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Impact of soil and water conservation measures on groundwater recharge, irrigation potential and productivity of crops of a watershed

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ABSTRACT

The present study was undertaken during 2011-2014 in Bharkatia watershed in Athagarh block of cuttack District, Odisha. The objective of the research work was to study the recharge of groundwater through different conservation measures like dug wells, tanks, recharge pit, tube wells, check dams etc. on ground water level and study the impact on increasing irrigation area, production and productivity of different crops in the watershed. Up to 2011, no conservation measures were taken up in the watershed. However, in 2011, twenty recharge dug wells, twenty recharge farm ponds, two numbers of recharge tube wells, 1120 numbers of recharge pits and one check dam were constructed in the watershed. Data on groundwater table rise, irrigation area and productivity of different crops during the study period of 4 years were collected and analysed for the study. The study reveals that average groundwater table came up by 0.27, 0.40 and 0.35 m during pre-monsoon, monsoon and post-monsoon periods in 3 years period after construction of various conservation measures with an average rise of 0.34 m. Increased groundwater recharge helped in augmenting the groundwater potential in the watershed. Because of increased groundwater irrigation, the cropped area in the watershed increased by 308 ha in 3 years period. The productivity of different crops also increased. The yield of *kharif* and *rabi* paddy increased by 36.8 and 17.1%, respectively in 2014 as compared to 2011 when no conservation measures were taken up for groundwater recharge. The yield of other crops including vegetables also increased substantially due to application of more irrigation water from the raised groundwater table.

1. INTRODUCTION

Land and water are the two most vital natural resources of the world and these resources must be conserved and maintained carefully for environmental protection and ecological balance. Due to urbanization and industrialization, per capita availability of cultivated land in the country has decreased from 0.34 ha in 1961 to 0.12 ha in 2014 and the projected estimate indicates that it will further decline to 0.1 ha by 2025 AD (Naik, 2016). Prime soil resources of the world are finite, and prone to degradation through misuse and mismanagement. Total global land degradation is estimated at 1964.4 M ha, of which 38% is classified as light, 46% as moderate, 15% as strong and the remaining 0.5% as extremely degraded, whereas present arable land is only 1463 M ha which is less than the land under degradation (Koohafkan, 2000). In India, out of 328 M ha of geographical area, about 55% (182 M ha) is affected by various soil erosions and land degradation. Out of the 182 M ha area, 68 M ha are critically degraded and 114.03 M ha are severely eroded (Velayutham, 2000). Therefore the problem of land degradation due to soil erosion is very serious and with increasing population pressure, exploitation of natural resources, faulty land and water management practices, it will further aggravate.

Like soil, water which is another vital resource for agricultural production is declining day by day. Per capita water availability in India is low compared to many other countries. Due to multiuse of water coupled with population exploitation, the per capita water availability will further decrease in the years to come. In 2025 AD, the per capita annual water availability in the country would be 1400 m^3 which would be less than China and our neighbouring countries like Pakistan and Nepal. The per capita water availability in the country is reducing progressively due to increasing population. The per capita water availability in India in 1955 was 5300 m^3 which has come down to 1500 m^3 in 2014 as against the world average and Asian average of 7050 and 2860 m^3, respectively. With the projected population growth, urbanization and industrialization, the average will dwindle to about 1200 m^3 by 2050 AD. Under such a juncture, the share of water for irrigation may decline to 70% in 2050 AD as compared to its 84% share being available now (Panigrahi, 2014). Considering all the above mentioned facts, it is high time now to develop a comprehensive strategy to search for new avenues to increase the potential of soil and water natural resources and conserve them from degradation and utilize them judiciously and optimally so that we will obtain sustainability in agricultural production and productivity especially in the rainfed areas including watershed areas.

Eastern India including the state of Odisha, is bestowed with ample rainfall resources with average annual rainfall of 1500 mm, 80% of which is concentrated during the rainy season between June to September. During this period, about 50% of the annual rainfall comes from a few intense storms (Pisharoty, 1990). Water received from such intense storms is subjected to high runoff losses that cause a lot of soil and nutrient erosion and goes as a waste. The fate of millions of poor farmers in the region can be greatly improved by use of technological advances such as effective rainwater conservation and management. Rainwater conservation may be achieved in any of the following three ways. They are (i) conservation in soil reservoir, (ii) conservation in surface reservoir and (iii) conservation in groundwater reservoir. Out of the above three methods, conservation in groundwater reservoir is the best source since it does not require any vast areas for construction of surface reservoirs where the effective rainfall is to be stored. Conservation of water in soil reservoir though is the cheapest method but the stored soil moisture cannot hold it for a longer period. Conservation of *in-situ* rainfall as well as surface runoff in the form of groundwater recharge is also a cheap and eco-friendly method.

