Enhancing Agricultural Water Efficiency through Conservation and Groundwater Management in Akola District, Vidarbha Region

ABSTRACT

Rainfall is the single input in the Dryland agriculture for fulfilling the crop water requirement. Based on the watershed approach it is possible to make a quantitative evaluation of water resources and their change under the influence of man's activities. Knowledge of the water availability assists the prediction of the consequences of artificial changes in the regime of streams, lakes, and ground-water basins. An understanding of the water balance is also extremely important for providing protective irrigations. To explore the impact of water conservation configurations on groundwater establishment at Kajaleshwar micro watershed of Tq. Barshitakli, Distt. Akola in Vidarbha region of Maharashtra the study was completed under Agri- Consortia Research Platform on Water, All India Coordinated Research Project for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Drainage (Nala), widening and deepening and repairs of established rainwater harvesting and storage structures were ensured for impact evaluation. Groundwater data was collected for 51 observation wells in the vicinity of 10 cement nala bunds (CNBs) for analysis of rainwater harvesting influence on groundwater regime in micro watershed area. During 2017 (36 wells) average depth of water level was 4.07 m and during 2019 (36+15= 51wells) it was increased and found to be 2.81m. Well water levels were observed to be increased in 2019 as compared to 2017. The yield of soybean crop with one protective irrigation at pod filling stage during Kharif season was (1483 kg/ha) increased by 26 % as compared to without irrigation (1180 kg/ha).During Rabi season on an average the yield of Chickpea crop with two protective irrigations at initial and pod filling stage was (1773 kg/ha) increased by 38.73% as compared to without irrigation (1278 kg/ha). In the event of a protective irrigation, the yield of Chickpea was (1539kg/ha) increased by 20.42 % as compared to without irrigation (1278 kg/ha). Thus, it can be inferred that if conservation measures are implemented technically then yield sustainability in agriculture can be achieved. Due to acceptance of comparable types of rainwater harvesting and non-natural recharge structures, groundwater possessions will be augmented. This will support in expansion of integrated farming systems which eventually will be helpful in increasing the yields and water efficiency of the area where such works are being accepted.

Keywords: Conservation, groundwater level, resource, yield.

1. INTRODUCTION

Groundwater resources assessment in a variety of areas of the country shows numerous problems. A broad spatial-temporal transformation in the amount of groundwater resources permits orderly exploration to place most exceptional open wells and bore well's location for tapping this substantial natural resource in earth surface. "The water conditions for agriculture, municipal and industries are accountable for increase in use than the annual groundwater recharge and it was detected that throughout last decades every country will be facing scarce rainfall, thus day by day declines groundwater table. Continuous utilization from groundwater reservoir in surplus of replenishable groundwater recharge may obvious effect in decreasing of groundwater table, agricultural production and human creature" (Magesh et al., 2011; Thomas et al., 2012; Collin, M.L. et al. 2001; Moukana, J.A. 2008). "Groundwater in basaltic and lateritic formations of Deccan traps occurs under water table and semi-confined conditions. The transmissivity values of these formations range between 100 and 1100 m 2 /day and the specific capacity varies from 0.22 to 1.2 m 3 /m draw down. Water has become a scarce resource here not only due to deficient rainfall but also due to over exploitation of groundwater". (Ramamohan Reddy et al., 2013). "Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use/land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare" (Patode et al., 2017). "Hence, the accurate delineation and sustainable management of groundwater are essential to meet growing demands, ensuring its availability not only for the present generation but also for future ones" [Goswami et al., 2022]. "For the region like Vidarbha in Maharashtra State of India, where precipitation is very uncertain and nearly 89% of the cultivated area is under rainfed farming there is required for water resources planning and development in the micro-watershed area". (Dongardive et al., 2018). "Normally, in these areas, dry spells are experienced during July, August and September, which coincides with the vegetative or reproductive stages of major rainfed crops, and results in the reduction of crop yield drastically" (Rejani R. et al., 2022). "Since rainwater collection and its judicious use is the need of the day, everybody should adopt the technical things that are important for proper implementation and construction of water storage structures" (Sharma *et al.*, 2010).

