Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
https://www.phytojournal.com
JPP 2023; 12(5): 147-156
Received: 23-07-2023
Accepted: 27-08-2023

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Impact assessment of watershed approach (Change detection in water bodies' area and LULC, NDVI, NDMI) for reducing vulnerability of drinking water & availability of water for agriculture of Dahegaon Cluster watershed in Gangapur block of Aurangabad District-Maharashtra

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DOI: https://doi.org/10.22271/phyto.2023.v12.i5b.14723

Abstract
Water conservation is very vital in drought prone areas for drinking water security in India. Severe water scarcity of drinking water was being faced for 6 to 9 months in by 60% of villages in the Dahegaon watershed in year 2018 due to depletion in ground water level. The land degradation over the years resulted in silted tanks, reduced storage capacities and potential of recharge and observed that narrowed down of natural drainage. The crop productivity and area under cultivation was less due to unavailability of water for protective irrigation. With an aim to conserve water to improve drinking water availability during water scarce period (Jan-June), various measures implemented 6068 ha watershed to reduce water stress and build capacities for sustainable use of resources. It included rejuvenating the streams, tanks, soil conservation treatments, promotion of water use efficient technologies and build capacities of community to manage natural resources.

There is a reduction of 82.92% in the requirement of tankers over the baseline year 2017 while dry spell analysis shows that despite 58 days of dry spell in year 2021, tankers were not required. The comparative analysis of well water levels (May month) below ground level (bgl) in 96 observation wells showed that there is a change of 10.38% (2.7m) in maximum water level bgl, 5.26% in minimum bgl water levels and 13.79% (1.79m) in average bgl water levels. The area under agriculture is also increased in summer season under crop land 29.03 % year 2021 against Base line 12.50% in year 2017and under (plantation) horticulture crops 9.90 % against base line 2.14% respectively. The area under water bodies in March season also shows increase 124 % against base line year2017. The NDVI & NDMI mean value results show positive change over the baseline 0.34 from 0.23 and 0.02 from -0.00 respectively. The overall water conservation approach found effective to minimize dependency on tanker water supply for drinking and also increased area under agriculture and horticulture. The approach is replicable in similar drought prone areas to resolve water availability problems. Further study to understand the impact on agriculture and drinking water in drought years is essential.

Keywords: Water conservation, drinking water, well water levels, agriculture, dry spells, NDVI, NDMI, and LULC

Introduction
India is predominantly a rural based agrarian country. Agriculture and allied sectors such as horticulture, livestock, forestry and fisheries together contribute 17.8% of the country's Gross Value Added (GVA) for the year 2019-20, (Economic Survey, 2020-21) and provides employment for more than 50% of the nation's workforce. Thus, it becomes imperative that for the economy of the country to thrive and remain healthy, agriculture must be duly taken care. It also assumes prime importance that since 53% of net sown area in the country is rain fed, all efforts need to be taken to address the concerns of rain fed areas. Even after realizing the full irrigation potential, about 50% of the cultivated area in the country will remain rain fed. Despite India ranking first in rain fed agriculture globally in terms of area and production, productivity is among the lowest in the world. Rain fed agriculture is complex and diverse which is highly dependent on rainfall.

Integrated Watershed based approach has become most accepted method for sustainable development of rain fed areas world over.

The watershed is a system-based approach that facilitates the holistic development of agriculture and allied activities in the proposed watershed area. It seeks to improve and develop all types of lands that fall in a particular watershed. The stress is on improvement of waste land, run off reduction, water conservation and protective irrigation mechanism.

Watershed programs are expected to result in increase of bio-mass, agricultural productivity, increased soil moisture and ground water recharge. All these positively influence vegetative cover. Watershed programs also change the land use and land cover. The changes in land use/land cover are considered as a measure to analyse the impact of the watershed program. Changes in land use/land cover also plays an important role in the global environment change process (Patel *et al*., 2013) [6]. The Normalized Difference Vegetation Index (NDVI) provides a robust index of productivity as it measures chlorophyll content on scale from -1 to +1 and this index has been used extensively for land cover mapping. This method has been used extensively across the world. The NDVI have deduced values corresponding to dense vegetation, open vegetation, degraded vegetation, fallow land and water bodies.

Objective: The aim of the study was to know the changes in LULC and NDVI/NDMI & water body area due to implementation of watershed various interventions from Dec 2017 to Nov 2021 using remote sensing and GIS.

The satellite remote sensing provides an excellent source of data from which updated land use/land cover changes can be extracted in an efficient way. This is the most effective method which has been adapted by many researchers, (Thakkar, *et al*., 2017) [7], (Bhandari, *et al*., 2012) [5], (Nagaveni, *et al*., 2017) [8]. RS and GIS has been proved as an effective tool to monitor and manage the natural resources and assess the impact and watershed during pre and post development. In watershed several natural resources (soil and water conservation) and Production Systems Improvement (PSI) activities were taken up during the project period. These programs are likely to increase the area under cultivation, decrease area in wasteland, conversion of annual crop land to horticulture, change in water body area.

