the watershed. A groundwater level recorder will be used for measuring water levels in the watershed.

Land and water interventions activities alter the water balance. It reduces runoff losses and increase groundwater recharge. Watershed development program promote reducing the runoff from the watershed by harvesting rainwater through water conservation structures such as Percolation tanks, Check dams, Earthen dams, Check walls, Sunken pits, Gully control structures, etc. The rainwater harvested into groundwater storage can be utilized for drinking, supplemental irrigation during Rabi season. There are two major streams that are flowing in and around the Patnikota village (Figure 17). During reconnaissance survey, it is observed that there are few existing broken check dams constructed by different government organizations. A demand-oriented approach, in which demands/requests by villagers or the watershed community for harvesting rain water were followed for constructing water harvesting structures.

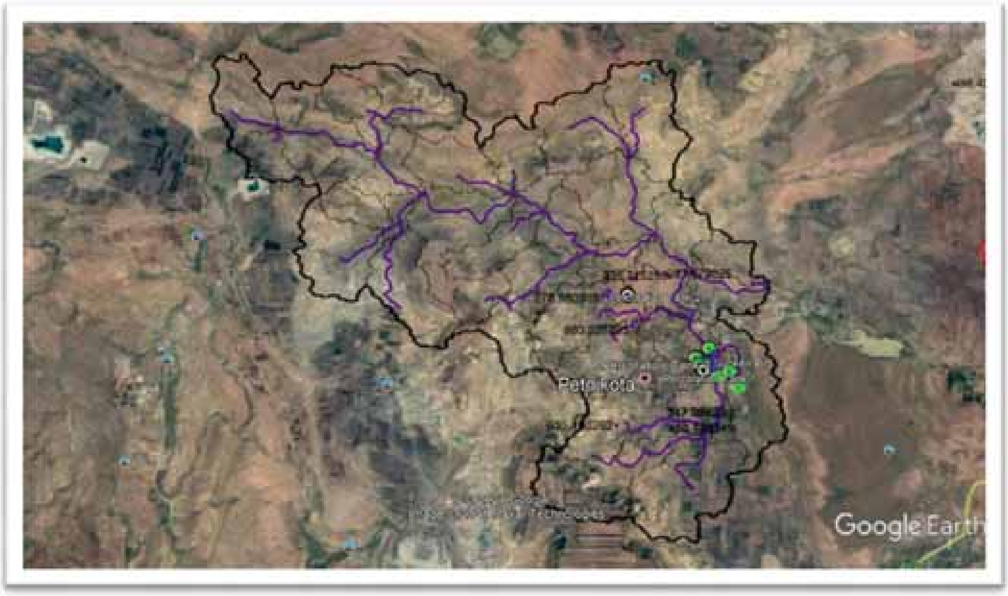


Figure 17. Spatial distribution of streams and water conservation structures created in the watershed.

Patnikota: As per the demand of villagers during PRA, high priority has been given to harvesting rainwater during non-agricultural seasons (summer) in both the watersheds. In Patnikota village, among the proposed structures, eight rainwater harvesting structures that have runoff potential and are located near to the village dug and bore wells were constructed (Three Percolation tank and five sunken pits) in the watershed (Figures 18, 19 and 20). The total water storage capacity created by these structures (Percolation Tank 1, 2 &3) is around 15000 m^3, which was already harvested 52889 m^3 of surface runoff (up to 31th March 2021) and expected to harvest about 50000 m^3 (from June to December 2021) every normal rainfall year (Table 9).

Table 9. Details of rain water harvested through different structures in Patnikota watershed.

S No	Name of the Structure	Year of Construction	Capacity (m^3)	No filling	Total Rain water recharged so far (m^3)
1.	Sunken pits (5 no's)	2019	750	22	15015 (90% GWR and 10% Et)
2.	Percolation Tank 1	2019	2000	14.8	27851(98% GWR and 8% Et)
3.	Percolation Tank 2	2020	3000	4.97	13717 (98% GWR and 8% Et)
4.	Percolation Tank 3	2021	9500		
			15250		**56583**

Figure 18. Google Earth Image showing sunken pits and percolation tank1 & 3 created on a stream in the watershed.

Figure 19. Percolation tank1 & 3 created on a stream in the watershed.

Figure 20. Percolation Tank 2 and Sunken pits created on a stream in the watershed a) before and b) after rain water.

Ayyavaripalli: Similarly, water storage capacity was increased by desilting existing three water harvesting structures (Two Percolation tank and one check dam) in the watershed (Figure 21). The total additional storage capacity that was created in the Ayyavaripalli watershed is 8940 m^3, which was already harvested 59384 m^3 of surface runoff (up to 31th March 2021) and expected to harvest about 50000 m^3 (from June to December 2021) in every normal year (Table 10).

Table 10. Details of rain water harvested through different structures in Ayyavaripalli watershed.

S No	Structure Type	Year of construction	Capacity created (m3)	No of fillings	Total Rain water recharged 2020 (m^3)
1	De-siltation of Check dam	2020	2040	10	19380 (90% of GWR and 5% Et)
2	De-siltation of Percolation Tank 1	2020	3150	7.3	24355 (95% of GWR and 5% Et)
3	De-siltation of Percolation Tank 2	2020	3750	5.7	21251 (92% of GWR and 8% Et)
		Total	8940		64986

