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Research Article

IMPACT OF RAIN WATER HARVESTING STRUCTURES ON GROUND WATER DEVELOPMENT – A CASE STUDY ON CHEVELLA WATERSHED, TELANGANA STATE, INDIA

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ABSTRACT

Development of watershed's has been a part of Indian Nation's developmental programs and is aimed at uplifting the rural poor and to assure food security. Watershed development helps to improve the groundwater resource, assured quality water supply for drinking and irrigation and to increase the crop yield. In the chevella watershed 419 Rain water harvesting structures are constructed and created a space for storage of 428,265 cu. m of water resource. It is observed that 1392 ha. m of water recharged from rainfall and 30.46 ha. m from Rain water harvesting structures. As a whole 1422.46 ha. m recharged the aquifer and the water table increased correspondingly. It is found that after the implementation of watershed program, concentrations of almost all the water quality parameters improved and suitable for drinking and irrigation. Regarding the crop area, in Kharif season 418.445 ha. m and in Rabi season 254.952 ha. m increased.

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INTRODUCTION

Watershed Development programs began in the early 1970s as a way to address food security and rural poverty in India's rained regions. The GOI's initial interest in WSD (watershed development program) was spurred by a growing realization that there were production limits to agriculture from India's Green Revolution (Joshi *et al*., 2005). The Green evolution focused on promoting high-yielding crop varieties, and large-scale irrigation of the country's plains, which represent less than 40 percent of arable land area. Rain fed regions, conversely, represents almost 65 percent of cultivable area in India and 55 percent of agricultural production. Despite representing the majority of cultivable area, rain fed areas is less productive than irrigated areas, with crop yields at about a third of the national average. This low productivity is due to a variety of reasons. Rain fed areas is characterized by erratic, deficient, and delayed rainfall patterns. Rain fed regions also represents 73 agro-climatic zones and are characterized largely as having hilly, mountain- ous terrain. As a result, large-scale irrigation is often difficult or impossible and it is difficult to implement a standard remedy to improving crop production and livelihoods (Planning Commission 2012). Rain fed regions has also historically experienced severe degradation due to heavy deforestation and unsustainable agricultural and livestock practices. Populations living in these regions are also some of India's poorest, with insufficient access to education and agricultural markets (Ahmad *et al*. 2011). Over the past fifty years, WSD has evolved from a top–down, technical, and bureaucratic approach to a participatory, ecosystems-based approach including social, ecosystem-based, and technical interventions. For example, early programs from the 1970s administered by the Ministry of Rural Development (MoRD), like the Drought Prone Areas Programme (DPAP), the Desert Development Programme (DDP), and the Integrated Wasteland Development Programme (IWDP), focused on technical interventions to promote soil and water conservation measures in drought-prone areas and on installing water-harvesting structures (Shah and Amita 2001; Kerr *et al*., 2002). Overall, WSD projects improved crop yields, especially irrigated areas, but net returns were fairly low. Additionally, benefits were found to be unequally distributed between land-owning and non-land-owning households. Non-governmental organizations became more active as PIAs in the early 1990s. Various bilateral programs, like the Indo-German Watershed Development Programme (IGWDP), were instrumental in providing NGOs with funding and flexibility to test emerging concepts and methodologies in participatory watershed

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development on technical interventions (Palanisami and Kumar 2009).

Study Area

The Chevella watershed is covering 23 villages and 34 habitations of Chevella and Sankarapalli mandals located in Rangareddy district of Telangana State (Table 1). The sub basin is located in the central part of the district, which is about 42 km from Hyderabad, lying on Hyderabad to Tanduru road. Chevella watershed forms part of survey of India toposheet Nos. 56 K/3 of 1: 50,000 scale, lying between East longitude 78^0 04′ 10" and 78^0 13′ 58" and North latitude 70^0 26′ 50" and $70^0$17′ 52".