Study Area

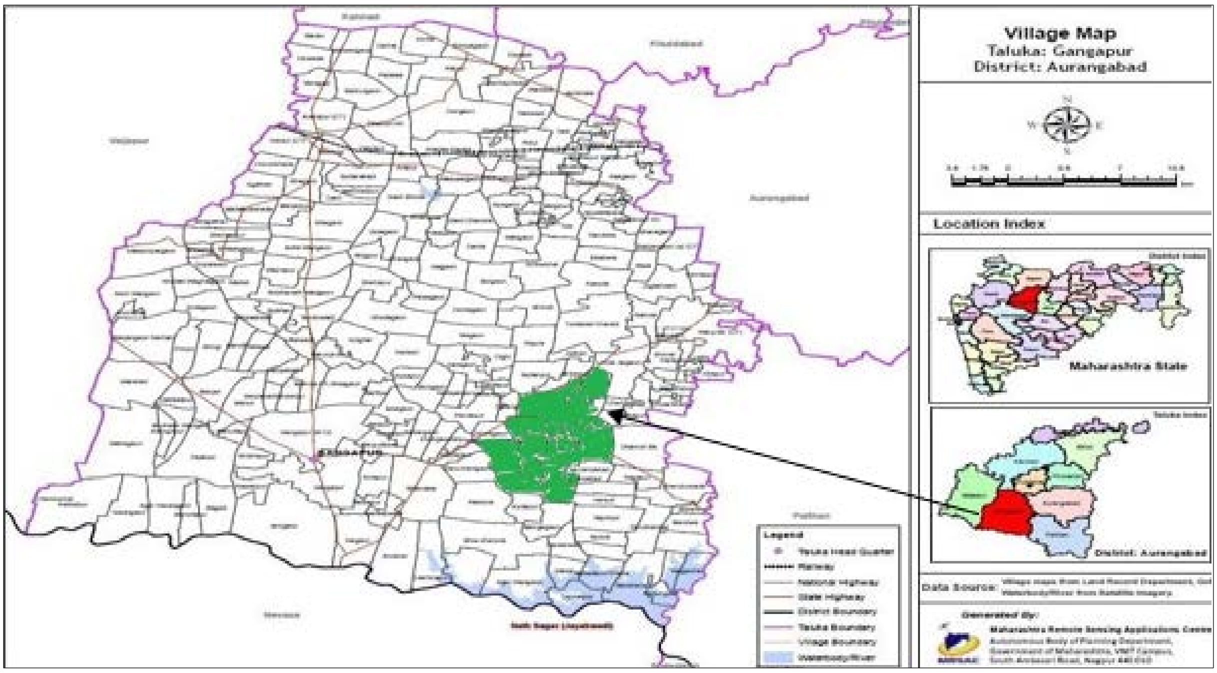


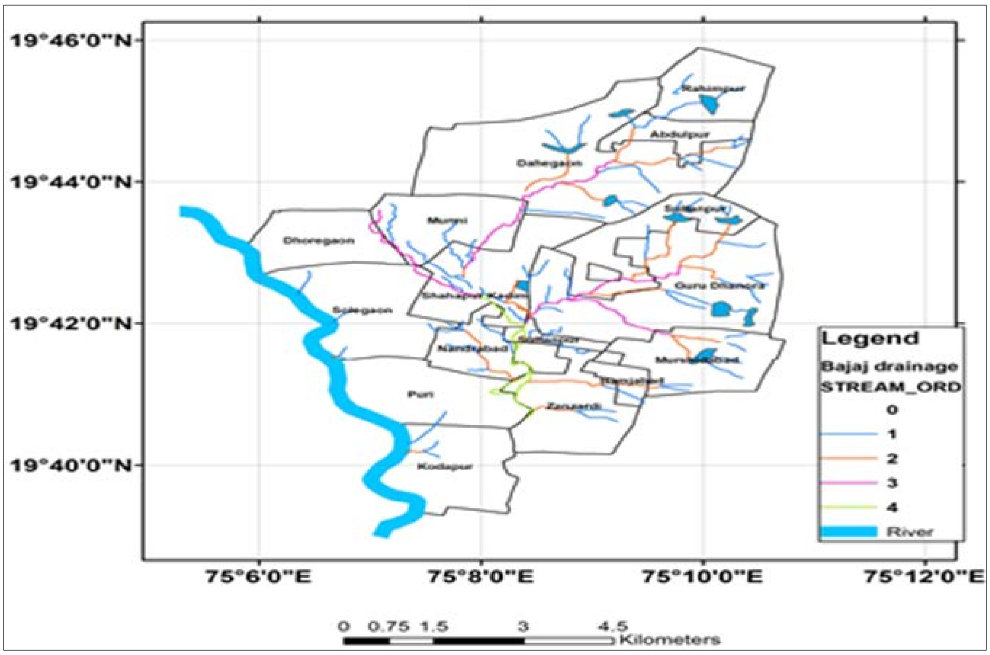
Fig 1: Study Area

Aurangabad is the district headquarters situated in upper Godavari basin and in the extreme northwest of Marathwada region. It lies between 19°15' and 20 °40' N and 74°37' and 76°52'E. Major part of the district falls in Godavari basin with a small area in north eastern parts in Tapi Basin. Depending on the drainage and geomorphology, the district has been divided into 52 watersheds. Ground water has special significance for agricultural development in the district as 71% of irrigation is ground water based.

The climate of the district is characterized by a hot summer and a general dryness throughout the year. December is the coldest month with the mean maximum temperature of 28.9 °C, while the mean minimum temperature is 10.3 °C. May is the hottest month with the mean maximum temperature of 39.8 °C and the mean minimum temperature of 24.6 °C. The Normal rainfall of the district for the period 1998 to 2022 is 581.7 mm.

Under the Corporate Social Responsibility activities of Bajaj Ltd, the Bajaj Water conservation Project (BWCP) is under implementation in 14 drought prone villages in Gangapur block of Aurangabad district. BISLD is working from Dec-2017 onwards with Bajaj Auto Ltd. to support the overall aim of BWCP to cover an area of 59,830 ha (6068 ha through BISLD project) addressing the need for water conservation and increasing the water availability in the project areas. The major highlights of the project are its unique model of community participation through means of cash and kind both, use of satellite images and remote sensing for thematic mapping, Government participation has been ensured through convergence with the Department of Agriculture, (Jalyukth Shivar) in their various ongoing schemes in the project region. This project tenure is four year and as on date 14 villages have become tanker free (earlier they were dependent on water tanker 6 to 9 month supply for drinking water) and total 3685 TCM water storage capacity has been created through various interventions under Water Resource Development. The overall objective is improving lives of people through integrated approach for water and livelihood enhancement in the selected villages.

The present study pertains to Dahegaon cluster of 14 villages Watershed which is part of Gangapur block of Aurangabad District. The watershed is located between North Latitude 19°46'0" and 19°40’0” and Eastern Longitude 75°6'0" and 75°12'0". It is at a distance of 40 kms from the district headquarters and 20 Km block Block headquarters. The total geographical area of the watershed 6068 ha. And net treatable area is 5310 ha. The average annual rainfall in the cluster Watershed area is 535 mm.