Groundwater recharge or deep drainage or deep percolation is a hydrologic process where water moves downward from surface water to groundwater. Groundwater recharge is the enhancement of natural ground water supplies using man-made conveyances such as infiltration basins, trenches, dams, or injection wells. This process usually occurs in the vadose zone below plant roots and is often expressed as a flux to the water table surface. Aquifer storage and recovery (ASR) is a specific type of groundwater recharge practiced with the purpose of both augmenting ground water resources and recovering the water in the future for various uses. Recharge occurs both naturally (through the water cycle) and through anthropogenic processes (*i.e.* artificial groundwater recharge), where rainwater and or reclaimed water is routed to the subsurface.

Artificial recharge is the planned, man-made increase of groundwater levels. By improving its natural replenishment capacities and percolation from surface waters into aquifers, the amount of groundwater available for abstraction is increased. Artificial groundwater recharge is becoming increasingly important in India, where over-pumping of groundwater by farmers has led to underground resources becoming depleted. In 2007, on the recommendations of the International Water Management Institute, the Indian government allocated ₹ 1800 crore to fund dug-well recharge projects in 100 districts within seven states where water stored in hard-rock aquifers had been over-exploited (Anonymous, 2014).

Artificial recharge methods can be further classified into two broad groups: direct methods and indirect methods. Direct methods can again be classified into surface spreading techniques and subsurface techniques. The most widely practiced methods of artificial recharge of groundwater employ different techniques of increasing the contact are and resident time of surface water with the soil so that maximum quantity of water can infiltrate and augment the groundwater storage. Under the surface spreading techniques various methods available are flooding, ditch and furrows, surface irrigation, stream modifications and finally the most accepted one and suitable for small community water supplies are runoff conservation structures. Under the subsurface techniques injection wells and gravity head recharge wells are common ones. Indirect methods of artificial recharge adopts the technique of induced recharge by means of pumping wells, collector wells and infiltration galleries, aquifer modifications and groundwater conservation structures, which require highly skilled manpower and other resources.

Watershed management including soil and water conservation measures plays a crucial role in increasing groundwater recharge. Prasad (1999) studied the impact of watershed management including contour bund, graded bund etc. in the degraded watershed and reported that these structures could substantially increase the groundwater status in Chhaljawa watershed of Baran district of Rajasthan that augmented the production and productivity of different crops. Panda (2009) constructed various soil and water conservation measures like trenching, bunding, loose boulder check dams, ponds and other water harvesting structures in the Barapitanala watershed of Odisha and found that the groundwater level increased successively that resulted in increasing the irrigated area in the watershed by 2.53 times within a period of 4 years. Sharda *et al.* (2005) also studied the impact of participatory watershed management and observed that the groundwater recharge could be facilitated due to the construction of various soil and water conservation structures in the watershed. Similar conclusions on enhancement of groundwater recharge by soil and water conservation measures have been reported by other researchers (Kumar *et al.,* 2011; Mondal *et al.,* 2006; Goel *et al.,* 2007 and Paul *et al.,* 2016). The objective of the present research work is to study the recharge of groundwater through different conservation measures like dug wells, tanks, recharge pit, tube wells, check dams etc. on rise of ground water level and study the impact on increasing irrigation area, production and productivity of different crops in the watershed.

2. MATERIALS AND METHODS

The present study was undertaken during 2011-2014 in Bharkatia watershed in Athagarh block of Cuttack district, Odisha. The watershed is located15 km away from the river Mahanadi. The project area is located at $20^0$31'20” to $20^0$34'45”N latitude and $85^0$17'05” to $85^0$50'55” E longitude. The project area covering an area of 20 km^2 includes the villages of Jemadeipur, Kusupangi, Sarkoli, Korikol, Chabjaunri, Torada, Parbatia, Gurudijhatia, Kotar, Pithakhia, Ramchandrapur, Radhapriya, Balisasan, Bali, Sitarampur, Oranda, Chotiamba, Kaduanuagaon. The area gets an average annual rainfall of 1450 mm in 72 rainy days. Out of 1450 mm annual rainfall, 78% is received in 4 rainy months (monsoon season) *i.e.* from June to September. Rainfall distribution is very erratic and uneven. The maximum temperature in the area goes up to 46^0C in May and the minimum temperature goes down 8^0C in the month of December. Relative humidity ranges from 43 to 91%. The watershed is generally flat with undulating topography. Basically it is a fan shaped watershed. Physiographically the zone is located in the coastal belt and has an altitude of ranging from 38 to 65 m above mean sea level (msl). The soil is mostly sandy loam to sandy clay loam and depth of soil is about 90 cm. Table 1 represents the various morphometric parameters related to the watershed.

