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# Artificial conservation measures on groundwater recharge, irrigation potential and productivity of crops of Bharkatia Watershed, Odisha

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## ABSTRACT

A study was undertaken in Bharkatia watershed in Athagarh Block of Cuttack District, Odisha during 2011-2014. The objective of the research work was to study the recharge of groundwater through different recharge structures like dug wells, tanks, recharge pit, tube wells, check dams etc., the resulting rise of ground water level and study the impact on increasing irrigation area, production and productivity of different crops in the watershed. Up to the year 2011, no conservation measures were taken up in the watershed. However, in 2011, twenty recharge dug wells, twenty recharge farm ponds, two recharge tube wells, 1120 recharge pits and one check dam were constructed in the watershed. Data on groundwater table rise, irrigation area and productivity of different crops throughout the study period of 4 years were collected and anlysed. 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 structures 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% 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.

**Key words:** Groundwater, *Kharif*, Monsoon, *Rabi*, Recharge, Summer, Production, Productivity, Watershed



## INTRODUCTION

Land and water are the two most vital natural resources Due to urbanization and industrialization, per capita availability of cultivated land in the country have declined from 0.48 ha in 1951; 0.20 ha in 1980 to 0.1 ha in 2010. Prime soil resources of the world are finite, and prone to degradation through misuse and mismanagement. Like soil, the availability of fresh water is declining day by day. With the projected population growth, urbanization and industrialization, the average per capita water availability may decline to about 1200 $m^3$ by 2050. As a result, the share of water for irrigation may decline to 70% in 2050 as compared to its 84% share being available now (Panigrahi, 2011).

Eastern India including the state of Odisha, is bestowed with ample rainfall resources with average annual rainfall of 1500 mm, 80% of which is received 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). Such intense storms give rise to high runoff and the consequent soil and nutrient losses. 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: in soil reservoir, in surface reservoir and in groundwater reservoir. Among these three, conservation in groundwater reservoir is the best option, as it does not require vast areas for water storage. Conservation of water in soil reservoir though is the cheapest method but the stored soil moisture cannot held it for a long 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.

Artificial recharge is the planned, man-made increase of groundwater levels, and is becoming increasingly relevant in India. In 2007, on the recommendations of the International Water Management Institute, the GoI allocated Rs 1800 crore to fund dug-well recharge projects in 100

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districts in seven states where water stored in hard-rock aquifers had been over-exploited.

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 (Mondal *et al.*, 2006; Goel *et al.*, 2007; Kumar and Kumar, 2015; Kumud *et al.*, 2016). Panda (2009) observed the water table level in wells in watershed areas with various soil and water conservation measures to rise by 3.9 m more as compared to the non watershed areas.

The objective of the present research work is to study groundwater recharge through different water conservation structures such as dug wells, tanks, recharge pit, tube wells, check dams etc. through water table rise and its impact on increasing irrigation area, production and productivity of different crops in the watershed.

## MATERIALS AND METHODS

The study was undertaken during 2011-2014 in Bharkatia watershed in Athagarh Block of Cuttack District, Odisha. The watershed is located 15 km away from the river Mahanadi. The project area is located at 20°31′20′′ to 20°34′45′′ N latitude and 85°17′05′′ to 85°50′55′′ E Longitude. The project area covering an area of 20 km$^2$ includes the villages: Jemadeipur, Kusupangi, Sarkoli, Korikol, Chabjaunri, Torada, Parbatia, Gurudijhatia, Kotar, Pithakhia, Ramchandrapur, Radhapriya, Balisasan, Bali, Sitarampur, Oranda, Chotiamba and Kaduanuagaon. The area gets an average annual rainfall of 1450 mm in 72 rainy days with 78% occurring in 4 rainy months from June to September. Rainfall distribution is very erratic and uneven. The maximum temperature in the area goes up to 46 °C in May and the minimum temperature goes down 8 °C in the month of December. Relative humidity ranges from 43 to 91%. The watershed is generally flat (fan shaped) with undulating topography. Physiographically the zone is located in the coastal belt and has an altitude ranging from 38 to 65 m above msl. The soil is mostly sandy loam to sandy clay loam of about 90 cm depth. Table 1 represents the various morphometric parameters related to the watershed.

