Impact Evaluation Study of Watershed Development Projects Using Geospatial Technology

Remote Sensing Cell

Farm Sector Development Department

NABARD

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1. Introduction

1.1 Background

NABARD has been implementing participatory watershed projects as a part of Natural Resource management since last three decades with an aim to reduce risk associated with rainfed farming systems and ensure livelihood security through holistic development involving soil and moisture conservation, productivity enhancement measures, climate proofing interventions and alternative livelihood interventions, etc. NABARD entered into watershed development space in the year 1992 through Indo-German Watershed Development Programme (IGWDP) in Maharashtra, wherein participatory approach of watershed development was adopted on a large scale for the first time.

Based on the success in implementation of the participatory watershed development under IGWDP, Watershed Development Fund (WDF) was set up at NABARD in 1999-2000 with an initial corpus of ₹ 100 crore contributed each by GoI and NABARD. It is augmented over the years through the interest differential earned under RIDF and interest accrued on the unutilised portion of the fund. The programme follows "Ridge to valley approach" with community participation in conservation and regeneration of natural resources within a micro watershed.

Under watershed development, the various programmes currently under implementation in 28 states are as follows:

i. Participatory watershed development under WDF (including CSR collaborated projects)
ii. Sustainable Development Plans (SDPs)
iii. Climate proofing in completed watershed projects (WDF-CP)
iv. Springshed Development Programme in NER
v. Integrated Water Management Scheme (IWMS)
vi. Pilot projects on reclamation of saline & alkaline soils
vii. Restoration and rehabilitation of degraded soils for food security (SEWOH)

Cumulatively, as against 3,401 watershed development and related projects sanctioned, 1,914 projects were completed successfully. The total project area covered is 23.43 lakh ha. Grant assistance committed under all programmes was at ₹2,389.52 crore, out of which an amount of ₹1902.46 crore was released as on 31 March, 2021.

With the increase in the number of projects and need for digitization of NABARD's intervention in NRM sector, NABARD entered into an MoU with National Remote Sensing Centre (NRSC), Hyderabad in 2015 for web-based monitoring of on-going projects. NRSC created NABARD BHUVAN portal which facilitates HO and ROs to track physical and financial progress of implementation of the projects on real time basis, apart from monitoring of the geo-tagged assets created in the project areas. A provision was made for geo-tagging of assets created in the watershed projects through mobile application developed by NRSC, Hyderabad for the purpose.

NRSC carried out impact evaluation studies of watershed projects in terms of changes in cropped area, area under forest, scrubland, fallow land, water spread area etc., through analysis of time series satellite data. Further, to carry forward the activities of NRSC, in-house Remote Sensing Cell (RSC) was set up at NABARD, HO which has been operational since March, 2021.

As on 28th February 2022, 901 watersheds boundaries have been onboarded on the portal with more than 55,000 geo-tagged assets, across different states of the country.

1.2 Geospatial technology for Impact Assessment of Watershed Projects

As the watershed development approach is an integrated one, there is a need for a suitable indicator to assess the progress of project implementation. It is necessary to holistically assess and evaluate the long-term effects and the impact of the activities through reliable methods. The repetitive coverage of the satellite provides an excellent opportunity to monitor the land resources and evaluate the land cover changes through a comparison of satellite images acquired for the same area at different time periods.

1.2.1 Remote Sensing and GIS

Geospatial Technology ("Geo" is a Greek word meaning Earth and "Spatial" means relating to space) can be defined as a technology used to collect, analyze, and store geographic information. It includes Remote Sensing and GIS among others.

Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information. Remote sensing systems which measure energy that is naturally available (Sun) are called passive sensors while active sensors, on the other hand, provide their own energy source for illumination. Remote Sensing offers various advantages over conventional techniques such as:

- Continuous acquisition of data
- Frequent and regular re-visit capabilities resulting in up-to-date information
- Capability to achieve a synoptic view
- Use of multispectral data for increased information,
- Inaccessible area coverage
- All weather and day/night capability
- Simultaneous observations from a single platform at different resolutions, angles, spectral regions over land, atmosphere and oceans

While there are many advantages, remote sensing has certain limitations:

- Periodic calibration of sensors is required
- Passive remote sensing data may be affected by cloud coverage
- Validation of information is required from other sources
- Sometimes different phenomenon being analysed may look similarly, during measurement which may lead to classification error.