Soil and Water Conservation Measures/Structures

Various soil and water conservation structures like Recharge pit, Recharge pond, Recharge dug well, Renovation of medium irrigation (MI) tank, Renovation of existing ponds, Check dams and Recharge tube wells were constructed in the watershed in consultation with the farmers and soil conservation department in the watershed. The purpose of constructing the structures in the watershed is to improve the groundwater status in the watershed. Periodically the groundwater table position in various tube wells and dug wells were measured throughout the year for three consecutive years *i.e.* 2012, 2013 and 2014 at various locations in the watershed. Descriptions of different structural measures are mentioned in short as follows.

Recharge Dug wells

In the watershed, 20 recharge dug wells were excavated up to a depth of 9 m in sloppy lands nearer to the renovated ponds. Diameter of the dug wells were 3.5 m each. Excess water after filling the pond was allowed to enter into the constructed dug wells. In addition, the runoff from the sloping

Table: 1
Morphometric parameters of watershed

S.No.	Morphometric parameters	Value
1	Stream order	III
2	Number of streams	
	I	5
	II	2
	III	3
3	Stream length, km	
	I	5.45
	II	4.87
	III	1.78
4	Length ratio	1.40
5	Basin length, km	5.66
6	Basin pere meter, km	14.47
7	Basin area, km^2	15.70
8	Drainage density, km^{-1}	0.85
9	Length of overland flow, km	0.68
10	Circulatory ratio	0.98
11	Elongation ratio	0.88
12	Stream frequency (per km^2)	0.64
13	Bifurcation ratio	2.72
14	Form factor	0.60

catchment was also channelized to these dug wells. The dug wells were back filled with gravel and sand charcoal layer by layer to facilitate in recharging the dried aquifer. The effect of recharged runoff water on groundwater levels were regularly observed in 7 observation wells in the entire watershed. These 7 observation dug wells are located in the villages of Chhotiamba, Kaduanuagaon, Parbatia, Gurudijhatia, Oranda, Chabjaunri and Jemadeipur with each village having one observation dug well. The recharge water is guided through a pipe to the bottom of well or below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer.

Recharge Ponds

Twenty numbers of small compartmental type ponds of size 15 x 10 m (bottom dimensions) and depth 2.5 m were excavated in the lateritic sloppy open fields in the watershed. The recharge ponds were constructed near to the dug wells in the watershed. Initial depth of the pond in the lower compartment was 1 m and then the depth of the upper compartmental pond was 1.5 m (Fig. 1). Top dimensions of the ponds were 20 x 15 m. It is observed that entire volume of water that enters in to the small ponds is percolated to the top surface aquifer within a period of a week, as the beds are totally lateritic. Fig. 1 shows the plan and cross section of the constructed recharge pond in the watershed.

Stone packing on upstream side of the pond was undertaken so that there will have no soil erosion. The length, breadth and height of stone packing were 15, 2.45 and 0.3 m, respectively.

Recharge Tube Wells

In the watershed, two numbers of recharge tubewell were constructed. The first tube well was constructed in the village Sitarampur and the second one in village Pithakhia. The depth of the tube wells was 148.2 m. The total volume of excavation for each tube well was found to be 108 m^3. The tube well was put inside a recharge pit of dimension: length of pit = 6 m, width = 6 m and depth of the pit = 7 m. The pit was packed with alternate layer of sand and pebbles as shown in Fig. 2 below. Water enters the recharge tube after passing through sand and then gravel layer. Different grades of gravels with diameter ranging from 9 to 12 mm have been used in the pit so that there will be no chocking of recharge tube by sand when water enters in to it.