### *Soil and Water Conservation Measures/Structures*

Recharge pits, Recharge ponds, Recharge dug wells, Renovation of medium irrigation (MI) tanks, Renovation of existing ponds, Check dams and Recharge tube wells were constructed in the watershed in consultation with the farmers and the Soil Conservation Department. Periodically the groundwater table position in various tube wells and dug wells were measured for three consecutive years i.e. 2012, 2013 and 2014 at various locations. Descriptions of different structural measures are as follows:

**Table 1.** Morphometric parameters of watershed

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

*Recharge Dug wells*

Twenty recharge dug wells were excavated to a depth of 9 m in sloping 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 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 wells are located in the villages Chhotiamba, Kaduanuagaon, Parbatia, Gurudijhatia, Oranda, Chabjaunri and Jemadeipur. 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 ponds of size 15 m x 10 m (bottom dimensions) and depth 2.5 m were excavated in the lateritic sloping open fields in the watershed. The recharge ponds were constructed near the dug wells. Initial depth of the pond (constructed in two compartments) in the lower compartment was 1 m and the depth of the upper compartment was 1.5 m (Fig. 1). Top dimensions of the ponds were 20 m x 15 m. It was observed that entire volume of water that enters the small ponds percolated down into the aquifer within a week, as the beds are totally lateritic. Fig. 1 shows the plan and cross section of the constructed recharge pond. Stone packing on upstream side of the pond was undertaken to avoid soil erosion. The length, breadth and height of stone packing were 15 m, 2.45 m and 0.3 m, respectively.

*Recharge Tube Wells*

In the watershed, two numbers of recharge tube well were constructed. The first was in the village Sitarampur and the second one in village Pithakhia. The depth of the tube wells were 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 = 6 m, width = 6 m and depth = 7 m. The pit was packed with alternate layers of sand and pebbles as shown in Fig. 2.

*Recharge Pit*

Recharge pits are constructed for recharging the shallow aquifer. Recharge pit may be circular, square or rectangular in cross section. If the pit is of trapezoidal shape, the side slopes should be steep enough to avoid silt deposition. In the present case