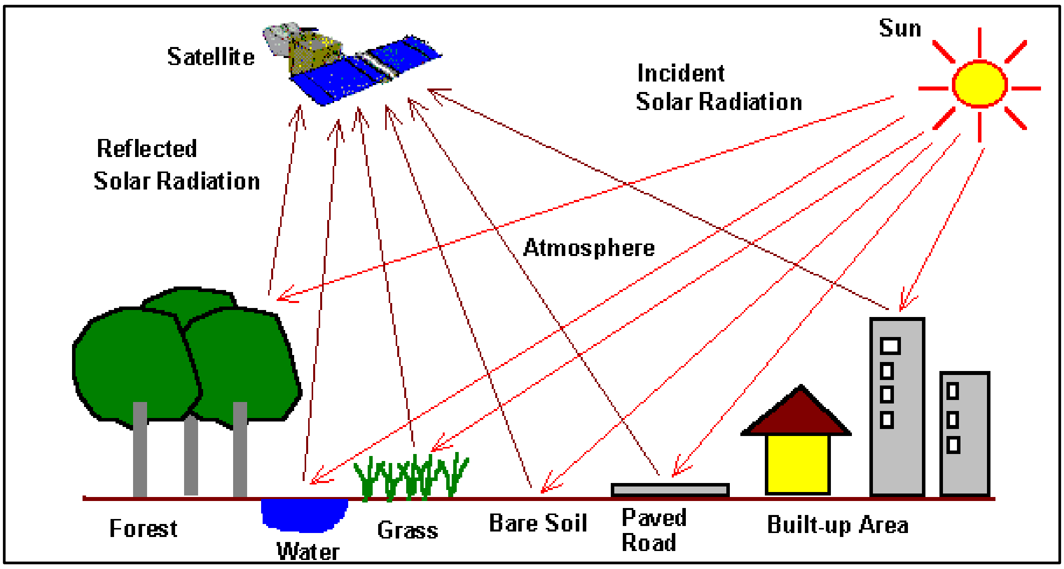
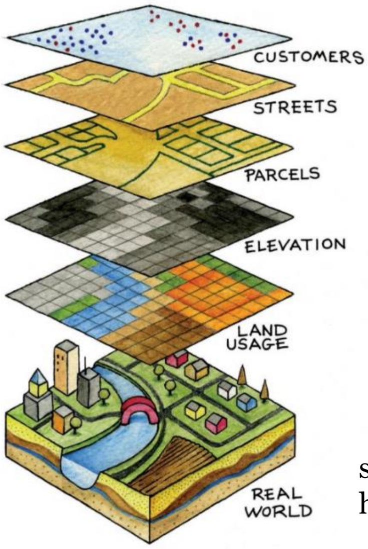


Figure 1-1 Remote Sensing System (Passive)
(source: https://crisp.nus.edu.sg/)

A geographic information system (GIS) is a system that creates, manages, analyzes, and maps all types of data. GIS connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there). This provides a foundation for mapping and analysis that is used in science and almost every industry. GIS helps users understand patterns, relationships, and geographic context.



source: https://medium.com/geekculture

Figure 1-2 World into GIS Layers

1.2.2 Land Use Land Cover (LULC)

Land-use refers to the way in which land has been used by humans and their habitat, usually with accent on the functional role of land for economic activities. Land-cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities e.g., settlements.

1.2.3 Change Detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Timely and accurate change detection of Earth's surface features provides the foundation for better understanding relationships and interactions between human and natural phenomena to better manage and use resources.

In general, change detection involves the application of multi-temporal (multiple images of the same scene acquired at different times) datasets to quantitatively analyse the temporal effects of the phenomenon. Because of the advantages of repetitive data acquisition, its synoptic view, and digital format suitable for computer processing, remotely sensed data has become the major data source for different change detection applications during the past decades.

Remote Sensing (RS) and Geographical Information System (GIS) have been proved as effective tools to monitor, manage the natural resources, and assess the impact on watersheds during the pre and post development. Change detection in watersheds would help in enhancing the capacity of local governments to implement sound environmental management.