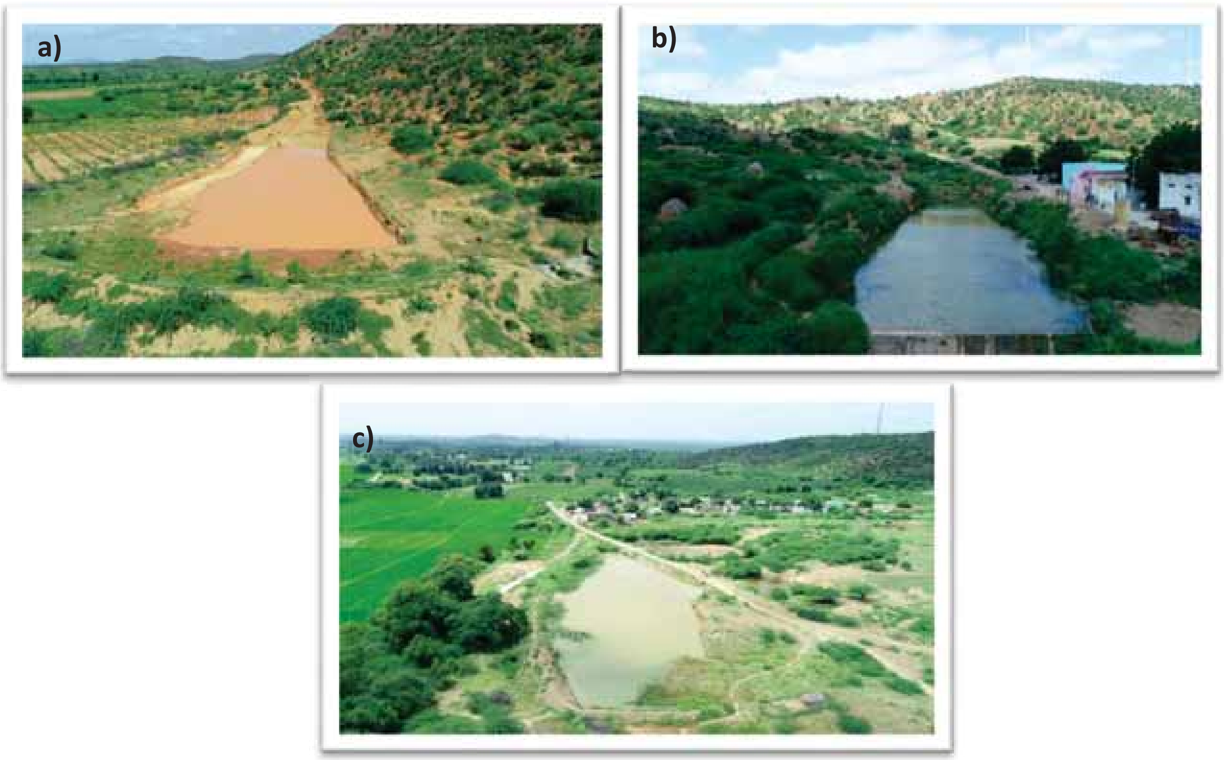


Figure 21. De-silted tanks in the Ayyavaripalli watershed a) Percolation Tank 1, b) Check dam and c) Percolation tank 2.

8. Hydrological Analysis:

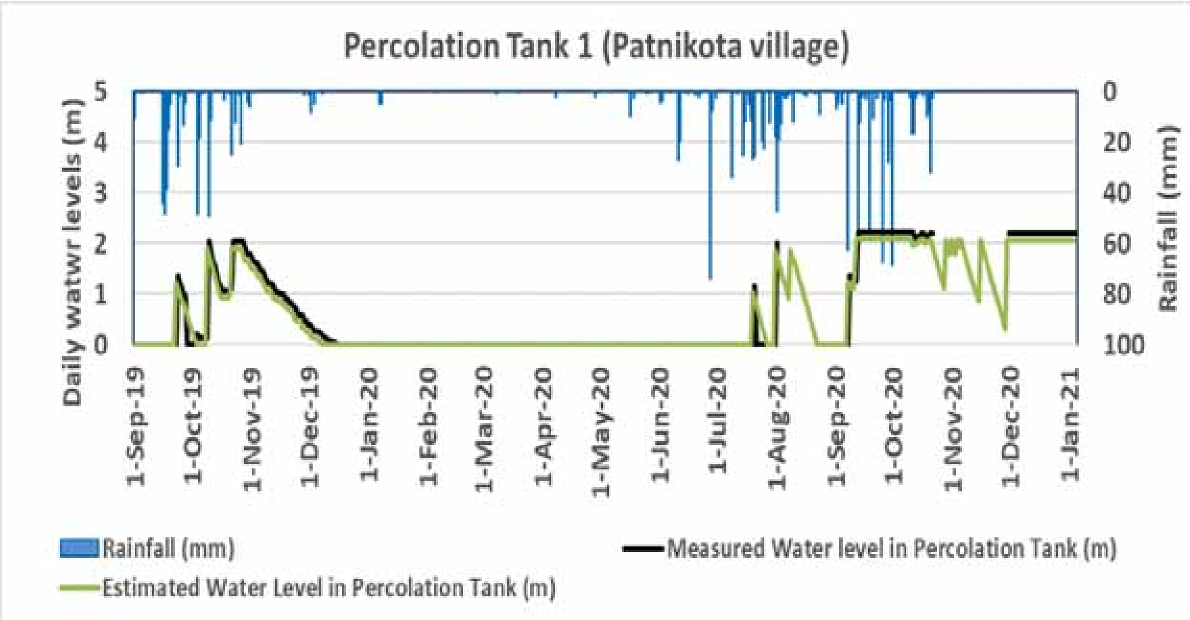
Impact due to rainwater harvesting structures: The water storage capacity of each rainwater harvesting structures depends on the type of structure and the storage capacity that can be created in that particular location. To estimate the amount of rainwater stored and recharged by each structure, water levels are measured at each major structure during monsoon season every two days.

To assess the total quantity of rainwater harvested and recharged by a structure, it is necessary to estimate how many times a structure has been filled. To estimate how many times a structures has been filled and understanding the details of the hydrological changes at major rainwater harvesting structures, a simple hydrological model was set up using the rainfall, evaporation rates and estimated percolation rates measured at the structures. From the model results, the number of times the structures were filled and recharged in a year was estimated at all the structures in both the watersheds as shown in Figures 22 & 23. The percolation

It has been observed that the water storage capacity of the structures is small and the number of fillings per year is large. The total quantity of rainwater harvested by these structures in both the watersheds is estimated as 121,500 m^3 (56583 m^3 in Patnikota watershed and 64986 m^3 in Ayyavaripalli watershed). It has also been observed that the evaporation rates are ranging from 5% to 8% of total rainwater harvested by the structures, and the evaporation rate also larger if the water storage capacity is large. The rainwater harvested monthly by these structure in both the watersheds is given in Figure 24. The rainwater harvested to groundwater storage during the monsoon season can be utilized during non-rainy days, especially during rabi season. It is estimated that the recharged rainwater provides lifesaving irrigation to nearly 1014 acres (Patnikota – 472 acres, Ayyavaripalli – 542 acres) of cultivable area in both the watershed. On the other hand, the same recharged rainwater provides about 3 irrigations for about 338 acres of millets or short duration vegetable crops during rabi season in the watershed as given in Table 11.

Table 11. Area that can be irrigated with recharged groundwater in the watersheds.

Area Irrigated	Patnikota (acres)	Ayyavaripalli (acres)	Total (acres)
As lifesaving irrigation (1 irrigation @ 30mm each)	472	542	1014
As supplementary irrigation (3 irrigations @ 30mm each)	157	181	338