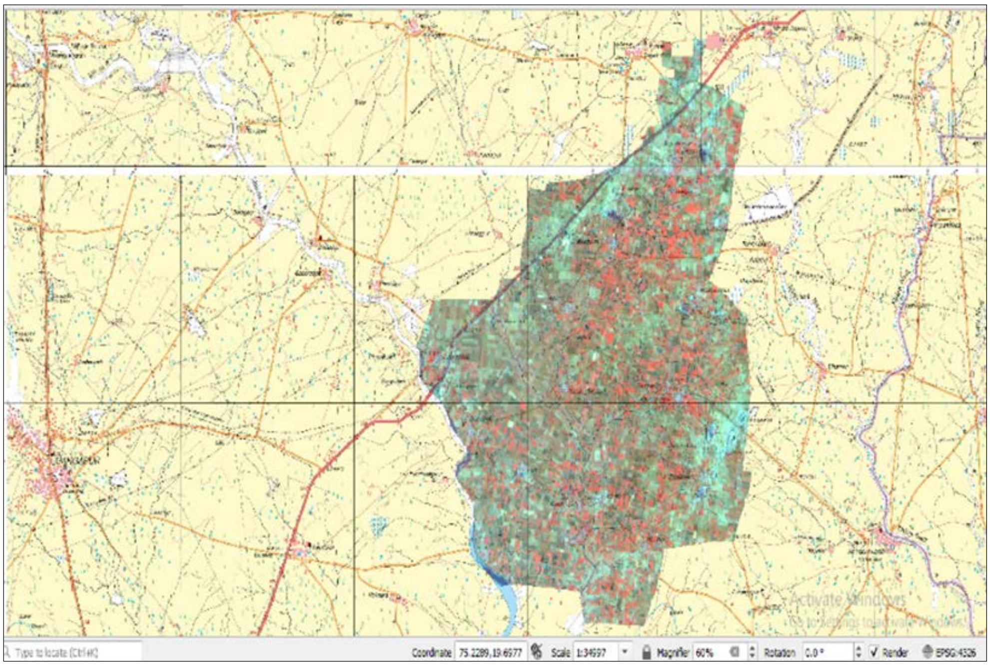


Fig 2: Topographical map

Dahegaon cluster watershed area is falling in Survey of India topographical map 47 M/1 and 47 M/2. The project area consists of watersheds with streams joining Shivana River near ‘Nathsagar dam’ at Paithan in Godavari basin. The WSD comprises relatively low-lying area.

Rainfall: Gangapur, Taluka always face scarcity conditions, as the rainfall is not dependable. The data analysed for 19 years (almost two decades) shows that out of 19 years, 14 years’ precipitation is less than the normal rain. The mean rainfall is 569.40mm and average rainfall for 10 years is 535 mm days are 40. The lowest rain received in year 2003 is 203.30mm while highest is 918.20mm in year 2006.The data also shows that the rainfall is less received than average for consecutive six years. Scarcity of water is observed in the dry period because there is scanty rainfall, uncertainty and unevenness of rainfall. About 80% of the rainfall is concentrated during south-west monsoon from June to September.

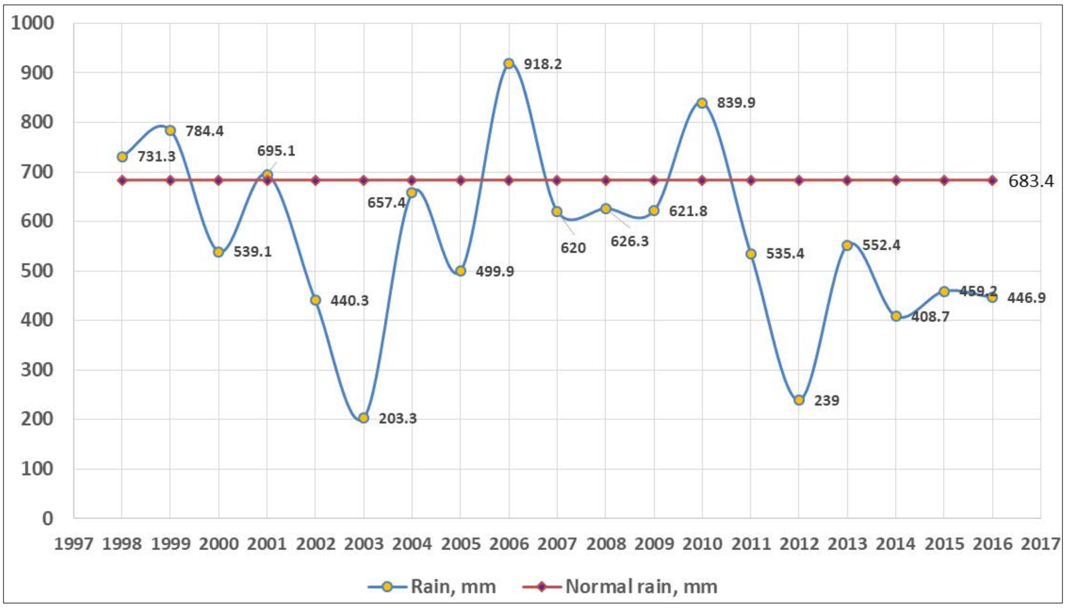


Fig 3: Annual rainfall, mm

Methodology: To know the changes in Water bodies and LULC,NDVI,NDMI due to implementation of watershed program, remote sensing technique is adopted following pre and post project period data analysis by using Sentinel 2A (10 m spatial resolution) satellite imageries for the years 2017 (Pre March 2017) to (Post – March 2022). The methodology adopted is given below: Satellite imageries for pre and post project period are download for the year 2017 to 2022.Topographical sheets are download from Survey of India (SOI) for reference maps.

To measure the changes in vegetation cover supervised classification (maximum likelihood classification) was conducted. Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) was carried out to identify the difference between NDVI & NDMI values for the years 2017 to 2022 respectively.