Recharge Pit

Recharge pits are constructed for recharging the shallow aquifer. Recharge pit may be of any shape *i.e.* circular, square or rectangular. If the pit is of trapezoidal shape, the side slopes should be steep enough to avoid silt deposition. In the present case the recharge pits were rectangular in shape. Recharge pits were excavated and is filled with rubble stone dry packing on upstream side. The length, breadth and height of the recharge pit were all equal to 2 m. Total volume of recharge pit was found to be 8 m^3 . The length, breadth and height for random rubble dry packing were 2, 2 and 0.3 m, respectively and volume of random rubble dry packing upstream of recharge pit was found to be 1.20 m^3. In the

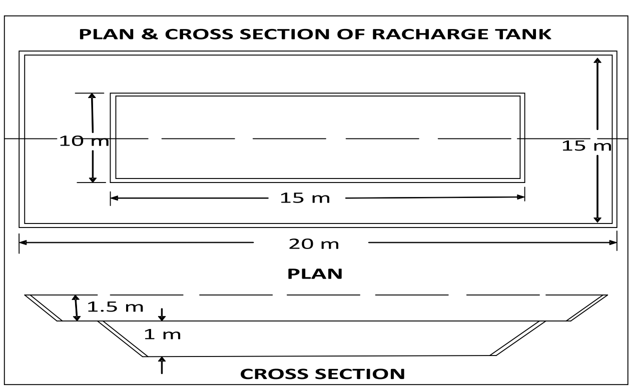

Fig. 1. Plan and cross section of recharge pond

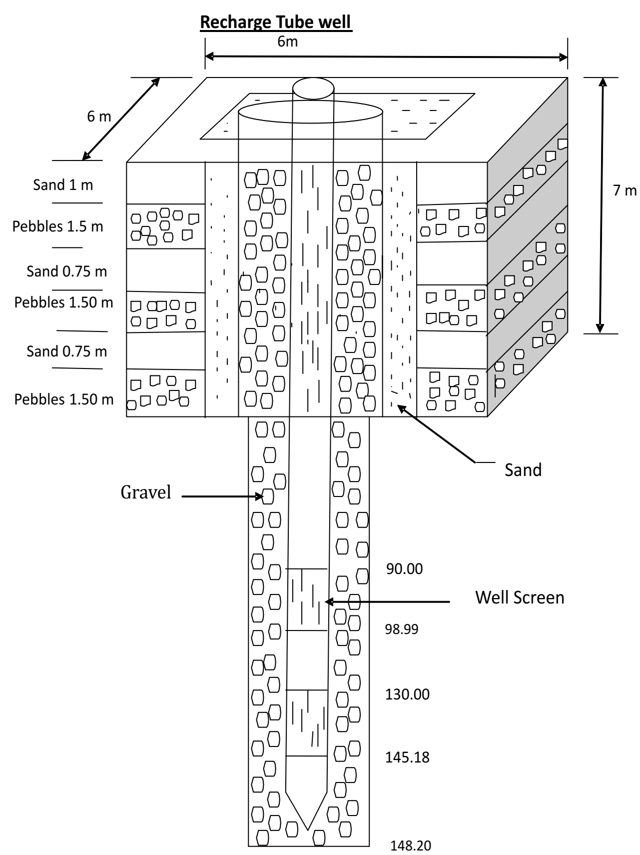

Fig. 2. Plan and cross section of recharge tube well

watershed, total 1120 numbers of recharge pits were constructed at different places in the watershed. Fig. 3 shows the section view of recharge pit.

Recharge Through Check dam

One check dam was constructed in the Barakatia watershed. The check dam (Fig. 4) arrested the flow of the partially thus enhancing the scope of ground water recharge. Besides augmenting the recharge, the structure is used to facilitate flow irrigation of about 20 ha of land.

The different structures as mentioned above were constructed at various places in the watershed. The construction was over in the year 2011. Data on groundwater table, area coverage of different crops and their productivity in the watershed were collected for three years *i.e.* 2012, 2013 and 2014. For comparison, data on groundwater table position in the watershed in the pre-treatment period *i.e.* 2011 were also collected. Data on area covered by different crops, and productivity of different crops in the watershed in the pre-treatment period *i.e.* 2011 were also collected. Because of several constraints including man power, funds etc. it was not possible to monitor the groundwater levels in all the wells in all places in the entire watershed. However, we considered the representative stations/places which cover the entire watershed almost uniformly to monitor the groundwater levels in the dug wells. In this study, the groundwater levels in each week for three years (2012 to 2014) in 7 representative stations were measure.