Topographically the area is elevated in the South, South-West and sloping towards the North, North-East. The maximum altitude is about 642 m (amsl) and the minimum altitude is about 557 m (amsl). The slope ranges from 1 to 5% and the rate of erosion is very high in nature. Prominent geological formations are granitic gneissic complex overlain by the Deccan Traps and laterites. The thickness of weathered zone varies from 6.0-10.0 m. The soils are mainly of two types. They are black and mixed soils with a thickness of 0.4 to 2.0 m. Average precipitation in this area is about 826 mm. Maximum and minimum temperatures are on an average 38.80C and 14.30C, respectively.

The Present study is aimed at computing water storage at various Rain Water Harvesting Structures (RHS), recharge from rainfall and RHS and their impact on groundwater development.

Table 1 List of habitations in the Chevella watershed

S.No	Mandal	Village	Habitation
1	Chevella	Chevella	Chevella
2		Devaniyerravalli	Devaniyerravalli
3		Gollapalli	Dharmasagar
4			Gollapalli
5		Ibrahimpalli	Ibrahimpalli
6		Kammeta	Gollaguda
7			Kammeta
8		Kesaram	Kesaram
9		Kummera	Kummera
10		Malkapur	Malkapur
11		Mundiyala	Mundiyala
12		Nyalatla	Nyalatla
13			Ramannaguda
14			Singappaguda
15		Ravulapalli	Mudimial
16			Ravulapalli
17		Urella	Urella
18		Yenkaypalli	Yenkapalli
19		Yerlapalli	Yerlapalli
20	Sankarapalli	Chandipa	Chandipa
21		Husainpur	Husainpur
22		Kottapalli	Kottapalli
23		Masaniguda	Masaniguda
24		Parveda	Kachchireddiguda
25			Kothaguda
26			Lachireddiguda
27			Parveda
28		Poddatur	Poddatur
29		Ramanthapur	Ramanthapur
30		Tangatur	Tangatur
31		Yarvaguda	Mancherlaguda
32			Yarvaguda
33		Yelwarti	Kojjagudem
34			Yelwarti

METHODOLOGY

Twenty three micro watersheds are identified under Chevella watershed. The watershed has its own Watershed Committee and watershed association for better implementation and management of watershed project to enhance people participation.

Information about the annual Rainfall has been collected from the mandal revenue offices of Chevella and Sankarapalli from 2001 to 2015 for analysis of trend and distribution of the rainfall pattern in the basin.

Interacted with the different stakeholders i.e. farmers, agricultural labour, self-help group members, watershed committee, watershed association members, Department of Agricul-ture, Irrigation and Social forestry of all 23 villages required data are collected 225 members are interviewed and discussed with focus group using prescribed format. Data are collected about the socio-economic status and impact of the watershed programme in their villages.

Identification of RHS in the basin carried out by transect walk from ridge to valley covering streams, tributaries, slopes, common property resources (CPR) and individual lands (Figure 1). At each structure dimensions like length, width, and depth/height of the structure are measured for estimating the quantity of the water harvested and estimating the recharge from the RHS. At the time of inception of the watershed a detailed transacts was carried out covering ridge to valley in the basin with community. Before going to prepare a watershed plan a clear mapping of the present structures is made and the locations feasible areas to construct the new structures are identified.

The study emphasized to understand the impact of structures based on the geological, structural and topographical characteristics of the basin.

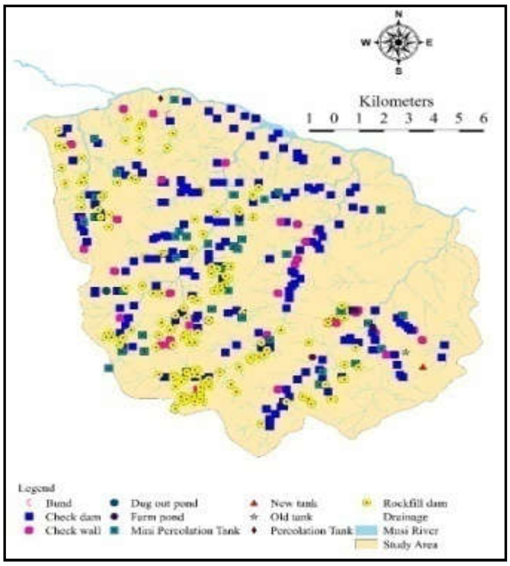

Fig. 1 Location map of Rain Water Harvesting Structures (RHS)