Results are studied and analysed for assessing the changes occurred due to implementation of the watershed programme.

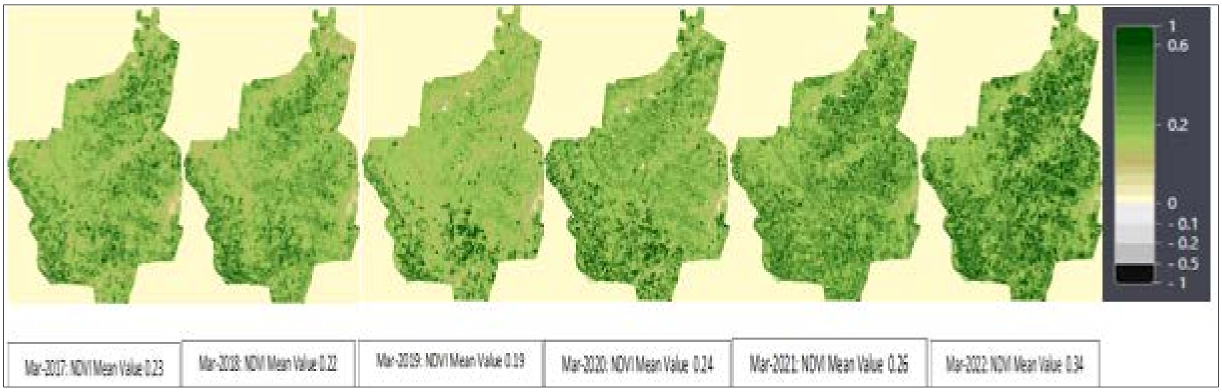


Fig 4: NDVI is calculated in accordance with the formula= NDVI = (B8-B4) / (B8+B4) i.e. - B8- NIR (Near infrared band), B4-Red band

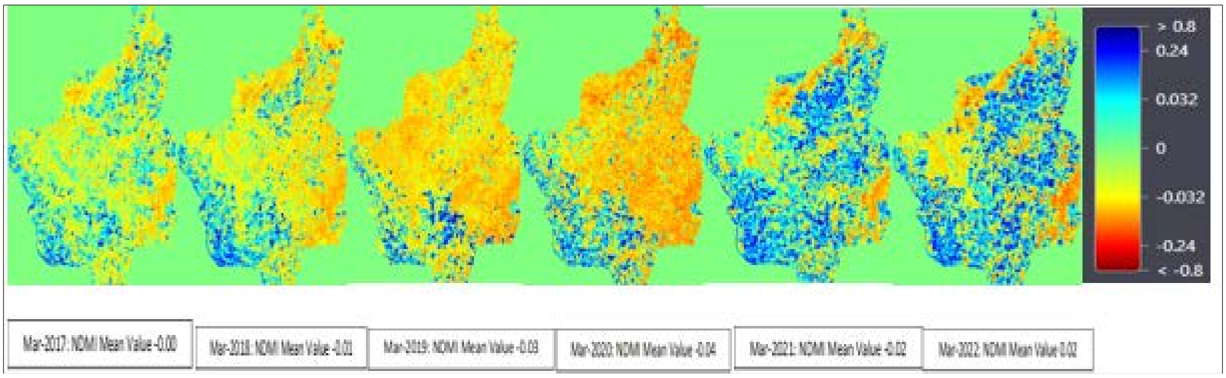


Fig 5: NDMI is calculated in accordance with the Formula= NDMI= (B8A-B11) / (B8A+B11 i.e. - B8A- Vegetation red range, B11- SWIR (Short wave infrared range)

Band details are given below (Source: EO Browser Sentinel Hub-ESA)

Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)
Band 1 - Coastal aerosol	0.443	60
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10
Band 5 - Vegetation Red Edge	0.705	20
Band 6 - Vegetation Red Edge	0.740	20
Band 7 - Vegetation Red Edge	0.783	20
Band 8 - NIR	0.842	10
Band 8A - Vegetation Red Edge	0.865	20
Band 9 - Water vapour	0.945	60
Band 10 - SWIR - Cirrus	1.375	60
Band 11 - SWIR	1.610	20
Band 12 - SWIR	2.190	20

NDVI is a measure of the state of plant health based on how the plant reflects light at certain frequencies. The NDVI Index defines values from -1.0 to +1.0 basically representing greenness. Chlorophyll (a health indicator) strongly absorbs visible light, and the cellular structure of the leaves strongly reflect near- infrared light.

Using the range of index values for different categories like dense vegetation, open vegetation and degraded vegetation are compared and analysed for the pre- and post- periods for the study area.

Land Use and Land Cover (LULC) Change detection

Remote sensing based image processing method of supervised classification technique is used to extract land use classes like crop land, fallow land, plantation (Vegetation) land, waste land, Settlement lands etc. from Landsat 8-9 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) The land use-land cover class wise statistical values are compared in order to evaluate the changes in the period of time from year 2017 and 2021.