1.3 Objectives

The impact evaluation study using RS and GIS has been carried out in 5 watersheds supported by NABARD from the states of Rajasthan, Gujarat, Jharkhand and Telangana. The objectives of the study are:

- LULC map preparation for three years i.e., pre-during-post implementation of watershed interventions
- Quantify the impact of watershed programme interventions on the land use land cover using multi-temporal satellite data

2. Data and Methodology

2.1 Data Used

2.1.1. Satellite Data

The satellite data used for the monitoring of watersheds were LISS III, LISS IV multispectral (image data within specific wavelength ranges across the electromagnetic spectrum) images obtained from National Remote Sensing Centre, Indian Space Research Organization (ISRO), and Sentinel 2 images obtained from European Space Agency (ESA) (Table 2-1). The satellite imagery was selected based on the following parameters:

- Cloud Coverage less than 10%
- Availability of the same satellite imagery for the three years (Pre-during-Post) for same season

S. No.	Satellite/Sensor	Spectral Resolution (µm)	Spatial Resolution (meters)	Temporal Resolution (days)
1	Sentinel 2 (Source: ESA)	Band 3: 0.56 Band 4: 0.66 Band 8: 0.84	10	5
2	IRS P6 LISS-III (Source: ISRO)	Band 2: 0.52-059 Band 3: 0.62-0.68 Band 4: 0.77-0.86 Band 5: 1.55-1.75	23.5	24
3	IRS P6 LISS-IV (Source: ISRO)	Band 2: 0.52 - 0.59 Band 3: 0.62 - 0.68 Band 4: 0.77 - 0.86	5.8	5

Table 2-1 General Specifications of satellite data

2.1.2 Ancillary Data

Monthly rainfall data obtained from India Meteorology Department (IMD) was used to understand the rainfall pattern in watershed project areas.

2.2 Methodology

Before implementing change detection analysis, the following conditions are ensured: (1) precise registration of multi-temporal images; (2) precise radiometric and atmospheric calibration or normalization between multi-temporal images; (3) similar phenological states between multi-temporal images; and (4) selection of the same spatial and spectral resolution images if possible. Changes on the landscape are detected as changes in the 'spectral space' occupied by an image pixel.