Pre and post watershed impact on the agriculture production was estimated by comparing the five years data of study area. Volume of the water storage has been calculated by multiplying the length, width and storage column of the water at each structure. Rain fall recharge is estimated by using rainfall infiltration factor method (GEC 97). Water levels are collected for the years 2007-08 to 2013-14 in pre and post monsoon periods.

RESULTS AND DISCUSSION

Water storage at RHS

Number of Type wise RHS created in chevella watershed are shown in Table 2 and Figure 2. Quantity of water that can be stored at each structure has calculated using a formula by taking average of length, breadth and depth at each structure. The stored water intern percolates into subsurface leads to increase in groundwater. As a whole 419 RHS are constructed in the Chevella watershed and total volume can be stored is 4, 28,265.4 cu. m. It indicates that this much quantity of water can be stored during a storm (Table 2 and Figure 3). Out of this 3,10,038 cu. m. of storm water stored in 41 percolation tanks, 95,396.3 cu. m. of water could be accumulate at 189 check dams, followed by 149 rock fill dams filled by 13,309 cu. m. 35 check walls to store 8,328.6 cu m. three farm ponds have capacity of 643.5 cu. m, and one farm pond has capacity of 100 cu. m. Earthen Bund has created at higher place of the watershed to store the water and to trap soil which has capacity of 450 cu. m.

Table 2 Details of water storage at RHS

Type of RHS	No. of RHS	Water Storage (cu. m)
Earthen Bund	1	450.0
Check dams	189	95,396.3
Check walls	35	8,328.6
Farm ponds	4	743.5
Percolation tanks	41	310038
Rock fill dams	149	13,309.0
	419	4,28,265.4

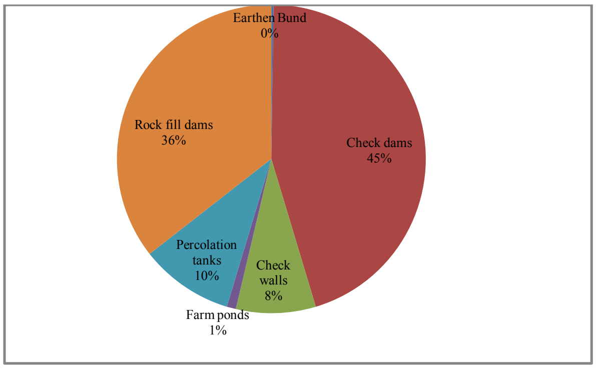

Fig 2 Number of RHS-Type wise

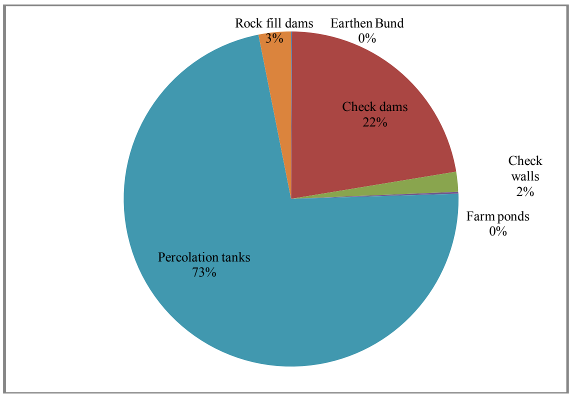

Fig. 3 Water Storage at RHS

Recharge from rainfall

Natural groundwater recharge is occurring through recharge from rainfall and other sources such as RHS. In the present study development of groundwater from rainfall and RHS is estimated to assess the impact of watershed activities in groundwater development. Other sources are canals and irrigation water. However, as there are no canal, irrigation tanks; and return flows.