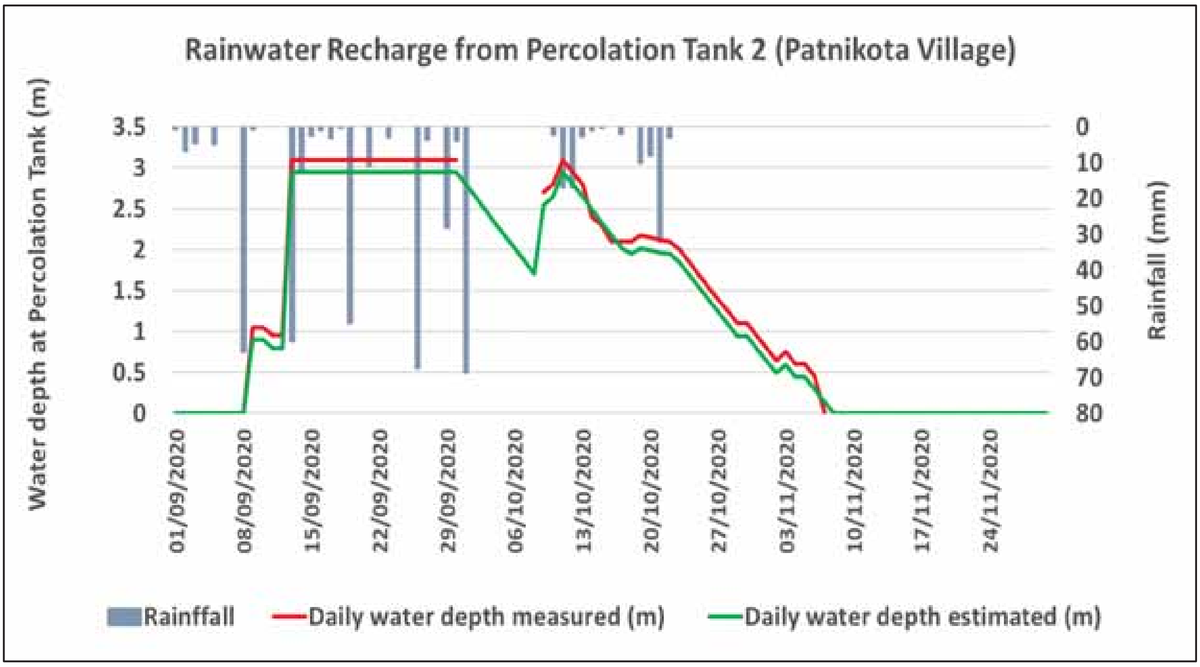
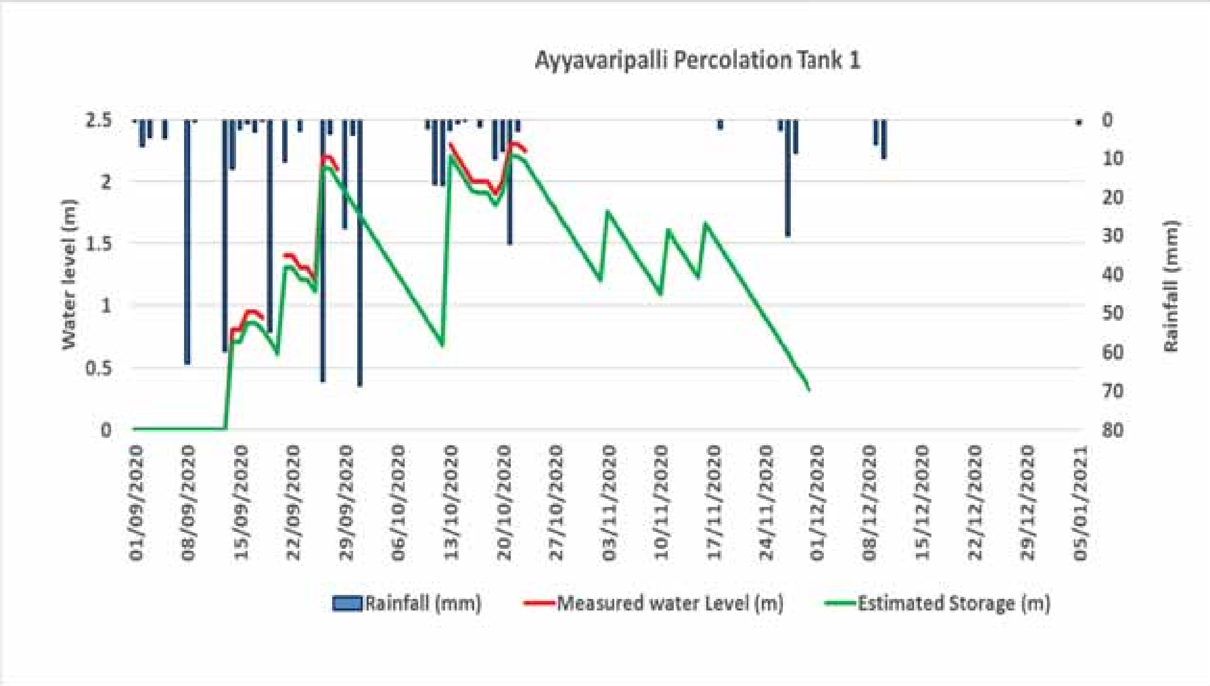


Figure 22. Measured and simulated water levels at major rainwater harvesting structure at Patnikota watershed (Percolation Tanks 1 & 2).



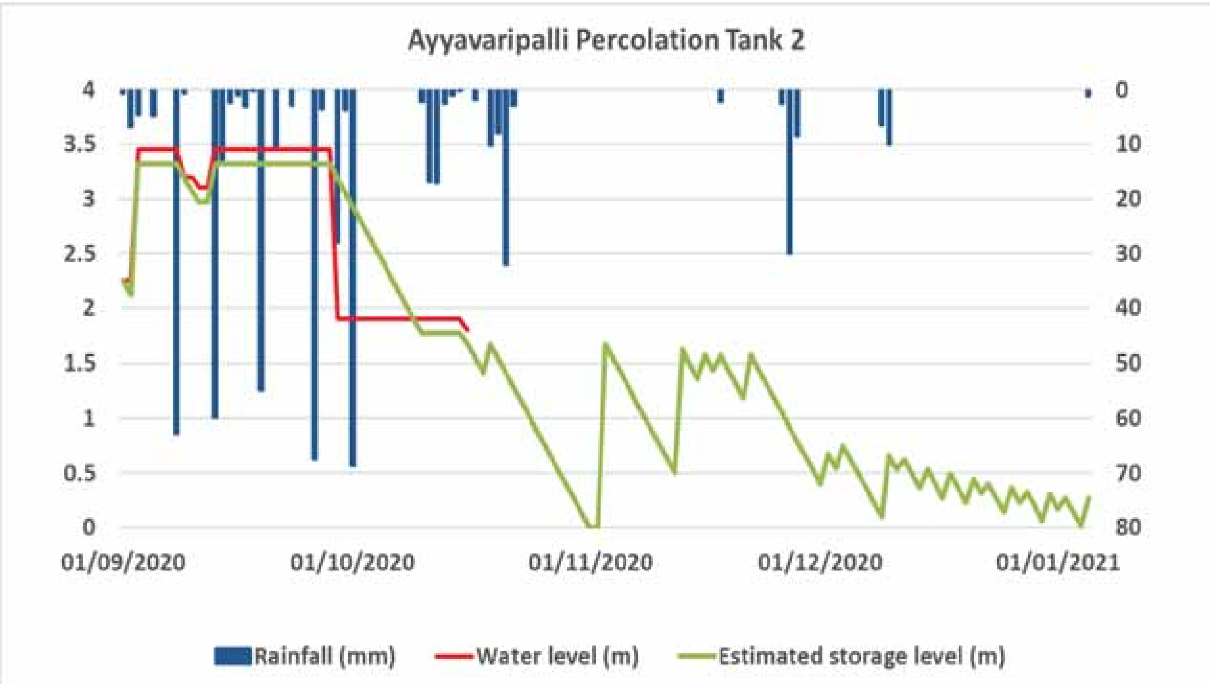


Figure 23. Measured and simulated water levels at major rainwater harvesting structure at Ayyavaripalli watershed (Percolation Tanks 1 & 2).