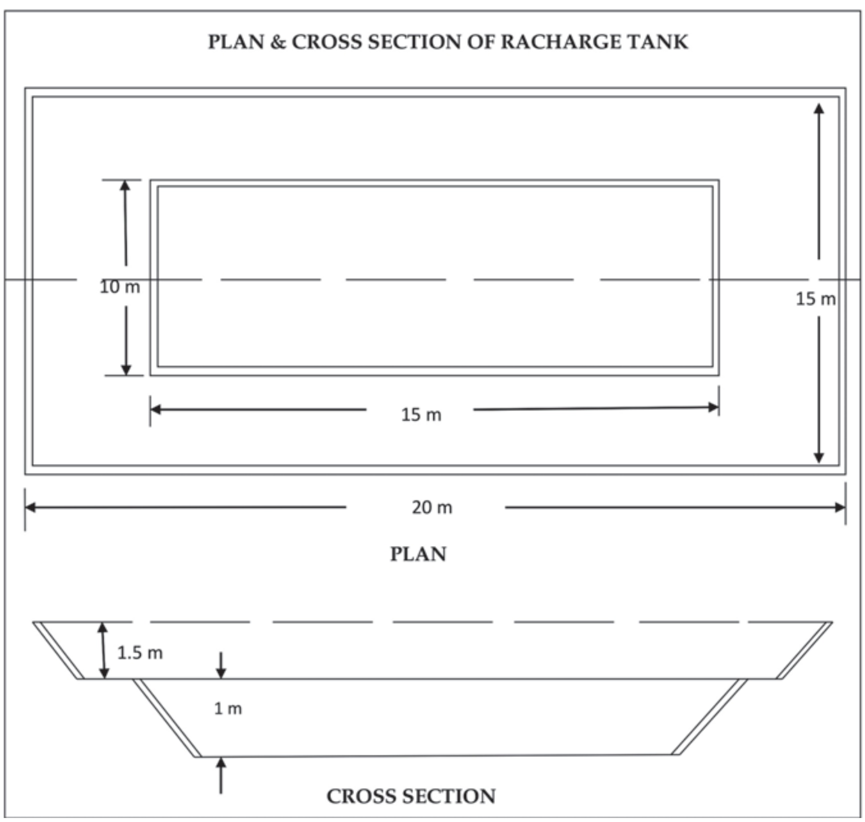


**Fig. 1.** Plan and cross section of recharge pond

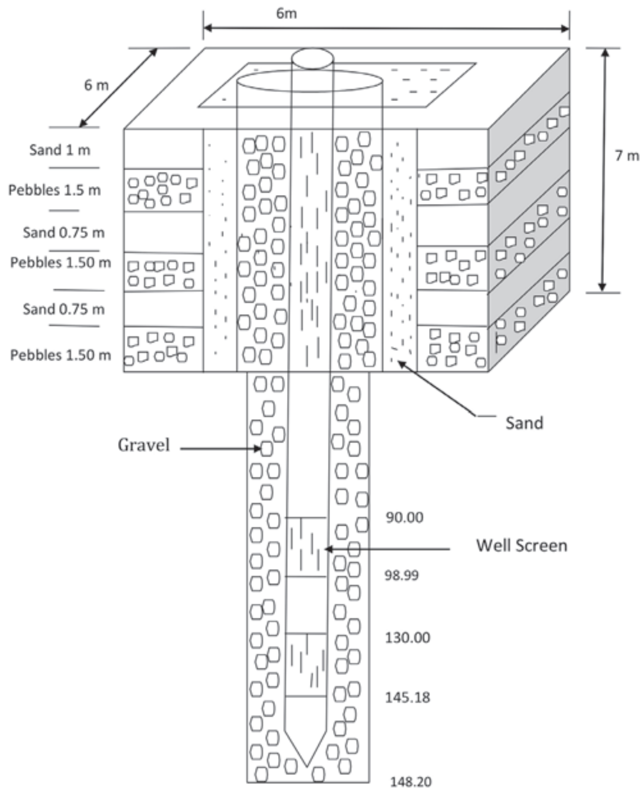


**Fig. 2.** Plan and cross section of recharge tube well

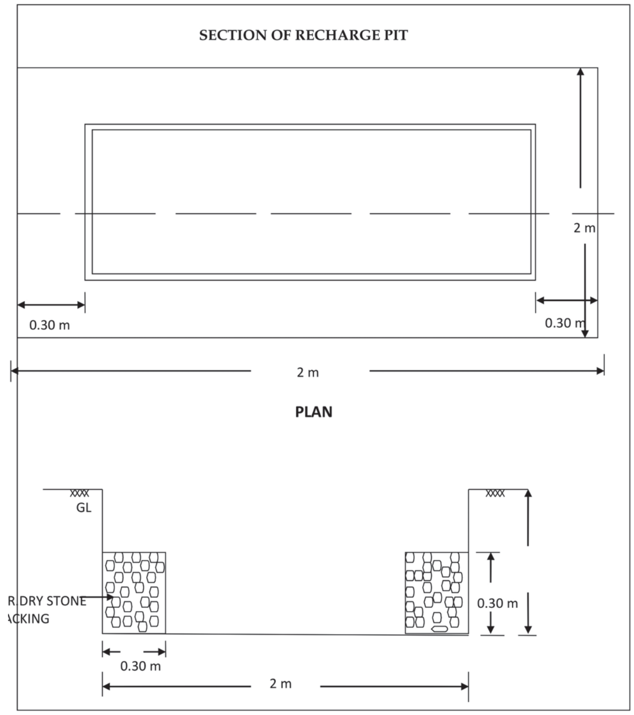


**Fig. 3.** Section of a recharge pit

the recharge pits were rectangular in shape. Recharge pits were excavated and filled with dry rubble stone on the upstream side. The length, breadth and height of the recharge pit were all equal to 2 m. The length, breadth and height for random rubble dry packing were 2 m, 2 m and 0.3 m, respectively and volume of random rubble dry packing upstream of recharge pit was 1.20 $m^3$. In the watershed, total 1120 numbers of recharge pits were constructed at different places. Fig. 3 shows the section view of recharge pit.