The gross groundwater recharge from rainfall through various geological formations in the Chevella watershed is shown in table 3 and figure 4. The following formula is used for the groundwater recharge.

Formula used: Groundwater recharge from Rainfall in cubic meters = Area of estimated unit in square meters X Average rain fall in meters X Infiltration factor of respective geological formation.

Table 3 Recharge from rainfall

Format-ions	Area (ha)	Rainfall (mm)	Rainfall (mm)	Fact-or	Recharge (ha. m)
Granite and alkali feldspar granite	7,229.7	853.4	0.9	0.11	678.7
Basalt, intertra-pean	11,269.6	853.4	0.9	0.07	673.2
Laterites	670.4	853.4	0.9	0.07	40.1
	19,169.7				1,392

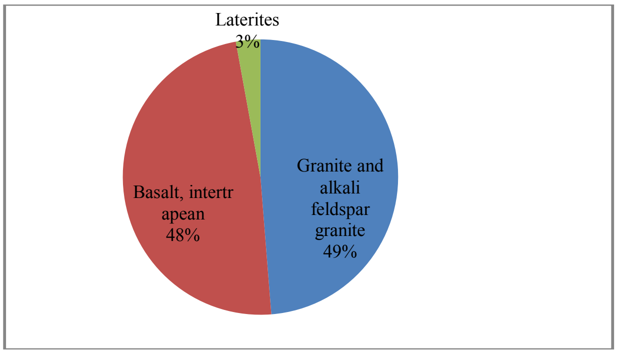

Fig 4 Water recharge through various geological formations from rainfall

From the table it is understood that 1392 ha. m of ground water is recharged into the watershed. Out of this 673.2 ha. m recharged through basalt and intertrapeans occupied about 11,269.6 hectares, where as in granite and alkali feldspar granitic terrain recharged about 678.7 ha. m 40.1 ha. m recharged the aquifer through laterites.

Water recharge from RHS

Estimated water recharge through percolation tanks in the Chevella area is 0.9 ha. m assuming that water stored from 120 days. Infiltration factor (1.44) is taken from GEC-97 recommen-dations and water availability days decided from the data collected from the farmers and rainy days in the Chevella area Table 4.

Groundwater recharge from other RHS in square meters = factor 0.25 X Gross storage; Gross storage in square meters = Storage capacity in square meters X Number of fillings.

Estimated water recharge through RHS is 29.56 ha. m from 11.82 ha. of water spreading area (Table 4 and Figure 5). Infiltration factor 0.25 is from as per GEC-97 recommendations. Average filling days are taken as 10 days.

Number of filling days in the structures derived from the data collection from the farmers during the field survey and rainy days in the Chevella watershed. Groundwater recharge from RHS is shown in Table out of the total recharge 29.56 ha. m check dams contribute highest quantity of all the RHS i.e., 23.8 ha. m. Among the other RHS rock fill dams contributed 3.3 ha. m and 2.1 ha. m by check walls. About 0.90 ha. m of water recharged from percolation tanks.

It is learn that 1422.46 ha. m if water resource is recharged from rainfall and RHS (Table 5). It is observed that major part of recharge (98%) is taken place through from rain fall, followed by check dams, rock fill dams and percolation tanks constructed in Chevella watershed (Figure 6).

Relation between rainfall and water levels

Average annual rainfall over the period of fifteen years (2001-15) the watershed is 831.4 mm, where 756.5 mm is from Chevella mandal and 906.4 mm from Sankarapalli mandal. It is also evident that the basin is experienced erratic rainfall even these mandals are quite adjacent to one another.