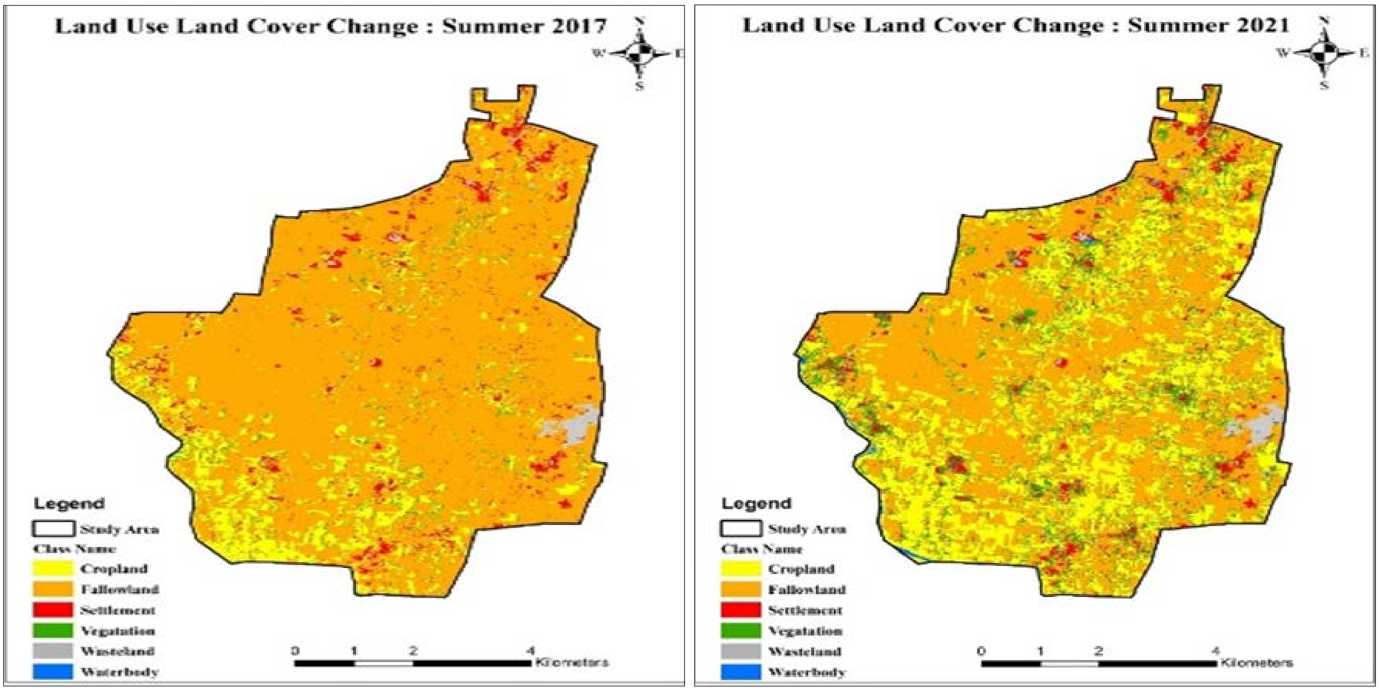


Fig 6: LULC -Map 2017 & 2021

Table 1: LULC- Change detection Calculated area through Landsat

		2017	2021	
Sr. no	**Class Name**	**Area in Ha**	**Area in Ha**	**Change %**
1	Cropland	758.53	1761.71	132
2	Fallow land	4575.64	3072.01	33
3	Wasteland	58.37	58.37	0
4	Settlement	221.55	221.55	0
5	Vegetation	130.29	601.04	362
6	Water body	13.26	29.70	124
		5744.39	5744.39	

The March 2021 instead of 2022 is taken due to unavailability of reliable data of 2022 (Cloud cover is very high causing less accuracy and opaqueness)

Source: Landsat 8-9 Operational Land Imager (OLI), Thermal Infrared Sensor (TIRS)

Bands	Wavelength (micrometres)	Resolution (meters)
Band 8 - Panchromatic	0.50-0.68	15
Band 9 - Cirrus	1.36-1.38	30
Band 10 - Thermal Infrared (TIRS) 1	10.6-11.19	100
Band 11 - Thermal Infrared (TIRS) 2	11.50-12.51	100

Consequence of the methodology

Statistical results of pre and post-values generated from the above methods are compared with the field investigation data. The results are used to analyse the changes taken place during the project period for studying the impact of the watershed programme.