"GIS can be used for storing and analysis of hydro-geological data as well as their spatial locations in a relational database. As a result, nowadays, remote sensing and GIS techniques are widely used for analysis of groundwater regime" (Hong Wang et al. 2014). "Groundwater resources assessment in many areas of the Vidarbha region is imperious for the developmental strategies of integrated watershed development and management. The widespread spatial-temporal changes in the occurrence of groundwater reserves enable systematic exploration to discover the best sites for utilizing this valued resource. Based on the pre and post project implementation data regarding, water storage, reuse of stored water, yield economics, increase in groundwater levels, availability of water in the surrounding wells, cropping pattern it can be recommended to undertake the deepening and widening of existing drainage line network along with construction or repairing of the permanent structure and reuse of harvested water through micro-irrigation in the entire Vidarbha region of Maharashtra for sustainable crop production and water resources development" (Patode et al., 2016). "The success of dryland farming mainly depends on the evenly distributed rainfall during crop growing period. The root zone soil moisture is utilized for transpiration, when the rainfall becomes insufficient to meet the potential needs to transpiration. This causes depletion in soil moisture storage and a situation which may be designated as agricultural drought" (Patode et al, 2017). "Researchers have recommended soil and water conservation measures like in case of 'Edulabad cheruvu' watershed depending upon the land attributes. Check dams are proposed on lower order streams to control water velocity and for storage. Construction of percolation tanks at suitable distances are suggested for supplemental irrigation" (Ramamohan Reddy et al., 2013). Taking into consideration the above facts, surface and groundwater management assessment and its use for agriculture is of prime importance.

2. MATERIAL AND METHODS

2.1 Study Area

The Kajaleshwar-Warkhed micro watershed is situated amongst 20°13′59" N latitude and 77°13'23'' E longitude at MSL elevation of 337 m and is having an average annual rainfall of 795mm. It is positioned at about 35kms from Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.). It is mostly an agricultural watershed with one shared big drain passing through the fields.

2.2 Methodology

Built on technical data of the existing drainage line, the work of broadening and excavating was done and the existing enduring rainwater harvesting structures (CNBs) were revamped. The recipients/ farmers in the locality of this drainage line were chosen for crop planning and usages of harvested water through micro-irrigation system were prearranged. The wells positioned adjacent to drains were surveyed and supervised for groundwater levels. The groundwater level variations in the watershed were studied. The variance in groundwater table was intended by comparation the groundwater table of both seasons noted with the help of GPS and water level indicator. The fluctuations in the water levels before and after implementation of the rainwater harvesting structure were observed.

2.2.1 GIS Data

The groundwater level data was converted in the Arc GIS domain for the influence of rainwater harvesting structure on the groundwater depth and crop production at the neighboring watershed area. The groundwater level variation maps were produced with the help of inverse distance weighted interpolation method (IDW) in the GIS setting. These groundwater maps could be beneficial for watershed modelling, future prediction of water levels and knowing impact changes in the watershed area.

2.2.2 Monitoring of wells

Wells were monitored for estimation of storage and groundwater levels respectively. To study the influence of cement nala bund on water level in wells, 51 observation wells were selected in the zone of influence i.e. at nearby distance from the CNB in the watershed and water levels in the wells were observed. The water levels of each well were recorded with the help of a water level indicator. One of the most common measurements in groundwater investigations is the determination of the depth to groundwater (Taley et al., 2016). The water levels in these wells were monitored periodically. Based on these observations groundwater level maps were prepared by using monthly data of the groundwater levels.

2.2.3 Check dams

Check dams are small structures built across gentle-stream slopes to capture runoff and boost groundwater recharge. They are effective in both hard rock and alluvial areas, with heights usually under 2 meters. Proper site selection and placement of water cushions prevent erosion. These dams/ cement nala bunds work best on lower-order streams with medium slopes and can manage catchment areas of about 25 hectares. Key construction factors include slope, soil cover and rock type, with nearby irrigation wells further aiding water management (Mondal et al., 2024).

3. RESULTS AND DISCUSSION

3.1 Groundwater Level Analysis

Groundwater level facts were composed from 51 observation wells around 10 CNBs for study of rainwater harvesting influence on groundwater regime in watershed area. It was detected that; the well water levels were observed to be increased in 2018 (Fig. 2) as compared to 2017 (Fig. 1) for maximum wells however in some wells the water levels in 2017 were more. During 2018 (51 wells) average depth of water level (Fig. 3) was 3.73 m and during 2019 (51wells) average depth of water level (Fig. 4) was 2.81 (Table 1). The groundwater level fluctuations in 2019 as related to 2018 were observed. The well water levels were found to be increased in 2019 as compared to 2018 for maximum wells. The average depth in the wells in 2019 was increased by 0.92m with respect to the levels in 2018 and by 3.44m as compared to the well levels during 2016 (Table 2 & Fig.3). It supports that the widening and deepening of drain (Nala) accommodate more water as compared to earlier situation. Additionally, the CNB's efforts to store rainwater for longer periods and ultimately led to the increase in the ground water recharge and this reflects into increased ground water levels.