Table 4 Groundwater recharge from RHS

Type of RHS	Fac-tor	Ave. water Spread area (ha)	No. of fillings	Ground water Recharge (ha.m)
EB	0.25	0.05	10	0.1
FP	0.25	0.07	10	0.2
PT	1.44	5.19	120*	0.9
CD	0.25	9.54	10	23.8
CW	0.25	0.83	10	2.1
RFD	0.25	1.33	10	3.3
Total		11.82		30.46

EB- Earthen Bund, FP - Farm ponds, PT-Percolation tanks, CD-Check dams, CW-Check walls, RFD- Rock fill dams.
*No. of days water available

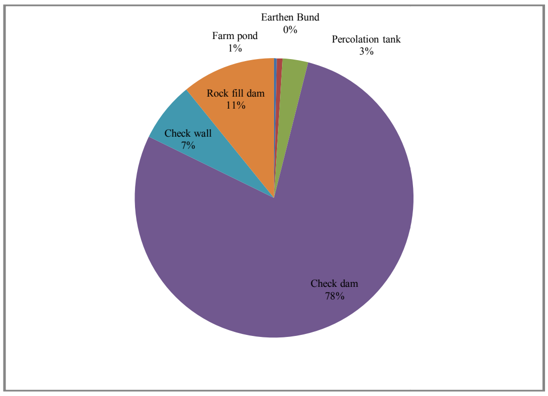

Fig 5 Water recharge from RHS

Table 5 Water recharge from rainfall and RHS

S.No	Recharge Source	Recharge (ha.m)
1	Rain fall	1392.00
2	Water conservation structures	30.46
	Total	1422.46

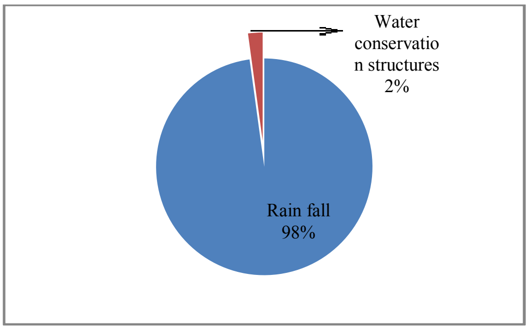

Fig 6 Water Recharge from Rainfall and RHS

Average ground water levels in the study area varied from 9.98 m bgl to 16.63 m bgl in pre monsoon and in post monsoon from 4.72 m bgl to 10.91 m bgl. There is no change in water levels during pre monsoon of 2010 and post monsoon of 2013 and 2014. 2011, 2012. Post monsoon season of 2014 shows decreasing trends. The recorded average lowest water level is 16.63 m bgl in pre monsoon of 2012 and average highest water level recorded is 3.96 m bgl in post monsoon of 2013 (Figure 7). Positive relation is observed between ground water levels and rainfall. (Ramesh and Sankra Pitchaiah, 2017b).

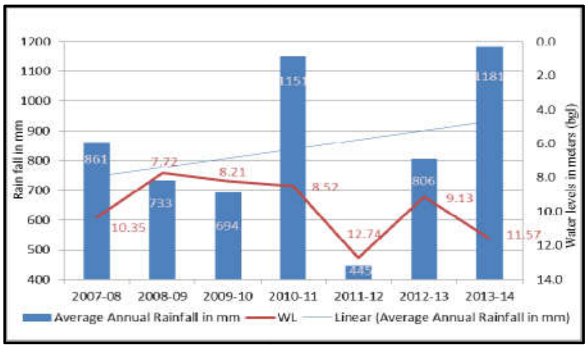

Fig. 7 Relation between rainfall and water levels variation (2008-14)

(Source: Ramesh and Sankara Pitchaiah, 2017b)

Cropping Pattern

The main crops grown in the watershed are maize, sunflower, grape, vegetables, Jowar, cotton, Bengal gram, Paddy, Red gram and other millets. Bore wells and dug wells are the source of water for crops.

The watershed development programme has led to significant changes in the additional area brought under irrigation (Hazra, 1989). Water management along with judicious use of water for raising crop is going to be instrument in sustainable agriculture production in our country (Bhagwan Singh *et al*, 2015). The study of cropping pattern is important to know the extent and proportion of area. Alloted from crops moreover, the development in the farm technologies and growth promoting inputs such as use of improved seeds, chemical fertilizers, pesticides/ herbicides and system of multiple cropping patterns brought drastic changes in the cropping pattern on farms. Hence, the study of cropping pattern is of great importance from economic point of view (Thakur *et al.*, 2014). It is well known fact that after implementation of watershed programme the water for irrigation was increased, which brings the changes in cropping pattern and increases the crop productivity in the watershed areas. Hence, an attempt is made to see the cropping pattern and crop productivity before and after watershed construction such studies are carried out in other areas also (Chauhan *et al*., 2009).