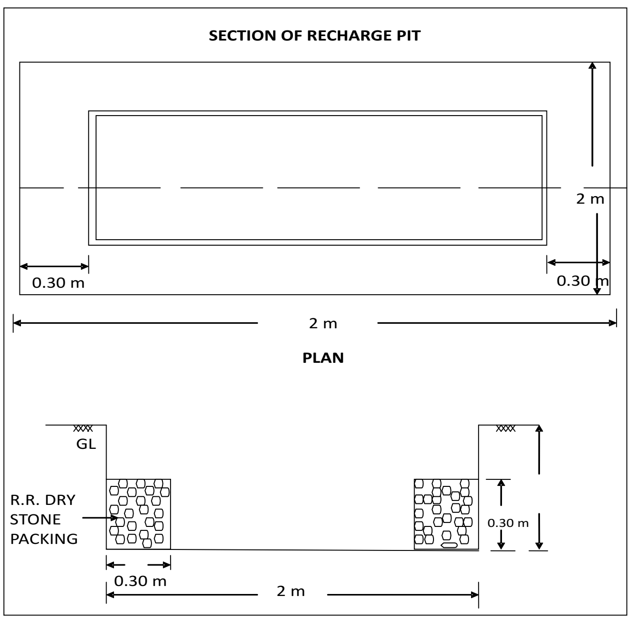

Fig. 3. Section of a recharge pit

Fig. 4. Check dam for groundwater recharge

3. RESULTS AND DISCUSSION

Effect of Different Conservation Measures on Ground Water Recharge

In this study the impact of different conservation measures like recharge through constructed ponds, dug wells, tube wells, check dams, recharge pits etc. were studied on rise of ground water table position in the watershed. The construction of different conservation measures were completed by 2011. The groundwater table position in the observation dug wells in pre-conservation treatment period *i.e.* 2011 was measured on daily basis from which the average weekly values were calculated. The values of water table positions below ground level (bgl) were found to vary from 7.37 to 10.8 m bgl. The position of the water table was low in the monsoon periods because of higher recharge due to rainfall. Water table positions were found to be at higher position below the ground level during the pre-monsoon period (Fig. 5). During the pre-monsoon period, there is scanty rainfall. Further, withdrawal of groundwater for irrigation during the post monsoon period and for domestic use throughout the year causes groundwater to recede in the watershed.

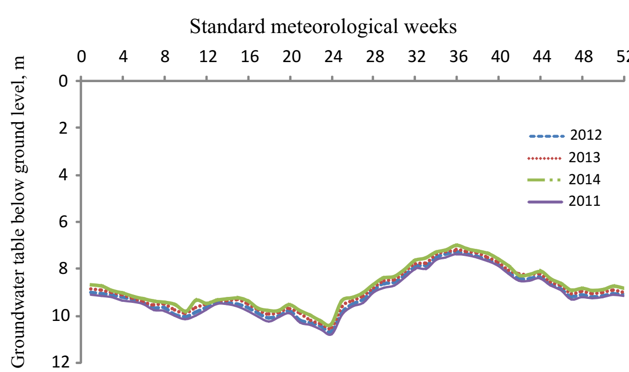

Fig. 5. Groundwater table position in watershed in different years due to groundwater recharge

After imposition of conservation measures, ground water table positions in the watershed were found to increase. The water table positions in the watershed were observed to be a spato-temporally variable factor. The water levels were found to vary at different places with different magnitudes at a particular time period. Further, in the same place, the water tables were observed to vary by varying magnitudes at different time periods in a year. As an example, the average water tables were found to range from 7.2 to 10.5 m at Chhotiamba in a year. Similarly the variation of groundwater table was from 7.1 to 10.7 m at Kaduanuagaon, 7.0 to 10.7 m at Parbatia, 7.0 to 10.5 m at Gurudijhatia, 7.0 to10.5 m at Oranda, 7.1 to 10.6 m at Chabjaunri and 7.0 to 10.6 m at Jemadeipur.