Result & Discussion

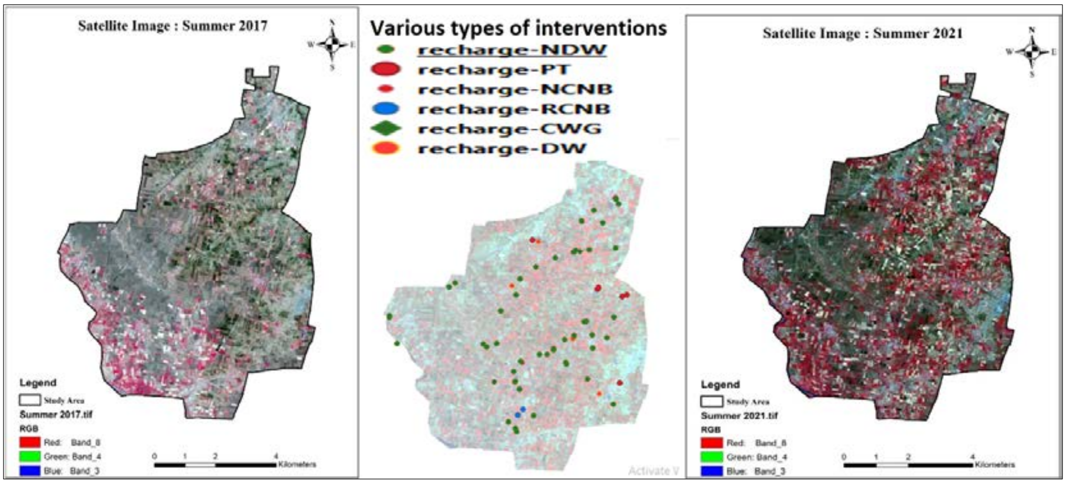


Fig 7: Satellite Images 2017 & 2021

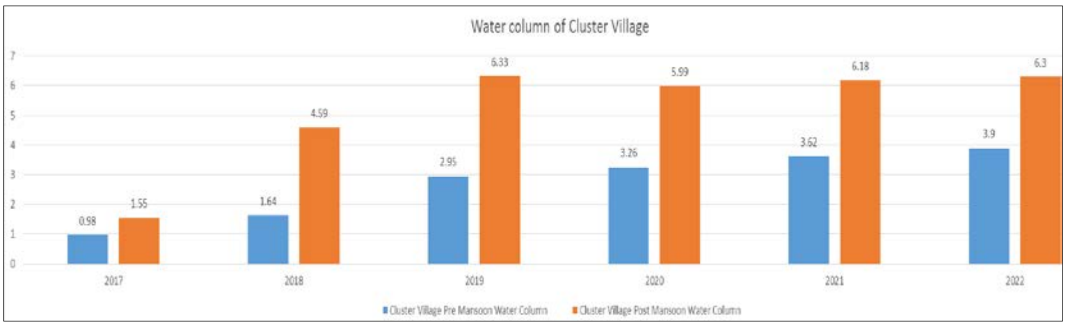


Fig 8: Water column of cluster village

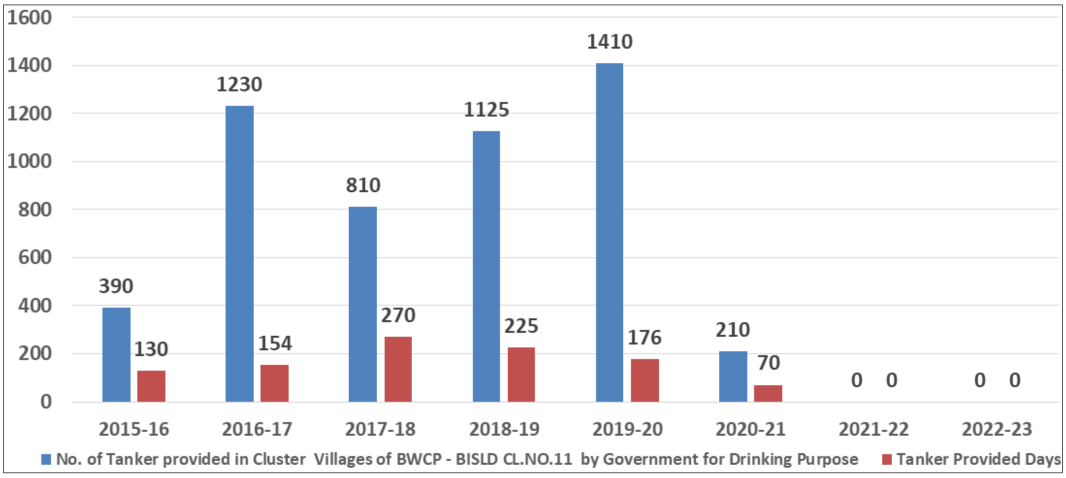


Fig 9: Year wise tanker provided with number of days

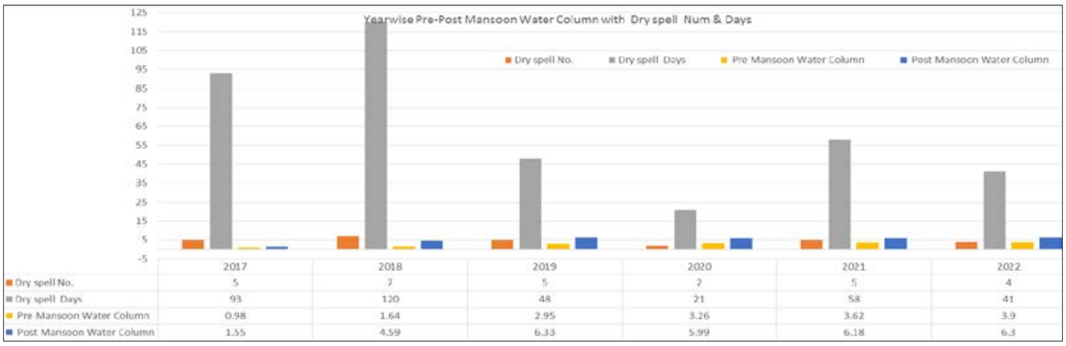


Fig 10: Year wise pre-post mansoon water column with dry spell num & days

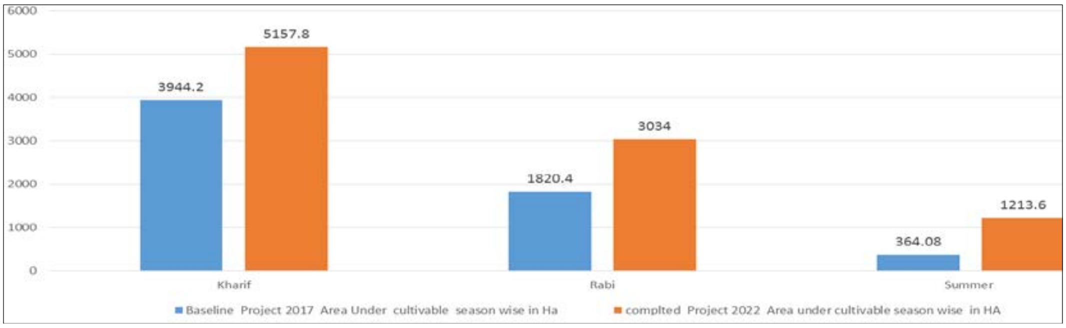
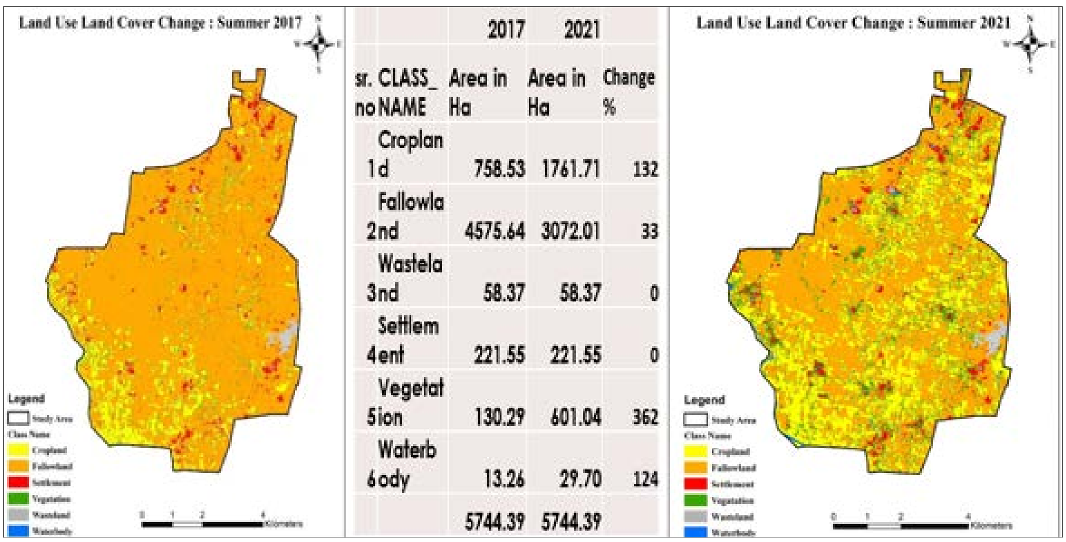