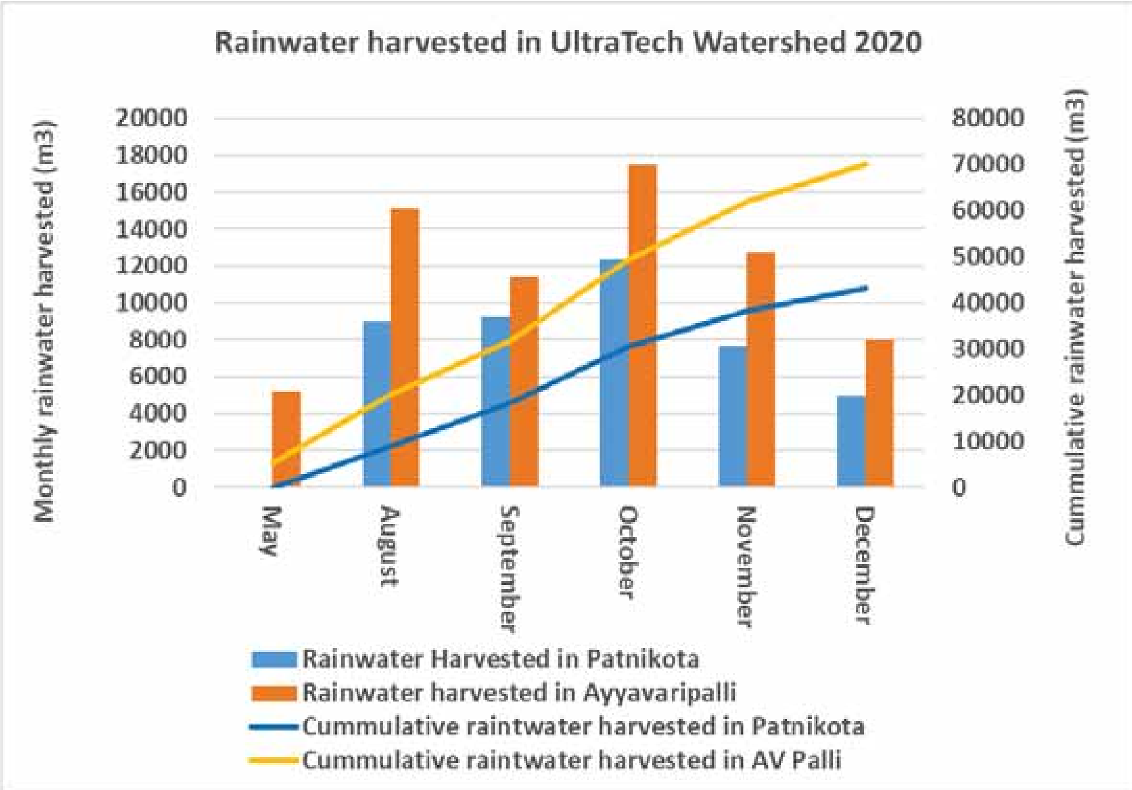


Figure 24. Rainwater harvested by the structures at Ayyavaripalli watershed.

Impact due on groundwater resources: To understand the trend of groundwater levels in the watershed and the impact of rainwater harvesting structures on surrounding dug and bore wells, monthly groundwater levels of 69 wells (59 bore wells and 10 open dug wells) situated around the rainwater harvesting tanks are being monitored since November 2019 in Patnikota watershed project as shown in Figure 25. Groundwater wells levels in all wells were observed to decline in March and begin to recover during monsoon season (June to October). Groundwater levels near rainwater harvesting structures are higher (1 m - 2.5 m) from July to January when compared with other wells away from the structures as shown in Figures 26, 27 & 28.

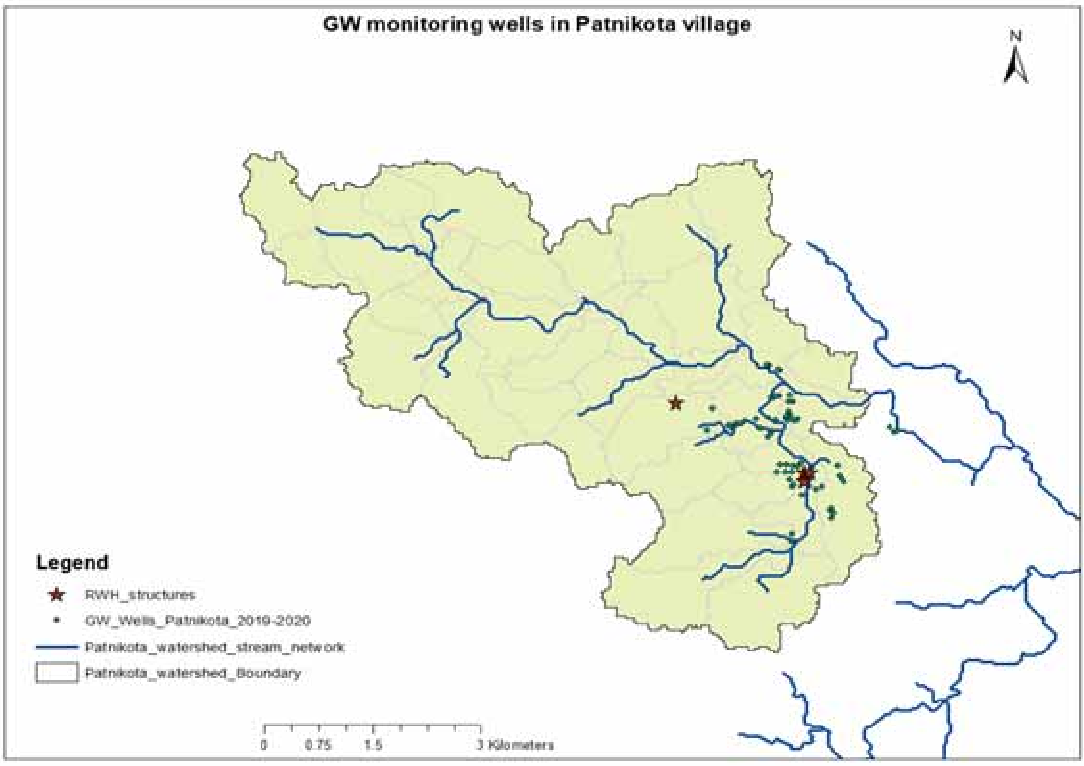


Figure 25. Location of rainwater harvesting structures and groundwater wells around in the Patnikota watershed.