*Recharge through Check dam*

One check dam was constructed in the Barakatia Nala. The check dam arrested the flow of the nala 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. Fig. 4 shows the preparatory work for construction of check dam. Fig. 5 shows the check dam in the watershed.

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

**Fig. 4.** Preparatory work for construction of check dam

**Fig. 5.** Check dam for groundwater recharge

in the watershed in the pre-treatment period i.e. 2011 were also collected on daily basis. 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 the watershed. For this, representative locations were selected. In this study, the groundwater levels were measured in each week for three years (2012 to 2014) in 7

**Table 2.** Average depth of water level in dug well (below ground level, m) in different places in the watershed

| Location Week* | Chhotiamba | Kaduanuagaon | Parbatia | Gurudijhatia | Oranda | Chabjaunri | Jemadeipur | In whole watershed |
|---|---|---|---|---|---|---|---|---|
| 1-4 | 8.92 | 9.0 | 9.0 | 8.97 | 8.825 | 9.02 | 9.05 | 8.96 |
| 5-8 | 9.42 | 9.52 | 9.42 | 9.47 | 9.425 | 9.37 | 9.35 | 9.41 |
| 9-12 | 9.6 | 9.62 | 9.87 | 9.92 | 9.65 | 9.62 | 9.67 | 9.7 |
| 13-16 | 9.17 | 9.25 | 9.42 | 9.35 | 9.5 | 9.67 | 9.47 | 9.4 |
| 17-20 | 9.75 | 9.67 | 9.77 | 9.75 | 9.95 | 10.07 | 9.77 | 9.8 |
| 21-24 | 10.17 | 10.22 | 10.32 | 10.12 | 10.27 | 10.47 | 10.2 | 10.25 |
| 25-28 | 9.1 | 9.15 | 9.37 | 9.27 | 9.3 | 9.25 | 9.27 | 9.24 |
| 29-32 | 8.15 | 8.27 | 8.4 | 8.42 | 8.05 | 8 | 8.27 | 8.22 |
| 33-36 | 7.45 | 7.47 | 7.4 | 7.2 | 7.22 | 7.42 | 7.57 | 7.38 |
| 37-40 | 7.57 | 7.57 | 7.62 | 7.2 | 7.47 | 7.42 | 7.27 | 7.44 |
| 41-44 | 8.1 | 8.1 | 8.65 | 8.15 | 8.15 | 8.3 | 8.1 | 8.21 |
| 45-48 | 8.8 | 8.65 | 9.02 | 8.82 | 8.72 | 8.82 | 8.95 | 8.82 |
| 49-52 | 8.92 | 9.0 | 9.17 | 8.95 | 9.1 | 8.9 | 8.9 | 8.98 |

N.B. * Standard meteorological week which starts as week 1 from Jan. 1 to Jan. 7, week 2 from Jan. 8 to 14 etc.