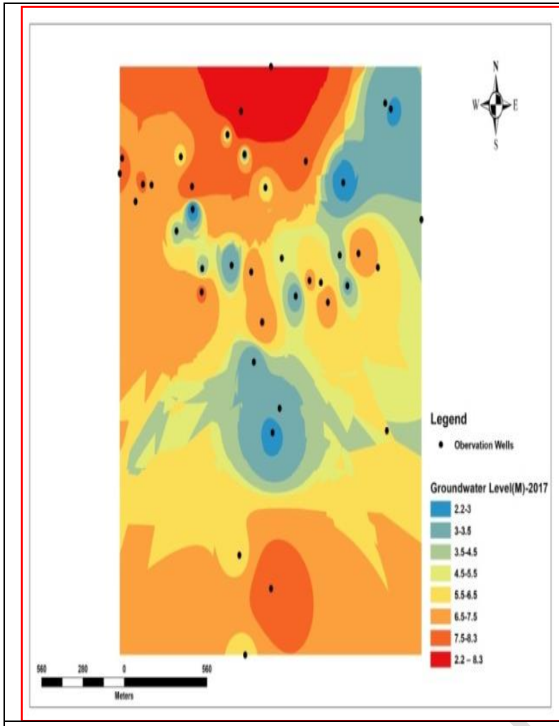

Fig1. Map of average depth of groundwater levels of wells during 2017

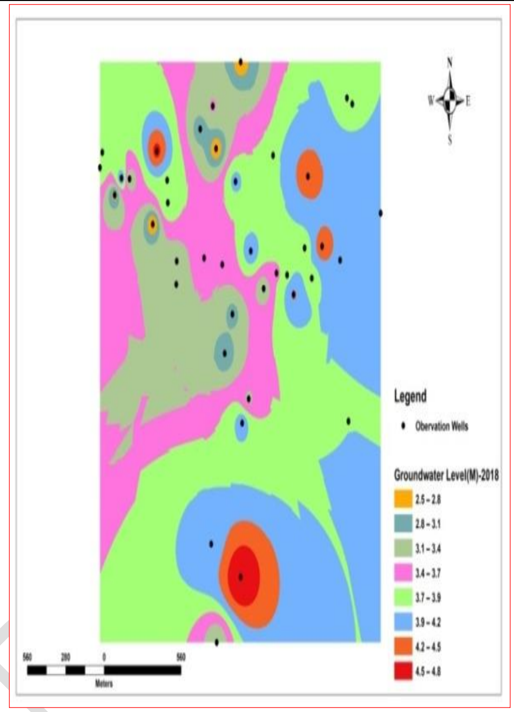

Fig 2. Map of depth of groundwater levels of wells during 2018

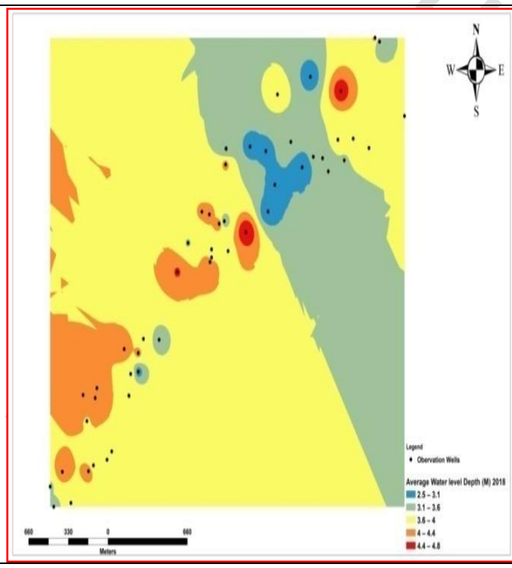

Fig 3. Map of average depth of water levels (m) during 2018

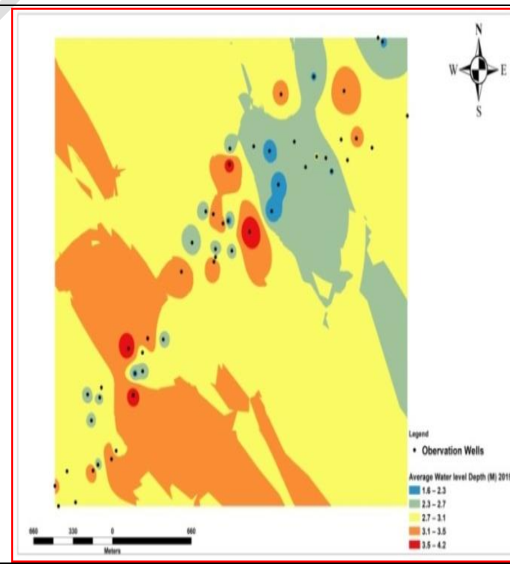

Fig 4. Map of average depth of water levels (m) during 2019

Table 1. Yearly average depths of water levels in the wells (m)