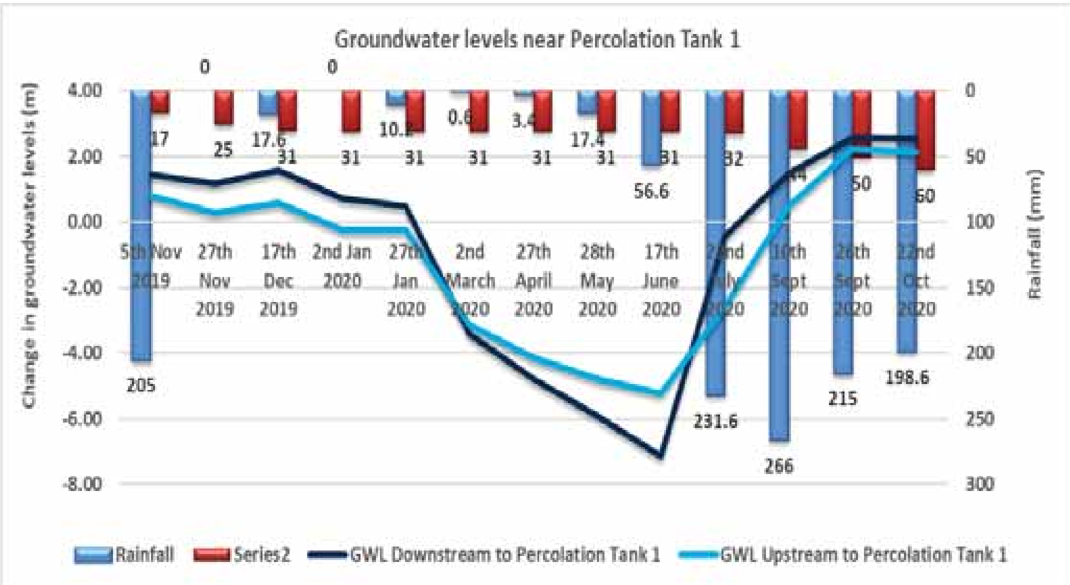


Figure 26. Groundwater levels in bore wells downstream and upstream to Percolation Tank 1.

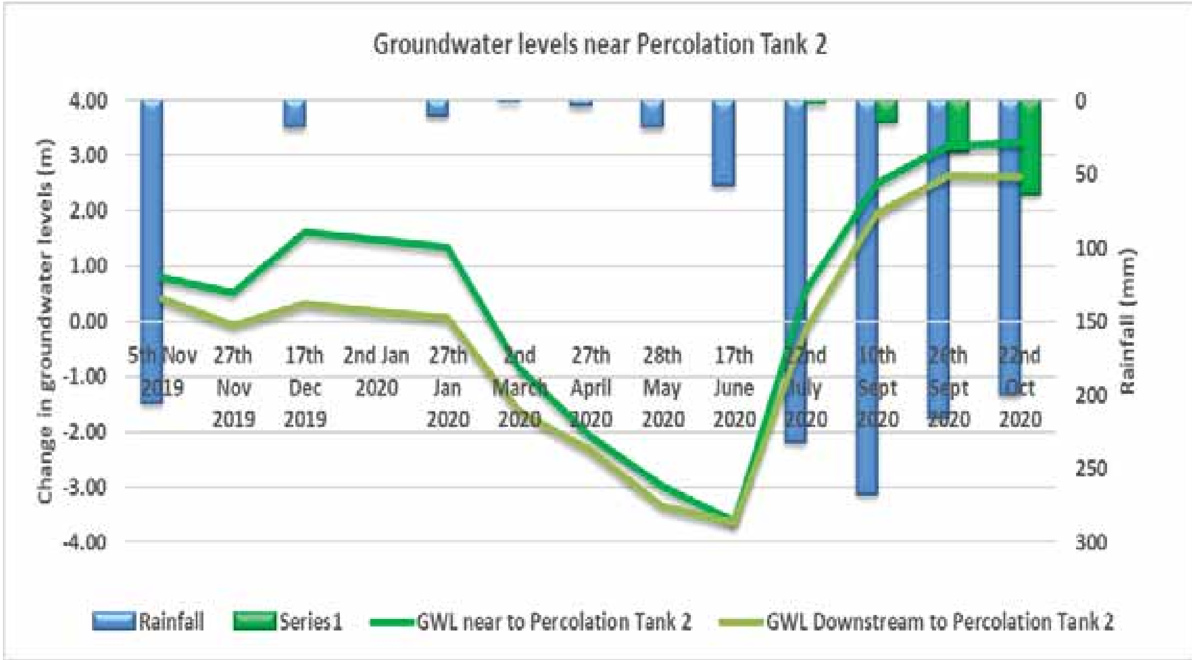


Figure 27. Groundwater levels in bore wells downstream and upstream to Percolation Tank 2.

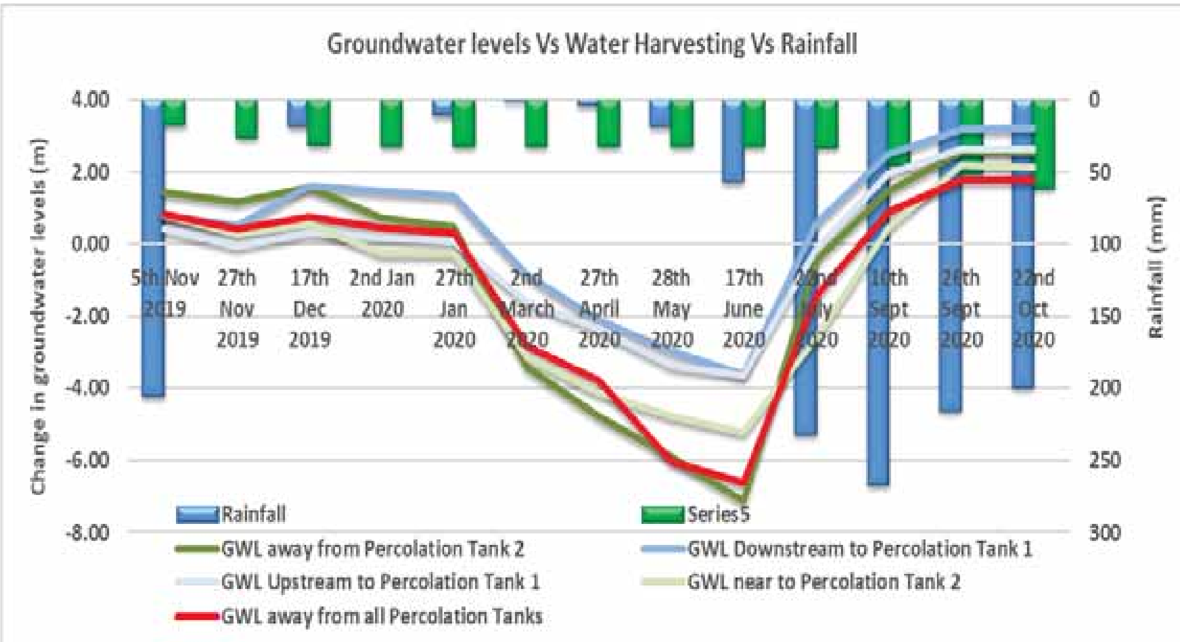


Figure 28. Behavior of groundwater levels in bore wells downstream and upstream to Percolation Tanks and wells away from the percolation tanks.