Groundwater table position was found to increase gradually over the years in all places in the watershed. For example, in first week of 2011 (before conservation measures were taken up), the water table was at 9.12 m bgl. In 2012, after 1 year of conservation measures were taken up, the water table rose by 0.11 m bringing it to a position of 9.01 m bgl. The groundwater table further increased by 0.16 m in 2013 and 0.18 m in 2014. Thus, in 3 years period, there was a total rise of 0.45 m because of groundwater recharge. The variation of groundwater table fluctuation was not uniform over different weeks in a year. The variation was dependent on groundwater recharge which depended on the amount of rainfall and runoff that was recharged. The average variations were found to range from 0.19 m (sixth week) to 0.64 m (11th week) with an average value of 0.34 m. The average values of water table during pre-monsoon, monsoon and post-monsoon periods in 2012 were found to be 9.92, 8.10 and 9.02 m, respectively. In 2011, these values were recorded to be 10.02, 8.18 and 9.10 m, respectively. Thus, during the pre-monsoon period, the average water table in the watershed rose by 0.10 m and during monsoon and post-monsoon periods, the rise was 0.08 m in each season.

The average rise over all the weeks in 2012 in the watershed was 0.09 m as compared to 2011 during one year after the soil conservation measures were taken up and groundwater recharge occurred. Similarly in 2013, average groundwater table during pre-monsoon, monsoon and post-monsoon periods in 2013 were found to be 9.76, 7.88 and 8.81 m, respectively as compared to the corresponding values in 2011. These figures indicate a rise of 0.16, 0.22 and 0.21 m during pre-monsoon, monsoon and post-monsoon periods, respectively in 2013. The position of the groundwater table further increased in 2014 after 3 years of imposition of the measures. Groundwater table came up by 0.27, 0.40 and 0.35 m during pre-monsoon, monsoon and post-monsoon periods in 2014 with an average rise of 0.34 m. Fig. 5 reveals how the ground water table fluctuates in the watershed during various weeks in each year. The graphs in this figure clearly indicates how the groundwater table rises over different weeks in each year because of groundwater recharge due to different soil and water conservation measures. The results indicate that further imposition of these measures in the watershed may bring up the water table by 3 m in about 10 years period which will facilitate more withdrawal of groundwater resources and consequently bring more area under irrigation and increasing production and productivity of different crops in the watershed.

Effect of Ground Water Recharge on Enhancing Irrigation Potential and Productivity

As mentioned earlier, several soil conservation measures were taken up to facilitate groundwater recharge in the watershed. The groundwater recharge helped in raising the groundwater potential. The raised groundwater table helped the farmers to discharge more ground water through different pumps and other water lifting devices. As a result, area under irrigation of different crops increased and ultimately production and productivity different crops increased. In addition to groundwater recharge, several structures were directly used as surface water storage reservoir which helped in facilitating in different forms of flow irrigation to the crop fields. For example, construction of a check dam in Barakatia watershed helped to provide flow irrigation to 20 ha area. These 20 ha area mainly covered paddy (15 ha) and vegetables (5 ha). Construction of two recharge tube wells in the village Sitarampur and Pithahkhia helped in augmenting ground water resources by recharging excess rainwater in the area. These two wells were used as discharge wells also for irrigation purposes. On an average they irrigated 50 ha area each in *rabi* and summer and when required to *kharif* crops too. These tube wells mainly irrigate paddy crops and oilseed crops.

In the pre-treatment period, the total area cultivated was 928.2 ha out of which *kharif* paddy covered 700.4 ha (75.5%). Since, paddy is the staple food of the farmers in the region and in *kharif* season there is abundant rainfall, farmers prefer to go for cultivating more paddy in the region. As shown in Table 2, area covered by other crops in the watershed is less. In *rabi* and summer seasons, the area receives scanty rainfall. The groundwater level is at deeper level and the watershed has no facility for canal irrigation. Hence, very less area is covered by crops in *rabi* and summer in 2011. However, after

Table: 2
Area (ha) coverage of different crops in the watershed in different years

	Area covered, ha				Productivity of crops, q ha^{-1}			
Crops	2011	2012	2013	2014	2011	2012	2013	2014
Paddy (*kharif*)	700.4	740.6	785.5	805.5	20.1	23.2	25.3	27.5
Paddy (*rabi*)	135.3	155.3	205.2	259.1	25.8	28.3	29.5	30.2
Mustard	8.2	10.3	12.6	15.3	7.1	8.6	8.8	9.1
Sunflower	2.1	2.0	5.5	7.8	12.2	17.5	18.3	18.0
Maize	20.2	22.6	24.5	28.3	37.5	45.8	49.5	54.6
Potato	3.2	5.1	7.3	10.2	108.3	120.9	128.2	132.7
Tomato	4.5	6.0	9.9	15.6	122.3	140.2	138.9	148.3
Brinjal	15.8	17.3	20.5	21.3	150.4	168.8	170.6	170.5
Chili	15.3	17.7	26.0	25.2	28.5	30.7	35.6	37.2
Cowpea	14.0	15.1	17.3	19.0	80.2	83.6	85.2	82.0
Raddish	2.3	2.2	4.5	6.6	70.5	80.2	86.4	95.2
Cauliflower	3.3	4.9	6.0	7.2	150.3	164.7	168.2	170.3
Cabbage	3.6	6.3	8.0	10.1	180.2	185.5	196.4	201.2
Sugarcane	-	1.1	2.5	5.0	-	378.5	381.6	380.2