Fig 11: Pre & post season wise area under the cultivation



sr. no	CLASS_NAME	2017 Area in Ha	2021 Area in Ha	Change %
1	Cropland	758.53	1761.71	132
2	Fallowland	4575.64	3072.01	33
3	Wasteland	58.37	58.37	0
4	Settlement	221.55	221.55	0
5	Vegetation	130.29	601.04	362
6	Waterbody	13.26	29.70	124
		5744.39	5744.39	

Fig 12: LULC -Change detection observation

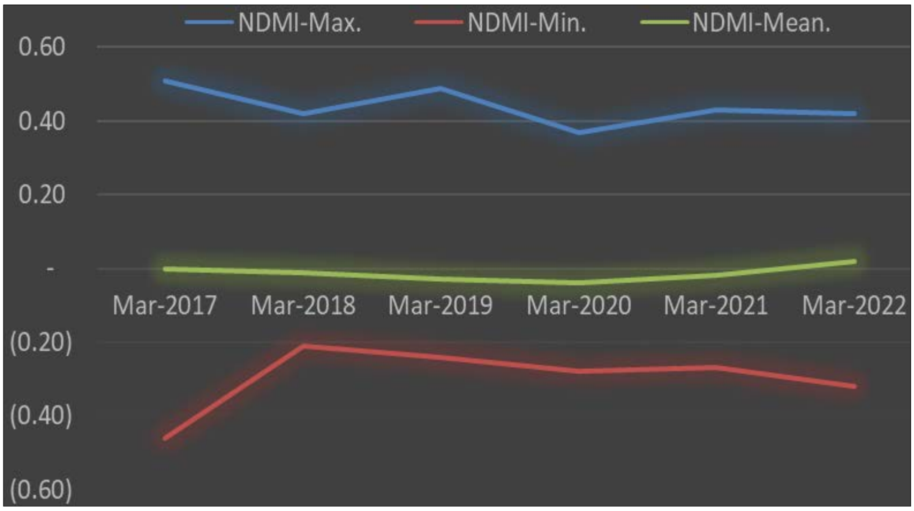


Fig 13: NDMI index-analysis

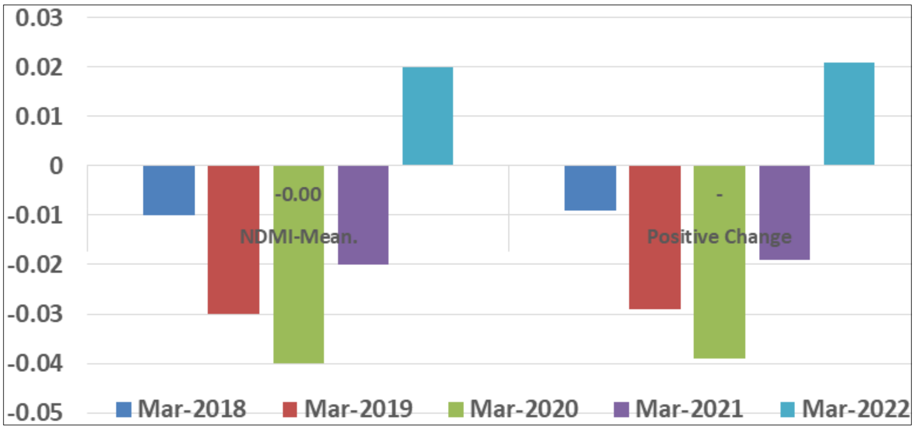


Fig 14: NDMI-mean change

Table 2: NDMI observation

Sr.No	Period	NDMI-Max.	NDMI-Min.	NDMI-Mean.	Positive Change	% Change
1	Mar-2017	0.51	-0.46	-0.00	-	-
2	Mar-2018	0.42	-0.21	-0.01	-0.01	**9**
3	Mar-2019	0.49	-0.24	-0.03	-0.03	**29**
4	Mar-2020	0.37	-0.28	-0.04	-0.04	**39**
5	Mar-2021	0.43	-0.27	-0.02	-0.02	**19**
6	Mar-2022	0.42	-0.32	0.02	0.02	**-21**