9. Participatory Research & Development (PR&D), Integrated Pest Management (IPM) and Integrated Nutrient Management (IPM) trials

Selection of suitable crops and cultivars for Kharif season has been carried out through Participatory Research and Development (PR&D) approach to analyze their yields in the watershed (Figure 29). Improved crop cultivars such as castor (DCH 519), black gram (PU31), groundnut (ICGV91114), Sweet Sorghum (Fodder grass) and pigeon pea (Asha, 87119), suitable to the soils were supplied to the farmers in the watershed (Figure 30). Many farmers came forward to participate in identifying suitable variety of pigeonpea, castor and black gram seed along with their local varieties. Nearly 368 acres of cultivable land with 125 farmers has been covered with improved seeds during kharif 2019 season. In which, 170 acre of farmers' fields are covered by improved Pigeonpea seed, 160 acres of farmers' fields are covered by hybrid Castor and 38 acres of farmers' fields are covered with Black gram crops in both the villages (Table 12). Similarly, during kharif 2020 season, nearly 89 acres of cultivable land with 25 farmers has been covered with improved seeds. In which, 57 acre of farmers' fields are covered by improved Pigeonpea seed, 6 acres of farmers' fields are covered by sweet sorghum and 25 acres of farmers' fields are covered with Black gram crops in both the villages (Table 13).

Table 12. Details of improved seed distributed in both the villages in 2019-20.

	Patnikota Watershed				Ayyavaripalli Village			Total
	Pigeonpea	Castor	Black Gram	Total	Pigeonpea	Castor	Total	
Area (Acre)	138	151	38	327	32	9	41	368
Farmers (no's)	47	32	6	85	33	7	40	125

Table 13. Details of improved seed distributed in both the villages in 2020-21.

S No	Crop	Variety	Number of farmers	Seed (kgs)	Area of coverage (acres)	Total coverage (acres)
1	Pigeonpea	BSMR -736	2	95	19	57
	Pigeonpea	TS -3R	11	140	28	
	Pigeonpea	ICPL8863	3	50	10	
2	Black gram	PU 31	4	100	25	25
3	Sorghum		4	18	6	6
4	Groundnut	ICGV91115	1	180	3	1
5	Kitchen garden	9 vegetables	100			

Figure 29. A meeting with farmers in participation research and development approach in a) Patnikota and b) Ayyavaripalli villages.

Figure 30. Distribution of improved seeds to the farmers a) Patnikota and b) Ayyavaripalli villages.

All the farmers are being in regular contact with our research team to get support on pest and diseases that occur during crop cultivation. In both the seasons, seed germination and crop condition are very good in both the villages (Figure 31, 32 & 33). Farmers are educated on pest management strategies and the use of yellow sticky traps and pheromone traps. Installation of these traps allows farmers to monitor pest activity regularly, so that indiscriminate use of pesticides can be avoided and spraying of insecticides can be taken up only when pest levels reach a threshold. This is an eco-friendly option and involves species that do not harm beneficial fauna in the ecosystem.

Figure 31. Germination test conducted a) before and b) after seed sown.

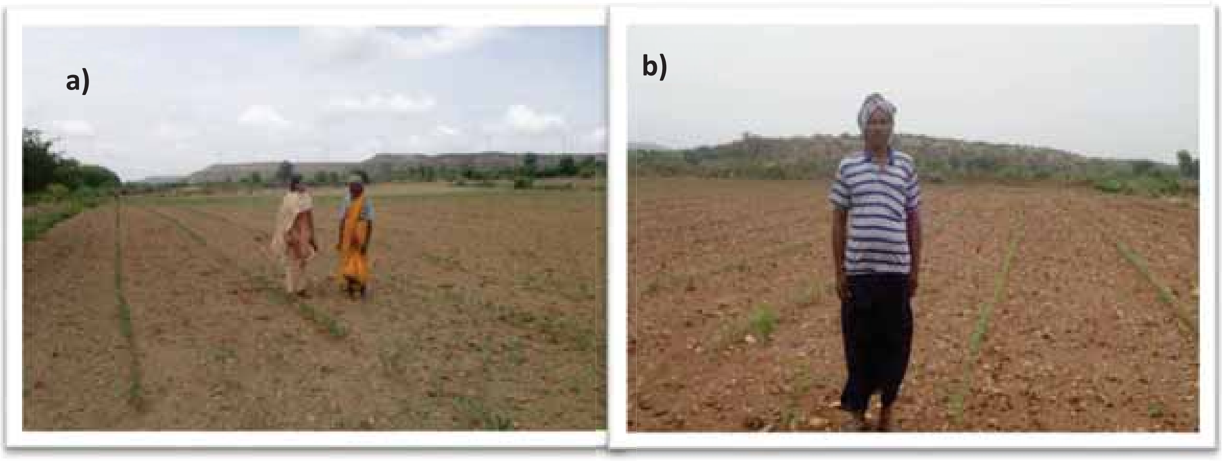


Figure 32. Pigeonpea crop sown in the farmers' fields (a&b) in the watershed.

Figure 33. Growth of a) castor and b) black gram crops in the watershed.

Crop yields analysis: Under crop enhancement activity, it is observed that the improved crop varieties of castor (DCH 147 and 519), Pigeonpea (Asha, BSMR 576 and TS 3R), black gram (PU 31) and groundnut (ICGV 91114) along with micro-nutrient (Boron) demonstrated on farmers' fields performed very well and helped farmers to increase yields by 35% in Castor, 17% in Pigeonpea and 38% in groundnut (Figure 34, 35 & 36).

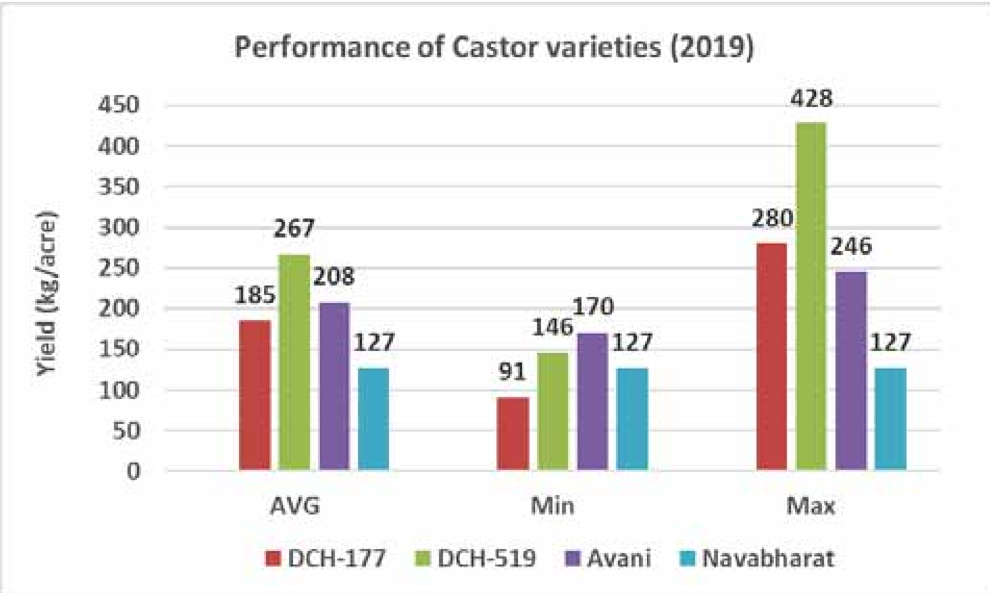


Figure 34. Performance of castor varieties with respect to local verities.