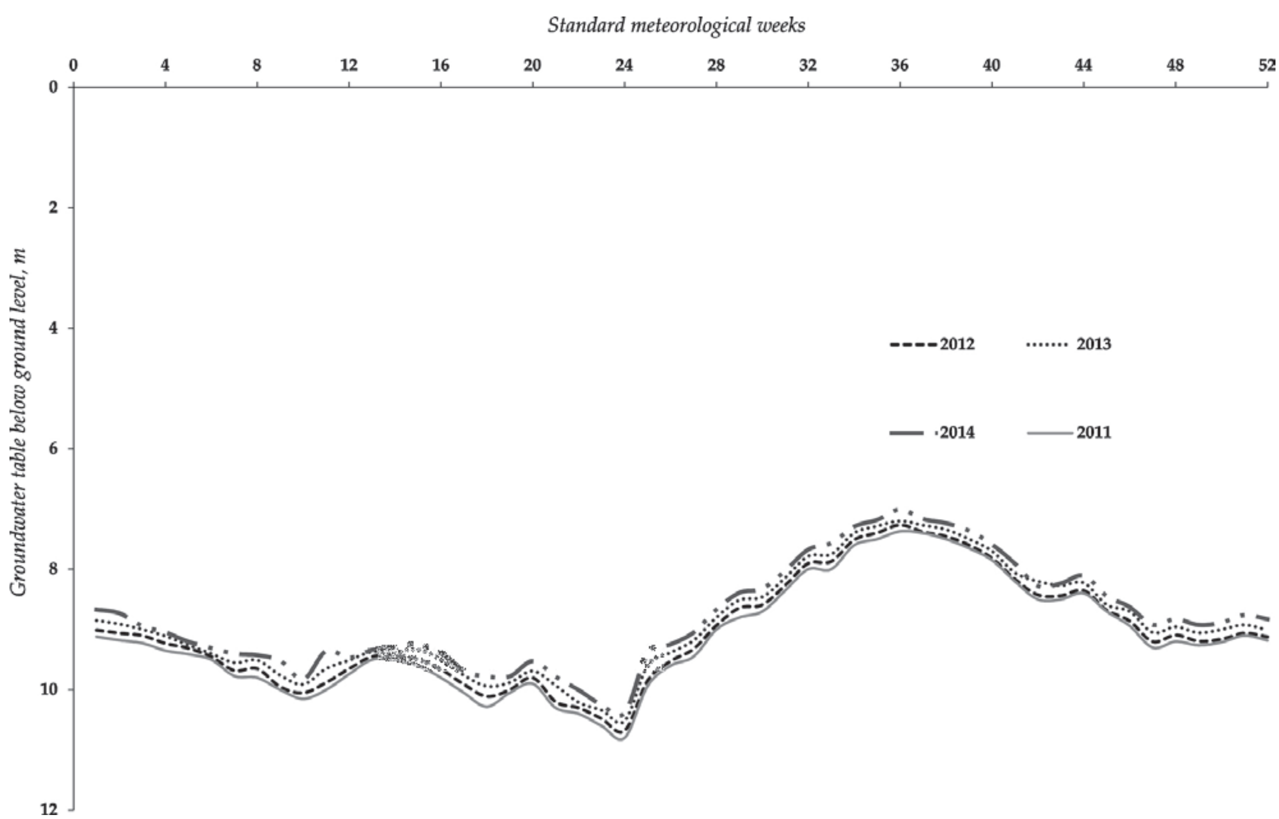


**Fig. 6.** Groundwater table position in the watershed in different years due to groundwater recharge

representative stations as mentioned in Table 2. The average groundwater table data (average of 2012, 2013 and 2014) of these stations are presented in Table 2. Groundwater table positions in the entire watershed for different years on weekly basis are shown in Fig. 6. Area coverage and productivity of crops grown in the entire watershed for various years are presented in Table 3.

## RESULTS AND DISCUSSION

### *Effect of Different Conservation Measures on Ground Water Recharge*

In this study the impact of different water conservation measures were studied on rise of ground water table. The construction of different conservation measures were completed by 2011. The groundwater table during pre-conservation

**Table 3.** Area (ha) coverage of different crops in the watershed in different years

| Crops | Area covered, ha | | | | Productivity of crops, q/ha | | | |
|---|---|---|---|---|---|---|---|---|
| | 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 |



period i.e. 2011 was measured on daily basis and the average weekly values were calculated. The water table below ground level varied from 7.37 m to 10.8 m. The water table was shallow during the monsoon because of higher recharge on account of rainfall. Water table positions were found to be deeper during the pre-monsoon period (Fig. 6) due to scanty rainfall. Further, withdrawal of groundwater for irrigation during the post monsoon period and for domestic use throughout the year causes water table to decline. The water conservation and recharge measures generally caused a rise in water table in the watershed.

Further, the groundwater table rose gradually over the years in all places in the watershed, as may be seen from Fig. 6.

*Effect of Ground Water Recharge on Enhancing Irrigation Potential and Productivity*

The groundwater recharge helped in augmenting 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 of different crops also increased. In addition to groundwater recharge, several structures were directly used as surface water storage reservoir which helped in facilitating direct flow irrigation to the crop fields. For example, construction of a check dam in Barakatia Nala 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 groundwater 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 tubewells 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 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 3, 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 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 (Table 3).

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.

## CONCLUSION

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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