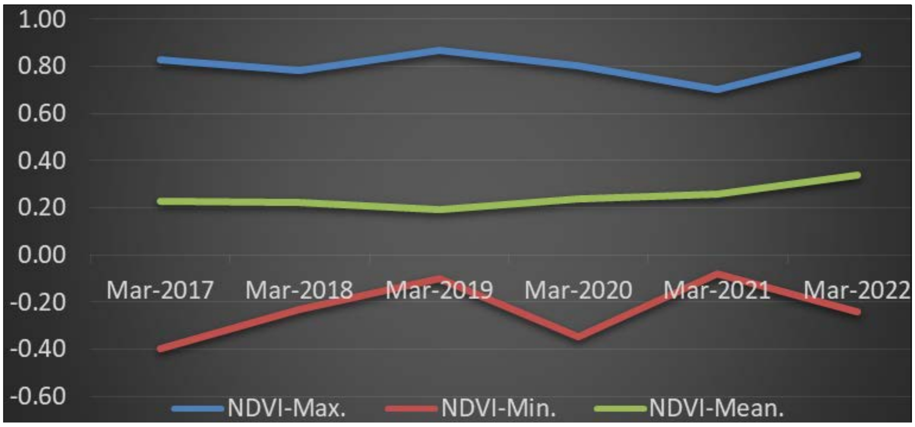


Fig 15: NDVI trend-2018 to 2022

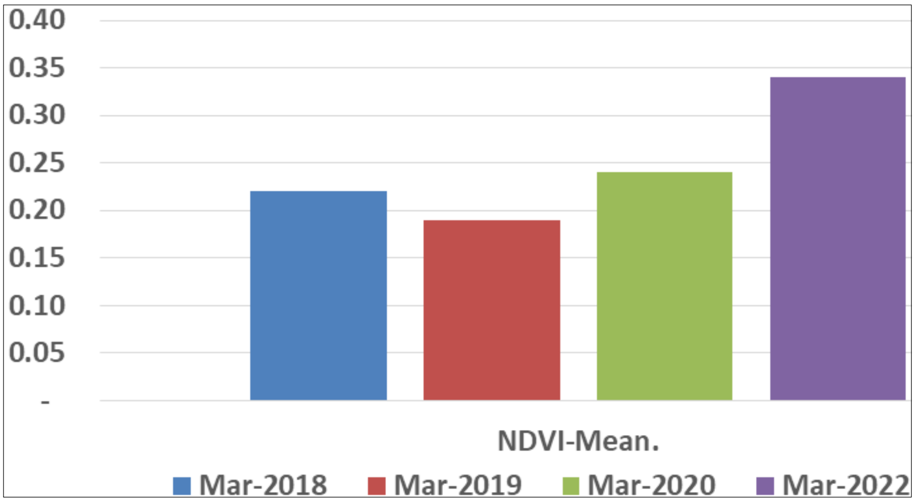


Fig 16: NDVI-mean change

Sr.No	Period	NDVI-Max.	NDVI-Min.	NDVI-Mean.	Positive Char	% Change	Rainfall,mm
				Avg. Rainfall			535
1	Mar-2017	0.83	-0.40	0.23	-	-	
2	Mar-2018	0.78	-0.23	0.22	-0.01	**-4**	293
3	Mar-2019	0.87	-0.10	0.19	-0.03	**-17**	548
4	Mar-2020	0.80	-0.35	0.24	0.02	**5**	1,053
5	Mar-2021	0.70	-0.08	0.26	0.04	**14**	665
6	Mar-2022	0.85	-0.24	0.34	0.12	**48**	731

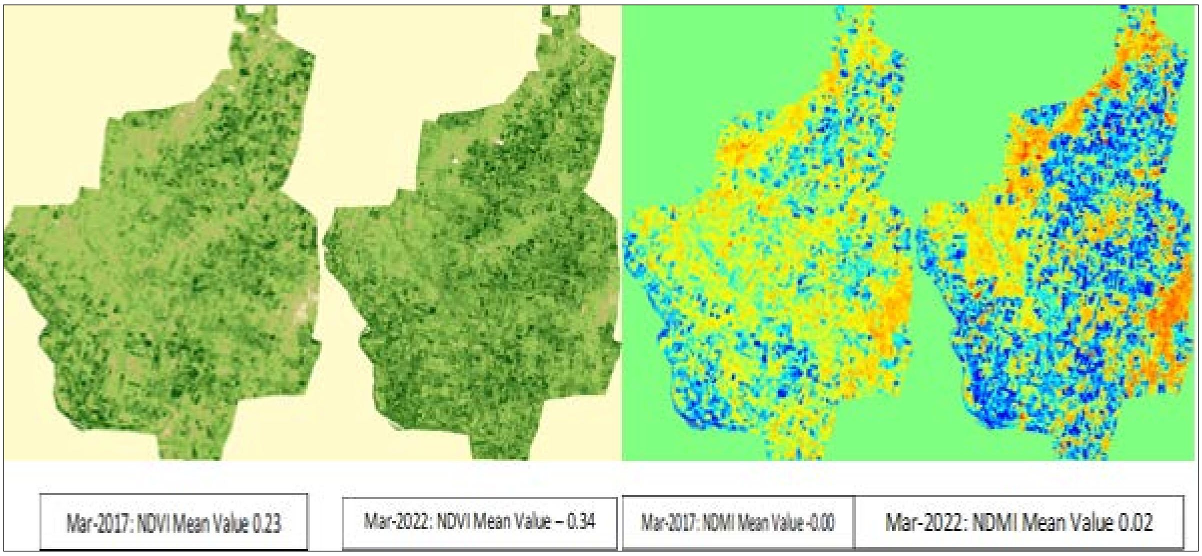


Fig 17: NDVI & NDMI year 2017 & 2022 map

Summary and Conclusion

There is a reduction of 82.92% in the requirement of tankers over the baseline year 2017 while dry spell analysis shows that despite 58 days of dry spell in year 2021, tankers were not required. The comparative analysis of well water levels (May month) below ground level (bgl) in 96 observation wells showed that there is a change of 10.38% (2.7m) in maximum water level bgl, 5.26% in minimum bgl water levels and 13.79% (1.79m) in average bgl water levels. The area under agriculture is also increased in summer season under crop land 29.03 % year 2021 against Base line 12.50 % in year 2017and under (Plantation) horticulture crops 9.90 % against base line 2.14 % respectively. The area under water bodies in March season also shows increase 124 % against base line year2017. The NDVI & NDMI mean value results show positive change over the baseline 0.34 from 0.23 and 0.02 from -0.00 respectively. The overall water conservation approach found effective to minimize dependency on tanker water supply for drinking and also increased area under agriculture and horticulture. The approach is replicable in similar drought prone areas to resolve water availability problems. Further study to understand the impact on agriculture and drinking water in drought years is essential.

Acknowledgment

The authors are thankful to the Corporate Social Responsibility of Bajaj Ltd. Bajaj Water conservation Project (BWCP) for funding the project and Govt. of Maharashtra especially agriculture department for convergence partial interventions of cluster watershed, we sincerely thankful for the support provided by the BAIF & BISLD colleagues, Seniors & Juniors as well as officials of BWCP, we are grateful to the community with whom this study was undertaken.

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