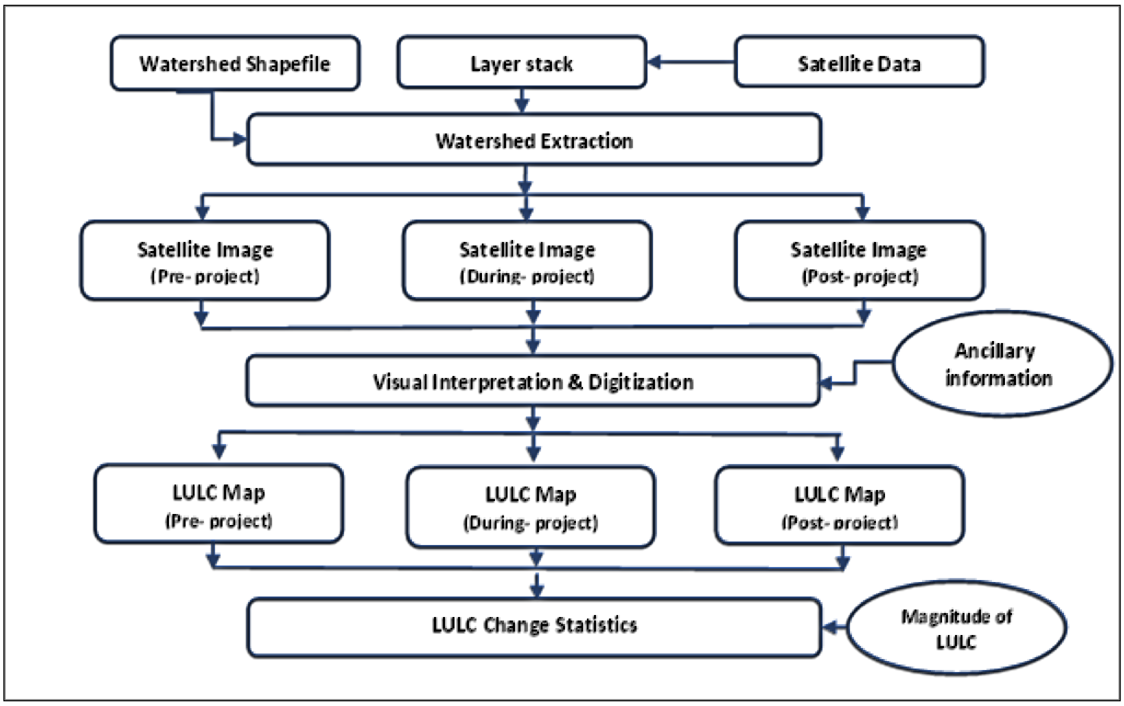


Figure 2-1 Flow diagram of Methodology

2.2.1. Pre-processing of Satellite Data

The satellite data obtained from respective space agencies are layer stacked i.e., the spectral bands required for generating land use/land cover (LULC) are selected and stacked together to prepare one composite image. As the precise registration of multi-temporal images is important, geometric correction is followed which is the process of correcting these displacements in satellite images to ensure that pixels/features in the image are in their proper and exact position on the earth's surface.

The geometrically corrected satellite imageries are clipped to the extent of respective watershed boundaries as received from implementing agencies.

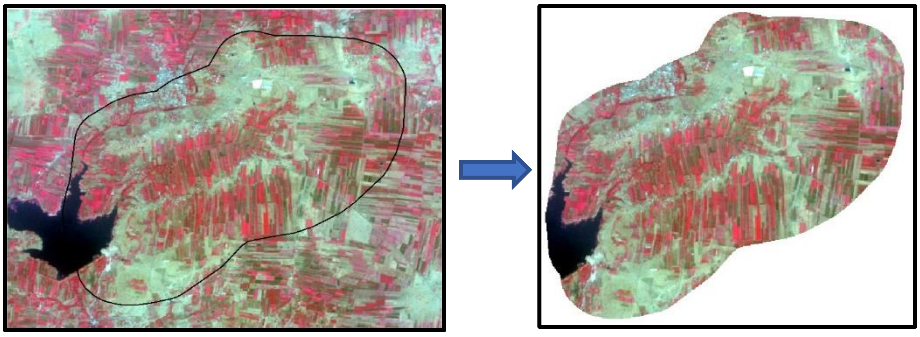


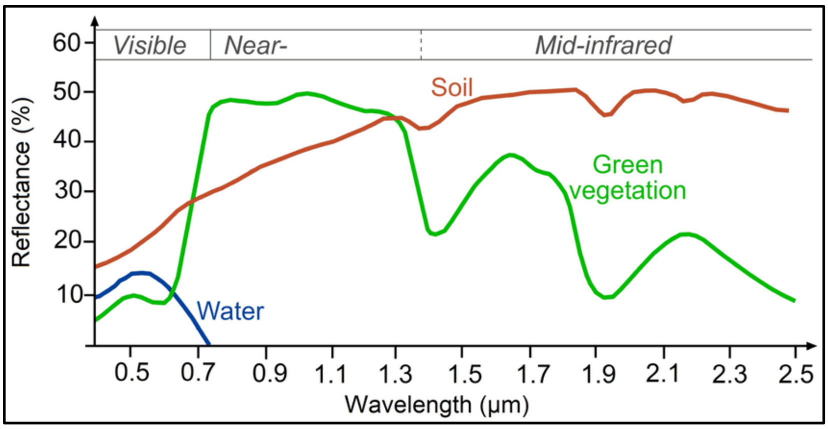
Figure 2-2 Clipped Satellite Image

2.2.2 Visual interpretation and Digitization for LULC Mapping

Features on the Earth reflect, absorb, transmit, and emit electromagnetic energy from the sun. Across any range of wavelengths, the percent reflectance values for landscape features such as water, sand, roads, forests, etc. can be plotted and compared. Such plots are called "spectral response curves" or "spectral signatures." Differences among spectral signatures are used to help classify remotely sensed images into classes of landscape features since the spectral signatures of like features have similar shapes.

Analysis of remote sensing imagery involves the identification of various targets in an image, and those targets may be environmental or artificial features which consist of points, lines, or areas. Targets may be defined in terms of the way they reflect or emit radiation. This radiation is measured and recorded by a sensor, and ultimately is depicted as an image product such as an air photo or a satellite image.