Average Depth of water levels in wells (m) during 2016	Average Depth of water levels in wells (m) during 2017	Average Depth of water levels in wells (m) during 2018	Average Depth of water levels in wells (m) during 2019
6.25	4.07	3.73	2.81

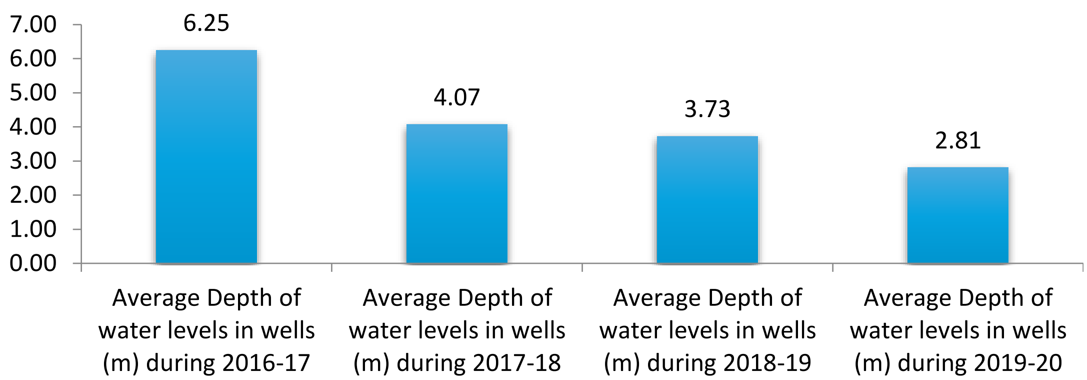

Fig 5. Yearly average depth of water levels in the wells (m)

The year wise increase in average well water depths as compared to the project implementation year are given in Table 2 and it was found that the well water levels were increased by 2.18m, 2.52m and 3.44m respectively during 2017, 2018 and 2019 over the year 2016.

Table 2. Year wise increase in average water levels in the wells over 2016-17 (initial year)

Increase over the year 2016		
During year 2017	**During year 2018**	**During year 2019**
2.18m	2.52m	3.44m

3.2 Uses of Harvested Water

3.2.1 Yield during Kharif season

The water was available during Kharif season for irrigating the soybean crop. The farmers in the vicinity of CNB's have the availability of water in their wells as well as in the drain (Nala). The farmers who have provided protective and without protective irrigation were surveyed regarding Soybean yield. Average year wise yield data of soybean was given Table 3. On an average, the yield of soybean crop with a protective irrigation at pod filling stage during Kharif season was (1483 kg/ha) increased by 26 % as compared to without irrigation (1180 kg/ha).

Table 3. Year wise average yield of soybean crop during Kharif season

Year	Avg. Yield (without irrigation, kg/ha)	Avg. Yield (one protective irrigation, kg/ha)	% Increase in yield with one protective irrigation over without irrigation
2016	893	1187	33.00
2017	1110	1371	23.50
2018	1305	1512	16.00
2020	1412	1860	31.73
Average yield	**1180**	**1483**	**25.68**

Note- Due to excess rainfall during **2019**, protective irrigation was not required in *Kharif* season.

3.2.2 Yield during Rabi season

Due to the availability of water during Rabi season, farmers could provide protective irrigations to their crops mainly Chickpea. Year wise yield data of chickpea was collected from the farmers and average yield data of Chickpea was given in Table 4. During Rabi season, the yield of chickpea crop with two protective irrigations at initial and pod filling stage was (1773 kg/ha) found to increase by 38.73% as compared to without irrigation (1278 kg/ha). In case of protective irrigation, the yield was (1539kg/ha) observed to be increased by 20.42 % as compared to without irrigation (1278 kg/ha).

Table 4. Year wise average yield of chickpea during rabi season

Year	Avg. Yield (without irrigation, kg/ha)	Avg. Yield (one protective irrigation, kg/ha)	Avg. Yield (two protective irrigation, kg/ha)	% Increase in yield with one protective irrigation over without irrigation	% Increase in yield with two protective irrigations over without irrigation
2016	1080	1193	1425	10.46	31.94
2017	1024	1240	1333	21.09	30.18
2018	1726	2018	2242	16.92	29.90
2019	1277	1654	1941	29.52	52.00
2020	1285	1589	1925	23.66	49.81
Av. Yield	**1278**	**1539**	**1773**	**20.42**	**38.73**

4. CONCLUSION

The average groundwater levels in the 51 wells during the year 2019 increased by 3.44m as compared to the groundwater levels of the year 2016. This is owing to the storing of rainwater in the broadened and excavated nala for retentive duration. It was likewise probable to apply the recharged water for protective irrigations to diverse crops. Due to acceptance of comparable types of rainwater harvesting and non-natural recharge structures, groundwater possessions will be augmented. This will support in expansion of integrated farming systems which eventually will be helpful in increasing the yields and water efficiency of the area where such works are being accepted in the Vidarbha region and other parts of the country.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare. All co-authors agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies are used.