the imposition of different soil conservation measures, groundwater recharge increased which augmented the groundwater resources in the area. As a result more area came under irrigation and the cropped area increased from 928.2 ha in 2011 to 1006.5 ha in 2012 (8.43% more than 2011). Percentage area increased to 22.31 and 33.1 in 2013 and 2014. Thus, there was an additional 308 ha more crop area in 3 years period. Out of these 308 ha additional crop area, *kharif* paddy and *rabi* paddy accounted to 105.1 and 123.89 ha, respectively. Rest 79.1 ha was occupied by oil seeds and vegetables. Even, it is surprising that there was no sugarcane in the study watershed but after increase of groundwater table some farmers started growing it. In 2014, 15 farmers in the watershed grew sugarcane in 5 ha area.

Productivity of different crops in the watershed also increased gradually due to application of frequent irrigation water. Yield of *kharif* paddy in 2011 was 20.1 q ha^{-1}. The yield was less because of unavailability of irrigation and the crop was grown purely as rainfed crop. The rainfall was non uniform and there were one critical dry spell of 14 days duration during the reproductive stage of paddy. This is the reason of obtaining low *kharif* paddy yield in 2011. However, after groundwater table rose, the farmers could supply some groundwater irrigation to the paddy as life saving irrigation which increased the yield. The yield of *kharif* paddy increased to 23.2 q ha^{-1} in 2012, 25.3 q ha^{-1} in 2013 and 27.5 q ha^{-1} in 2014. This is 15.4, 25.9 and 36.8% increase over *kharif* paddy in 2011. Farmers grew paddy in *rabi* season in low lying areas and areas where there is some feasible sources of irrigation like dug well, farm pond etc. The yield of *rabi* paddy was 25.8 q ha^{-1} in 2011. But with irrigation facility, the yield level increased to 28.3 q ha^{-1} in 2012 (9.7% increase over 2011), 29.5 q ha^{-1} in 2013 (14.3% increase over 2011) and 30.2 q ha^{-1} in 2014 (17.1% increase over 2011) (Table 2).

Yield of vegetables like potato, tomato, cabbage, cauliflower, radish, chili, and brinjal increased from 2.0 to 35.5%. Comparing the productivity of different crops in 2014 than 2011; the highest increase in yield was recorded for the crop sunflower (47.5%) followed by maize (45.6%). Thus the study reveals that construction of various soil and water conservation measures like recharge pit, recharge pond, recharge dug well, check dams and recharge tube wells helped in raising the ground water table through groundwater recharge and consequently enhancing cropped area, production and productivity of various crops in the watershed. It is expected that if the sustainability of the system continues, then in about 10 year's period, groundwater may come up by about 3 m and productivity of crops may increase by 50% in the watershed.

4. CONCLUSIONS

The comparison of water table in Barkatia watershed during 4 years of study period (2011 to 2014) shows that there is a trend of rising water table during different years after imposition of different soil and water conservation measures in the watershed. Average groundwater table came up by 0.27, 0.40 and 0.35 m during pre-monsoon, monsoon and post-monsoon periods in 3 years period after construction of various conservation measures with an average rise of 0.34 m. Groundwater recharge in the watershed helped in rising the groundwater level and increased the groundwater potential which helped in supplying more irrigation to different crops. Because of increased groundwater irrigation, the cropped area in the watershed increased by 308 ha in 3 years period. The productivity of different crops also increased. The yield of *kharif* and *rabi* paddy increased by 36.8 and 17.1% in 2014 as compared to the pre-treatment period *i.e.* 2011. The yield of other crops including vegetables also increased substantially. It is expected that if the sustainability of the system continues, then in about 10 year's period, groundwater may come up by about 3 m and productivity of crops may increase by 50% in the watershed. This will ultimately increase the livelihood status of the farmers in the watershed.

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