Recognizing targets is the key to interpretation and information extraction. Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of tone, shape, size, pattern, texture, shadow, and association.



source: https://seos-project.eu/

Figure 2-3 Spectral Signature

Onscreen visual interpretation technique has been used while preparing the LULC maps for the three years (pre-during-post). Satellite imagery were enhanced to improve the basic visual interpretation characteristics. The advantages for visual interpretation approaches are as following:

- Context / Texture / Pattern based classes can be delineated
- Various enhancement options are possible to exploit the capability of multiband / multi season data.
- Minimizes the issues of sensor radiometry and date of pass
- Temporal assessment is time effective
- Adoptability and operational feasibility is high
- Domain knowledge and site adaptation is used to ascertain land use units.

Based on the onscreen visualization, different classes are digitized viz., crop land, fallow land, waterbody, forest, barren land and scrubland. The LULC maps are generated for three different time periods viz. pre, during and post project implementation stages to map three scenarios of the watershed for the same cropping season. The first scenario (pre) is to map LULC conditions in the watershed before the start of watershed development project, the second scenario (during) is to map LULC conditions during the project implementation period and the third (post) is to map the LULC conditions after the completion of project.

The area of LULC classes is calculated for all three LULC maps and compared with each other to estimate the changes occurred in LULC of watershed over the period of project implementation. The magnitude of LULC change is calculated to understand the rate at which each LULC class has undergone change owing to the watershed development projects. This helps to estimate the impact of watershed projects such that further necessary measures can be taken up. Magnitude of LULC change and annual rate of change is calculated as:

Magnitude of LULC change (X) = Magnitude of LULC in Post-Implementation year – Magnitude of LULC in Pre-Implementation year

Annual rate of LULC change=Magnitude of LULC change/Total number of years

2.2.3 Validation of Results

Validation of LULC maps is done by correlating the maps with high resolution (sub-centimetres) Google Earth imagery. The results are also correlated with the photographs of geotagged assets.

3. Impact Assessment of Land Use and Land Cover Changes

3.1 Vagda Watershed, Udaipur district of Rajasthan State

3.1.1 Study area

Vagda watershed is located in Udaipur district of Rajasthan and covers an area of 1535.17 hectares. The watershed extends from 24^o 49' 34'' to 24^o 53' 42'' latitude and from 73^o 31' 15'' to 73^o 33' 59'' longitude (Figure 3-1). Vagda is hilly and undulating terrain with elevation varying between 667 m – 1046 m from mean sea level. The watershed project was supported under IGWDP. Capacity Building Phase of the project was sanctioned in 2009 and the project completed in 2018 benefitting 368 households.