To analyse the changes in cropping pattern of Chevella Watershed, 2007-08 and 2013-14 crops data have taken for both kahrif and rabi seasons. Table 6 shows the cropping pattern of the Chevella area. In 2007-08 Kharif season 9106.23 ha. m were cultivated where as it is increased to 9525.89 ha. m in 2013-14. After the implementation of watershed programme 419.65 ha. m are cultivated in Kharif season and in rabi season 254.952 ha. m are added.

The data reveals that in Chevella watershed 5 percent of cropped area increased due to watershed program in kharif season (Figure 8) and it is 18 percent in rabi season (Figure 9).

In Kharif season of 2007-08, vegetables were sowed in more area followed by Maize, cotton, paddy, red gram, fruits, 123.42 ha. (mango, 141.64 ha.; papaya, 2.4281 ha.; guava 3.64 ha.) flowers, 130.713 ha.; (rose 42.49 ha.; chrystamus 71.22 ha.; Kanakambaram 7.28 ha.; kagada 4.4515 ha.; Jasmin 5.2609 ha.; jowar 97.52 ha.; seasamum 4.85 ha. and turmeric (4.85 ha.), green gram (2.83 ha.) and fodder jowar (2.8328 ha.). In 2013-14 also sown area is in the same order in relation to cropped area.

Table 6 Cropping pattern in Kharif season (2007-08 and 2013-14)

Crop	Kharif (ha) 2007-08	Kharif (ha) 2013-14
Paddy	414.40	446.78
Jowar	97.53	106.83
Maize	2906.92	2972.07
Red gram	184.94	203.56
Green gram	2.83	4.45
Vegetables	3685.14	3829.21
Fruits	147.71	158.23
Sesamum	4.85	8.09
Flowers	130.71	166.32
Turmeric	4.85	4.85
Cotton	1523.67	1621.61
Fodder Jowar	2.83	4.046
Total	9,106.38	9,526.04

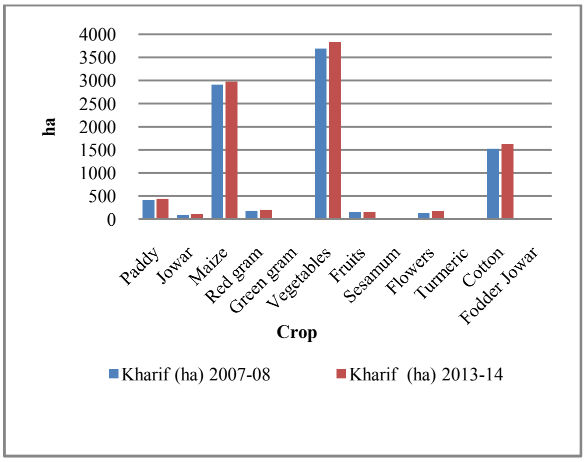

Fig 8 Crop wise cultivated area in Kharif season (2007-08, 2013-14)

In Rabi 2007-08 major portion of the Chevella watershed cropped with vegetables (942.10 ha. m) followed by Bengal gram (126.66ha.), paddy (93.48 ha.), flowers (87.41 ha.) including rose (25.09 ha.), marigold (10.92 ha.), chrystamus (42.49 ha.), kanakambaram (8.90 ha.), maize (84.57 ha.), oil seeds (55.44 ha.) including safflower(34.39 ha.), sun flower (18.21 ha.), ground nut(2.83 ha.), wheat (31.56 ha.) and jowar (16.59 ha.).