REFERENCES

Collin, M.L. and Melloul, A.J. (2001). Combined land-use and environmental factors for sustainable groundwater management. Urban Water, vol. 3, pp. 229–237.

Dongardive, M. B., Patode, R. S., Nagdeve, M. B., Gabhane, V. V., & Pande, C. B. (2018). Water resources planning for the micro watersheds using geospatial techniques, International Journal of Chemical Studies, 6(5), 2950-2955.

Goswami T, Ghosal S. (2022). Understanding the suitability of two MCDM techniques in mapping the groundwater potential zones of semi-arid Bankura District in eastern India. Groundw. Sustain. Dev, 17:100727.

Gustafsson, P. (1993). High resolution satellite imagery and GIS as a dynamic tool in groundwater exploration in a semi-arid area, Proceedings of the IAHS conference on Journal of Spatial Hydrology of Hydrology and Water Resources Management held in Vienna, Austria, on April 19-22 1993, pp. 93-100.

Hong Wang, Jianen Gao, Xinghua Li, Hongjie Wang and Yuanxing Zhang (2014). Effects of Soil and Water Conservation Measures on Groundwater Levels and Recharge Water 2014, 6, pp. 3783-3806.

Mondal, Sourav, Patode R. S., Mhaske, A. R., Gabhane, V. V., Tupe, A. R. and Anita Chorey. (2024). "Sustainable Water Resource Planning for Alanda Micro Watershed Using Geospatial Techniques". Asian Research Journal of Agriculture 17(4):260-67.

Moukana, J.A.; Koike, K. (2008). Geostatistical model for correlating declining groundwater levels with changes in land cover detected from analyses of satellite images, Computer Geosciences, 34, 1527–1540.

N.S. Magesh, N. Chandrasekar, J.P. Soundranayagam (2011). Morphometric evaluation of Papanasam and Manimuthar watersheds, parts of Western Ghats, Tirunelveli district, Tamil Nadu India: a GIS approach, Environmental Earth Science, 64 2011, pp. 373–381.

Patode, R. S., Nagdeve, M. B., & Pande, C. B. (2016). Groundwater level monitoring of Kajaleshwar-Warkhed watershed Tq. Bashitakli Distt. Akola. Advances in Life Sciences, 5(24), 11207-11210.

Patode, R. S., Nagdeve, M. B., Ganvir, M. M., & Gabhane, V. V. (2017). Evaluation of in-situ moisture conservation practices for sustainable productivity of major crops in Vidarbha region. International Journal of Current Microbiology and Applied Sciences, 6(10), 261-268.

Patode, R. S., Nagdeve, M. B., Pande, C. B., & Moharir, K. N. (2017). Land use and land cover changes in Devdari watershed. Trends in Biosciences, 10(8), 1622-1625.

Ramamohan Reddy, K., & Patode, R. S. (2013). Assessment of groundwater quality: A case study of Kondapur mandal, Medak district, Andhra Pradesh. Current World Environment, 8(2), 267-273.

Ramamohan Reddy, K., Murthy, R. S., & Patode, R. S. (2013). Thematic integration approach for watershed and land management. Indian Journal of Science and Technology, 6(10), 1-6.

Rejani, R., Rao, K.V., Reddy K. Sammi, Usharani, B., Chary, G.R., Gopinath, K.A., Patode, R.S. and Osman, M. (2022). Potential sites for different *in-situ* moisture conservation measures in Western Vidarbha zone of Maharashtra using geospatial techniques. *Indian Journal of Soil Conservation* 50(2): 120-127.

Sharma, B.R., Rao, K.V., Vittal, K.P.R., Ramakrishna,Y.S. and Amarasinghe, U. (2010). Estimating the potential of rainfed agriculture in India, Prospects for water productivity improvements, Agricultural water Management 97:23-30.

Taley S.M., Kale M.U., Jadhav K.A. and Ubarhande V.P. (2016). Hydro morphometric study of Akola district using Remote sensing and GIS,; Booklet/Dr.PDKV/Pub/447:69-80.