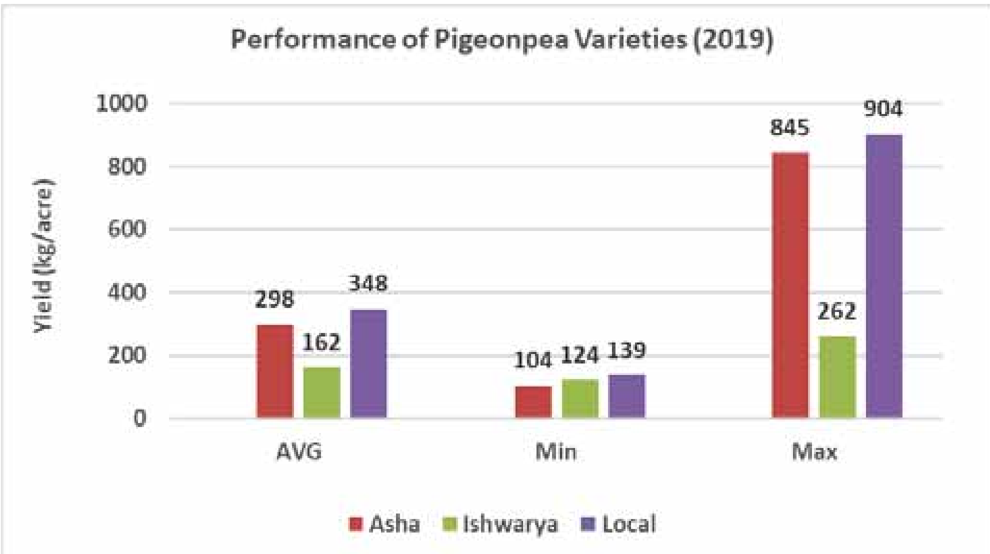


Figure 35. Performance of Pigeonpea varieties with respect to local verities in 2019.

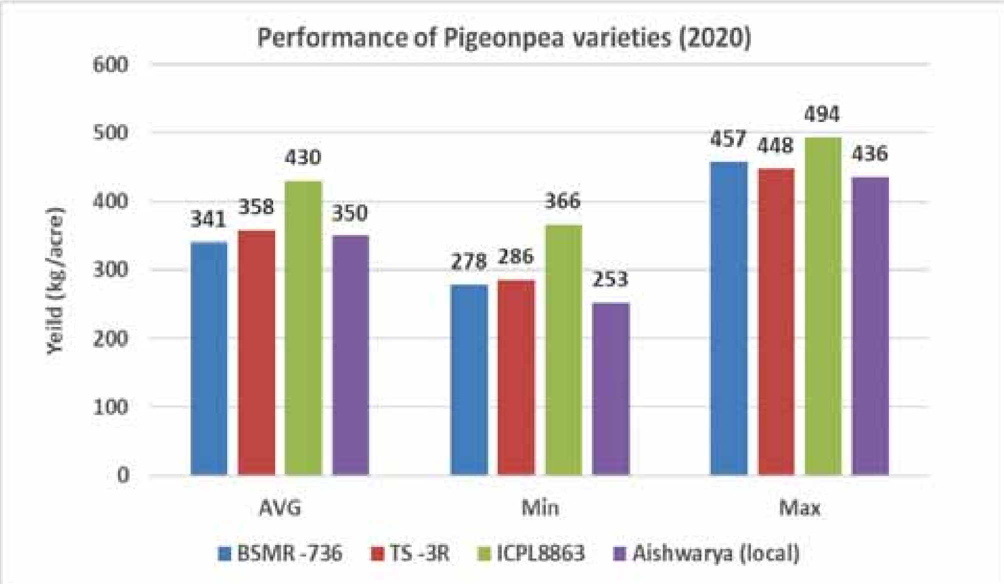


Figure 36. Performance of Pigeonpea varieties with respect to local verities in 2020.

10. Exposure visits of CSR team and Watershed farmers

CSR team of UltraTech cements, Tadipatri, Anantapur of Andhra Pradesh was invited for an exposure visits to ICRISAT located in Medak district of Telangana State. The team interacted with the scientists and Theme Leader, Dr. Sreenath Dixit, ICRISAT Development Centre, and visited ICRISAT Science Centre (Figure 37 & 38). The team visited various research and field activities within ICRISAT such as Broad Bed and Furrow fields, Heritage watershed, Meteorological Station, Transplanted Pigeonpea cultivation, Vermi and aerobic compost units, waste water treated wet lands, soil laboratories, etc (Figure 39). The team also visited Kothapalli watershed (Adharsha Watershed), to understand the impact of watershed activities on farmer's livelihoods and improving farmer's income (Figure 40).

Figure 37. *a & b) CSR team Interactions with Theme Leader, IDC Huddle Space, ICRISAT.*

Figure 38. *a & b) CSR team Exposure visit to ICRISAT Science Centre.*

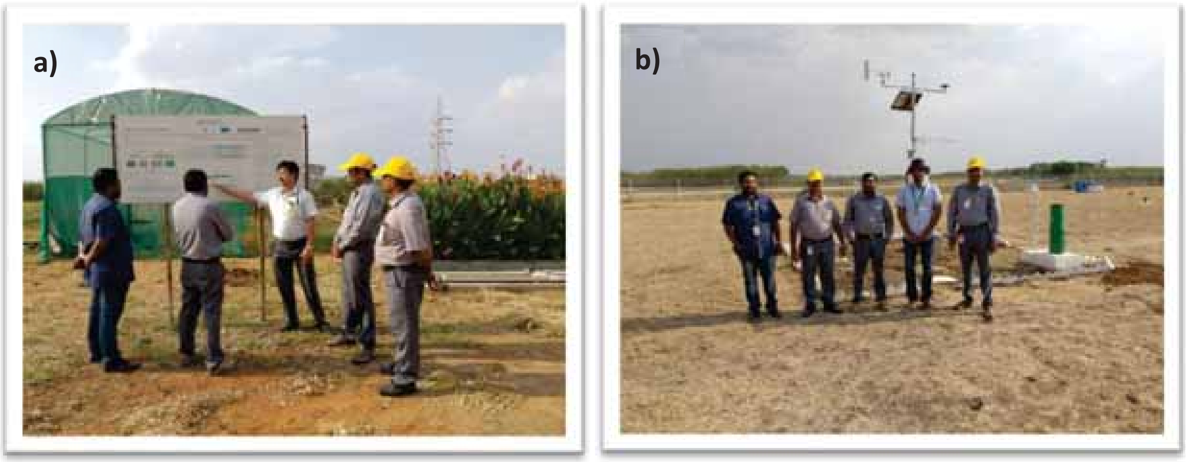


Figure 39. CSR team *Exposure visit to a) Waste water wet lands and b) Meteorological Station within ICRISAT.*

Figure 40. CSR team *Exposure visit to Kothapalli watershed, Rangareddy district, Telangana State.*

The CSR team also visited RECL-ICRISAT watershed, located at Penukonda mandal of Anantapur district in Andhra Pradesh. The team interacted with the local NGO also with the farmers to understand various activities carried out since inception of the project. The team also visited various activities such as bore well recharge pits, open well recharge pits, Loose boulder structures, check dams, productivities enhancement activities in various crops and in various farmers' fields (Figure 41).