Table 7 Cropping pattern in Rabi season (2007-08 and 2013-14)

Crop	Rabi (ha) 2007-08	Rabi (ha) 2013-14
Paddy	93.48	109.26
Jowar	16.59	27.11
Maize	84.58	100.36
Vegetables	942.12	1077.70
Flowers	87.41	115.33
Wheat	31.56	41.27
Bengal gram	126.66	142.04
Oil seeds	55.44	79.72
Total	1,437.84	1,692.79

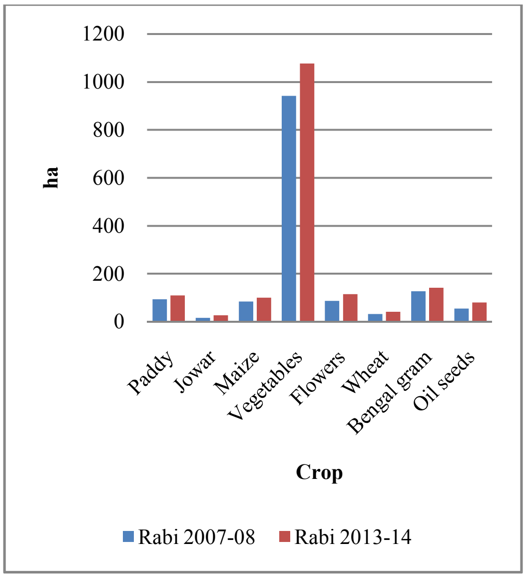

Fig 9 Crop wise cultivated area in Rabi season (2007-08 and 2013-14)

In Rabi 2013-14 also vegetables occupied major area about 1077.67ha. m, followed by Bengal gram (142.045 ha. m), flowers (115.335 ha. m) including rose (28.732 ha. m), marie gold (12.545 ha. m), chrystamus (61.1075 ha. m), kanakambaram (12.140 ha.m), paddy (109.265 ha. m), maize (100.362 ha. m), oil seeds (79.723 ha.m) including safflower (42.492 ha.m), sun flower (32.7795 ha.m), groundnut (4.4515 ha. m), wheat (41.277 ha. m) and jowar (27.1139 ha. m) (figure 5.57).

It is concluded that due to improvement of soil moisture and groundwater table the cropped area has increased in the basin. Implementation of watershed programme from the ridge to valley with the support of local farmers the groundwater table was increased and cropped areas was considerably increased in both kharif and rabi seasons.

Water Quality variation

Ramesh *et al*., (2017a) studied the variation in water quality before (2010) and after (2013) the implementation of the watershed program (Table 8 and Figure 10).

Table 8 Variation between 2010 and 2013 Pre-monsoon (Ramesh *et al*., 2017a)

Parameter	2010	2013
pH	8.3	8.15
TDS	1796.50	808.33
Hardness	761.87	352.89
Calcium	121.33	56.21
Magnesium	112.40	52.06
Bicarbonates	570.15	180.56
Chlorides	335.37	175.22
Sodium	221.79	121.31
Potassium	6.93	3.53
Sulphates	117.03	93.46
Nitrates	34.54	19.83
Fluorides	1.27	1.32
Iron	0.08	0.4

According to them concentrations almost all the water quality parameters are decreased from 2010 to 2013. It is also reported that the concen- trations are increased away from the RHS. So, it is concluded that RHS diluted the concentration and change the water quality from poor to good.

Ramesh *et al*., (2017b) study revealed that irrigation quality parameters such as SAR, KR, SSP, RSC and PI are within the permissible limit and the groundwater is suitable for the Irrigation.

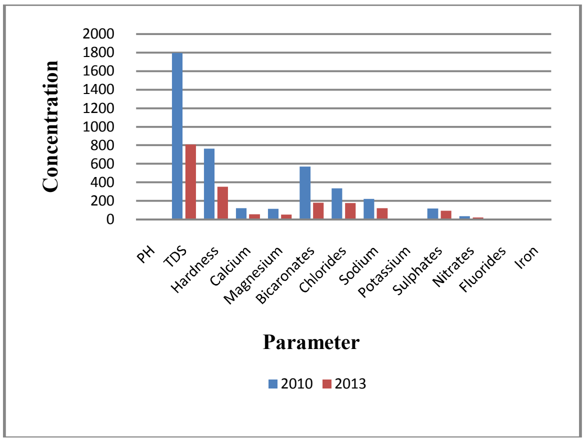

Fig 10 Comparison of water quality between 2010 and 2013

Based on WQI values, it has been observed that the percentage of good groundwater samples for drinking purpose has increased from 4% to 13%, whereas poor groundwater reduced to 87% in the wet period from 96% in the dry season due to the implementation of watershed program. It shows that groundwater quality has improved due to percolation of rain water into the sub-surface during the rainy season through rainwater harvesting structures. (Ramesh *et al*., 2018)

Need for people's participation

Peoples' participation in planning, developing and executing the watershed activities is indispensable. It calls for community participation and collective action. It is necessary because individual choices have collective consequences in the watershed framework. Action of one group of farmers at one location affects adversely (or favorably) the other group of farmers at different location. Often the different groups and locations have conflicting objectives with respect to their investment priorities and enterprise choices. These needs are to be converted into opportunities. The action of all the farmers in the watershed should converge in such a way that the positive externalities are maximized, and the negative ones are minimized. To achieve this, the community or stakeholders have to develop their own rules, which resolve their conflicting objectives.

First generation (1969-1974) and second-generation watershed programmes (1974-1979) were implemented without public participation. The third-generation watershed programmes (1990 onwards) were implemented with the support of local people. Watershed programmes were characterized by having the attribute of collective action that encompasses all beneficiaries and the stakeholders. People's participation is critical in the success of the watershed programme (Hanumantha Rao, 2000). The watershed benefits were more where the people's participation was high in implementation of the programme (Deshpande and Timmaiah 1999).

High Power Committee which is constituted by the Government of India recognized the need of people's participation and involvement of the Voluntary Agencies in the building proper social capital for better technology adoption these positions lead to the formation of community-based organizations (CBOs) i.e. Self-Help Groups, User Groups, Watershed Committee and Water Users Association. However, the purported transparency in development of action plan with agreement of all sections of the Society, involvement of women as equal partner while developing and executing the action plan, adequate flexibility and even mid-course corrections were not fully adopted. Emphasis need be on demand given participatory approaches in developing action plan. To sustain efforts, the beneficiaries should contribute 5 to 10 % (SC, STs 5% and others 10%) of the cost of all the interventions in improving their natural resources through soil conservation or water harvesting structures.

The Department of Land Resources has brought out a new initiative called Hariyali in the year 2000 with an objective of empowering Panchayat Raj Institutions (PRIs) both financially and administratively in implement-tation of Watershed Development Programmes. (Source: Hariyali Guidelines 2000). Under this initiative, all ongoing area development programmes namely, Integrated Wastelands Development Programme (IWDP), Drought Prone Areas Programme (DPAP) and Desert Development Programme (DDP) are to be implemented through the PRIs.

Until 1987, several pilot projects on watershed were implemented in different agro-ecoregions of the country. Over different plan periods, the nature and scope of watershed program was modified, and these were tuned to encourage more of peoples' participation. (Joshi *et al*., 2005). Watershed programmes promoted participation by villagers were found to be far more successful than those focused solely on technical interventions (Kerr 2002, Palanisami *et al*. 2009). Watershed programs are characterized by having the attribute of collective action that encompasses all the beneficiaries and the stakeholders. Therefore, people's participation becomes a critical determinant in the performance of watershed programs (Joshi *et al*., 2005).

CONCLUSION

Chevella watershed is a drought prone area, where people suffered a lot for drinking and irrigation water. Socio-economic conditions are poor in the area. The implementation of watershed program changed the face of the people. Water quality and crop area are improved, and the crop yields are encouraging. It is concluded that implementation of watershed program with the people's participation certainly yield positive results and improve the status of the rural people.

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