Figure 41. CSR team *Exposure visit to a) Bore well recharge pit, b) Open well recharge structure, c) Loose boulder structures, and d) Pigeonpea crops with drip irrigation system at RECL-ICRISAT watershed, Penukonda, Anantapur, A.P.*

An exposure visit was conducted fort the farmers from the Patnikota watershed to RECL-ICRISAT watershed near Penukonda, Anantapur district and also ICRISAT campus in Patancheru, Hyderbad. The community also visited various activities to learn about improved methods of cultivation, best agricultural practices, soil and water conservation, crop demonstration trials, etc. Nearly 25 farmers participated for exposure visit (Figures 42 & 43).

Figure 42. *a & b) Farmers exposure visit to RECL-ICRISAT watershed Penukonda, Anantapur, A.P.*

Figure 43. *Farmers exposure visit to ICRISAT watershed, Patancheru, Hyderabad a) ICRISAT visitor center; b) Groundnut experimental field, c) ICRISAT farm mechanization unit and d) ICRISAT soil Laboratory.*

11. Capacity Building and Income-generation activities

i. Patnikota Watershed: With a view to providing skills that will aid in generating incomes while supporting agricultural value chains (inputs, outputs and byproducts), a baking training class for 25 young and married women on baking biscuits, breads, puffs, cakes, etc., was conducted in the watershed (Figure 44). Mr. Nagabhushanam, from Rajahmundry, A.P, who have 20 years of experience in training women groups in baking products was taken classes to all the trainees for one week in the watershed. Importance was given to millet based baking items to improve nutrition in women and children. During the training program the classes were taken on baking items such as breads, cake, sweet and salt biscuits, dilpasand, egg and curry puffs, etc. The trainees were supported with all materials required for a month to have hands on experience and to concentrate in quality, hygiene, safety and taste. The program increased the confidence levels in the trainees, made them think towards extra income during their free time at home.

ii. UltraTech CSR villages: The success of the above training program led to have similar kind program to women in CSR villages at Vikas Centre of UltraTech cements. A Three-day training program under the leadership of Plant and Unit heads, UltraTech cements was conducted by Food and Housing Services (FHS), ICRISAT, who have international standard expertise in baking and cooking. The training was not only on millet based basking products and also millet based kitchen products. Millet based kitchen products are easy to cook at home with available house hold utensils. Nearly, 40 women were attended to this program from CSR villages near to the plant (Figure 45). The trainees are supported for a month by CSR wing to train the trainees and to have hands on experience on the products.

ii. Training in ICRISAT campus: The success of the above training programs in Patnikota village and at Vikas centre of UltraTech cements led to have similar kind program at ICRISAT centre for fine tuning their skills on hygiene and mixing ingredients in right proportions. A Three-day training program under the leadership of ICRISAT Theme leader was conducted by Food and Housing Services (FHS), ICRISAT, Patancheru, Hyderabad. Nearly, 15 women were attended to this program from both the watersheds and the trainees were trained to have hands on experience on the products. All the participants were trained on preparing aerobic and vermi compost culture using crop wastes after the crop harvest, and also trained on raising goats in the backyards to gain extra income (Figure 46).

Figure 44. *Training program on making different kind of baking products at Patnikota Watershed.*

Figure 45. *Training program on making different kind of millet based kitchen and baking products at Vikas centre, UltraTech Cements campus.*

Figure 46. *Training program on making different kind of millat based kitchen and baking products, Vermi & aerobic compost training unit and raring small ruminants (goats) at ICRISAT campus.*

12. Activities, milestones and impact, budget details for the period February 2019-March 2021

SN	Line items	Description	Work done	Outputs
1	Knowledge-based Entry Point Activity (KB-EPA) will be taken up in both villages	1. Identifying location for water harvesting structures as per local need and suitability of the site. 2. Soil sampling and knowledge dissemination.	• Identified locations for sunken pits, 1 check dam and 5 Percolation tank; • Soil samples collected, analyzed and soil health cards distributed to the farmers;	knowledge dissemination on climate variability and soil health was carried out through wall writings.
2	Participatory Rural Appraisal (PRA) & Baseline Survey	Survey will be conducted in the first year	• PRA has been completed; • Baseline survey completed.	Key issues identified from PRA; Survey analysis will be made as a report by end of the year.
3	Formation of Community-based Organizations (CBOs)	1. Watershed User and Labour Group; 3. Linking SHGs	• Watershed labour and water users groups are in process.	Linking SHG has been completed and Baking program has been carried out.
4	*In-situ* moisture conservation measures	1. Broad Bed and Furrow; 2. Conservation furrows; and 3. Ridge and Furrow will be demonstrated and trails will be conducted every year.	• Introduction of Broad Bed and Furrow and conservation furrows will be demonstrated using Tropicultor in Rabi season.	• Crops will sustains during long dry spells and their yield increases about 10-15%.
5	*Ex-situ r*ainwater harvesting through low-cost structures	Planning, designing and monitoring of construction of Ex-situ water harvesting structures such as check dams, Gulley control structures, farm ponds. etc. as per runoff estimation.	• Constructed 5 sunken pits, de-silted one check dam, constructed 5 percolation tank. • Created additional storage (24150 m3)	• About 24150 m^3 of storage capacity created, which harvested about 120000 m3 of rainwater and expected to harvested about 100000 m^3 of rainwater every year in the watershed.
6	Establishment of hydrological gauging stations	1. Rain gauge will be installed for rainfall monitoring 2. Runoff monitoring using auto loggers will be installed 3. Groundwater levels also will be monitored in selected wells	• Rain gauge has been installed in the watershed. • Groundwater levels are monitoring using GWL indicator	• Rainfall variability and rainy days will be analyzed; • Increase in groundwater levels will be monitored in the watershed.

7	Participatory Research and Development Selection of Crops and Cultivars along with participatory evaluation	Undertake farmer's participatory field experiments using well tested crop cultivars in limited farmers' fields which minimize the risk of the crop failure.	• Nearly 50-120 farmers' coming forward to participatory research and development demonstrations.	• Introduced improved crop cultivars of pigeonpea, castor and black gram over 500 acres.
8	PR&D, INM and IPM trials	•	• Yellow sticky traps; Pheromone traps; neem oil and benzoate applications are promoted in the village	• Reduce cost cultivation and pollution due to pesticides.
9	Capacity development & preparing training materials	1. Vermicomposting and aerobic compost making; 2. Gliricidia nursery raising; 3. Fodder management training; 4. IPM/INM/Weed management trainings; 5. Backyard poultry demonstrations; 6. Kitchen gardening activity .	• Promoting kitchen garden (250 HH) • Baking program for 80 women • Raising goats • Other trainings are in progress	• Improved nutrition and encouragement for increasing their income. Increasing ecological balances in the watershed.
10	Field Days	1. Exposure visit to nearest watershed in Anantapur or in Kurnool; 2. Fields days every year	• Exposure visits have been completed	• Exposure to different best agricultural practices and interactions with the best farmers in other watersheds.