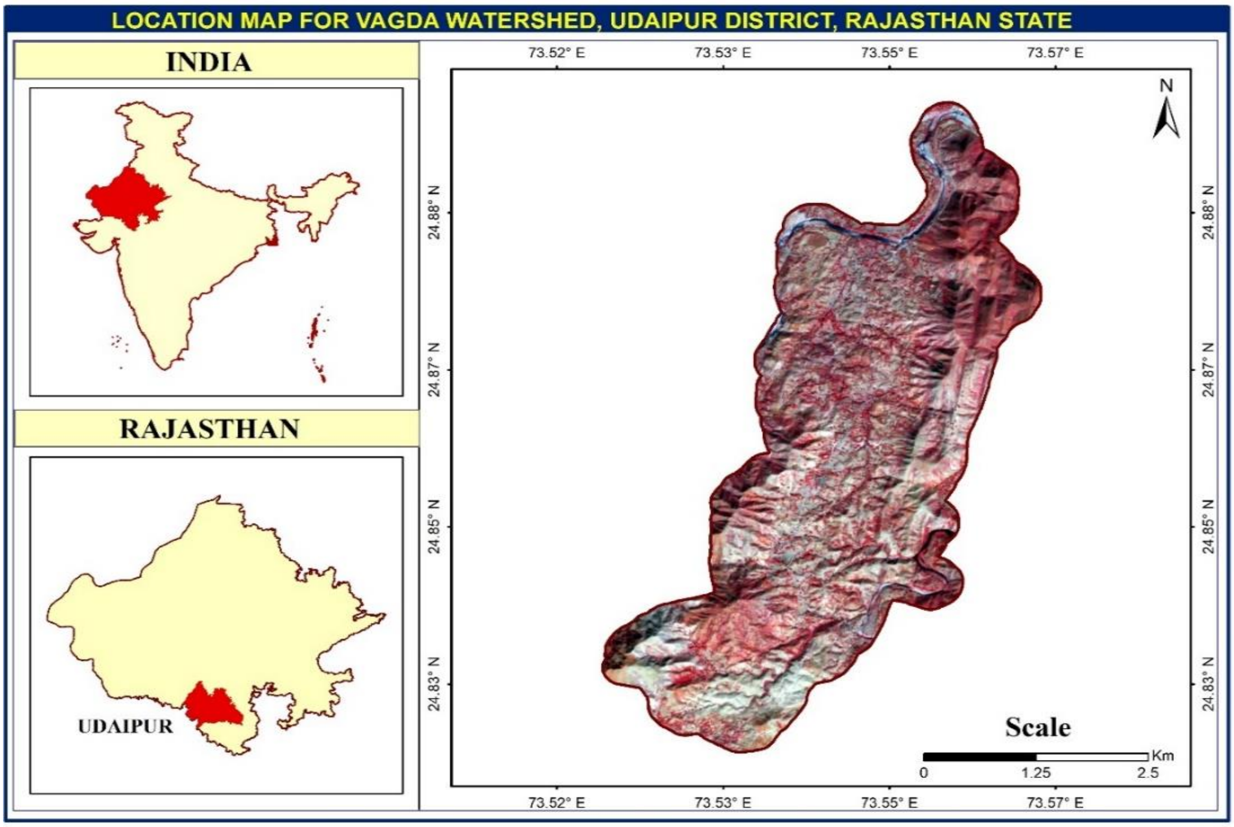


Figure 3-1 Location map of Vagda watershed

3.1.2 Comparative Assessment of Land Use Land Cover for Pre – During – Post Implementation

The study evaluated the Land Use Land Cover (LULC) changes in Vagda watershed occurred in pre-during-post implementation of NABARD assisted watershed development project. IRS-LISS-III multi-temporal satellite images were utilised to analyse and quantify the changes in land use land cover (Figure 3-2). To achieve the same, three satellite images pertaining to pre - during – post implementation stages were utilised. The details of satellite data used for change detection analysis are given in the Table 3-1 below:

Sr. No.	Sensor	Date of Pass	Season
1	LISS III	01-Nov-08	Rabi
2	LISS III	29-Dec-13	Rabi
3	LISS III	04-Oct-18	Rabi

Table 3-1 Specifications of satellite data of Vagda Watershed

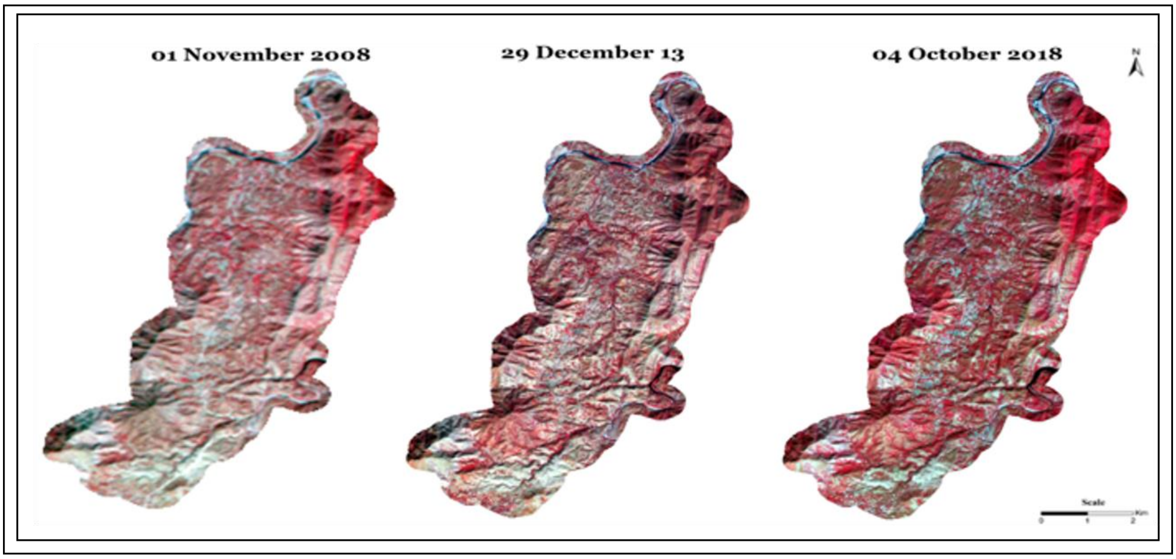


Figure 3-2 Temporal images of Vagda Watershed

The monthly rainfall data from the year 2006 to 2018 procured from India Meteorological Department (IMD) website as shown in Table 3.2 below:

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
2006	0	0	3.2	0	7.1	109.4	237.9	645.1	89.3	0	0	0
2007	0	1.9	0	0.4	3	32.3	236.3	222	17.9	0	0	0
2013	0	4.4	0	4	0.9	99.2	286.9	168.5	148.3	35.4	0	0
2014	19.1	1.8	0	16.3	21.2	3.1	273.2	164.1	240.3	0.1	0	0
2016	0	0	1.3	0	0.7	63.2	370.4	388.6	29.5	60	0	0
2017	2.7	0	0.3	0	11.1	97.5	493.8	155.9	63.5	0	0	0.7
2018	0	0	0	0	0	117.6	200.5	154.6	89.6	1.1	0	0

Table 3-2 Monthly Rainfall (mm) of Vagda Watershed

The land use land cover (LULC) maps were prepared by on-screen digitization through the visual interpretation method. LULC changes were identified in treated watershed area by comparing multi temporal data i.e. pre (2008), during (2013) and post (2018) as shown in Figure 3-3. Table 3-3 shows the area change statistics. Figure 3-4 highlights the gradual transformation of different land use to crop land. The area transformation as visualised in Google Earth Imagery is shown in Figure 3-5.

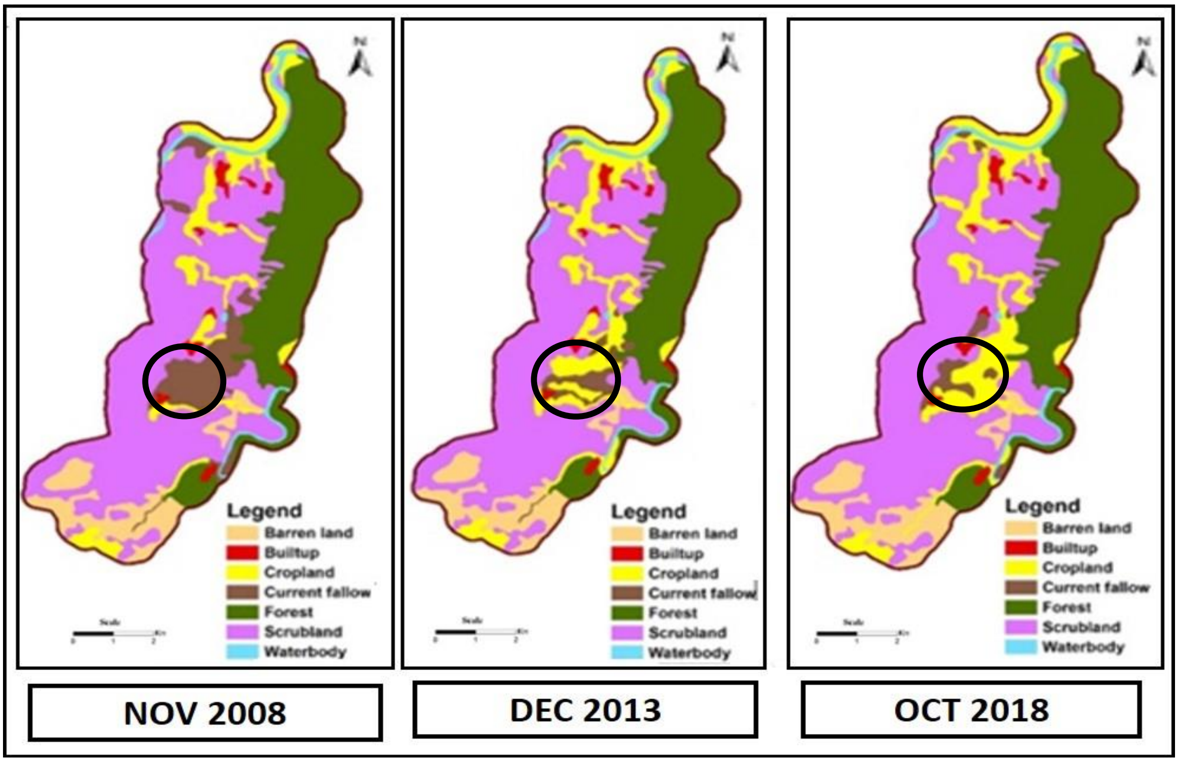


Figure 3-3 LULC Map of Vagda Watershed for 2008, 2013 and 2018

LULC	Area under different LULC (ha)		
	2008 (ha)	**2013 (ha)**	**2018 (ha)**
Crop Land	152.22	220.59	235.85
Current Fallow	111.73	47.35	32.15
Scrub Land	696.84	691.7	691.4
Barren Land	124.85	124.85	124.85
Builtup Land	21.7	23.01	23.06
Waterbody	38.47	38.31	38.51
Forest	389.36	389.36	389.36

Total Area (ha)	**1535.17**	**1535.17**	**1535.17**

Table 3-3 Distribution of LULC in Vagda Watershed

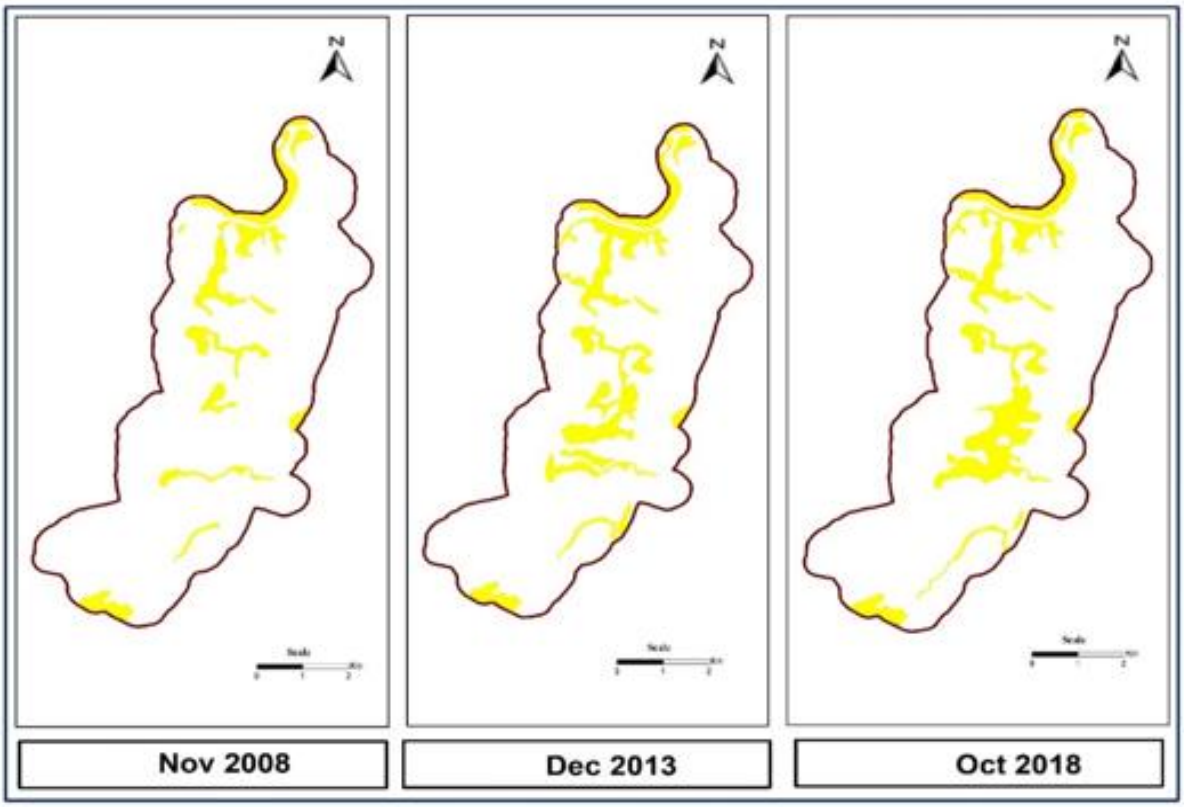


Figure 3-4 Transformation of different land-use to cropland of Vagda Watershed

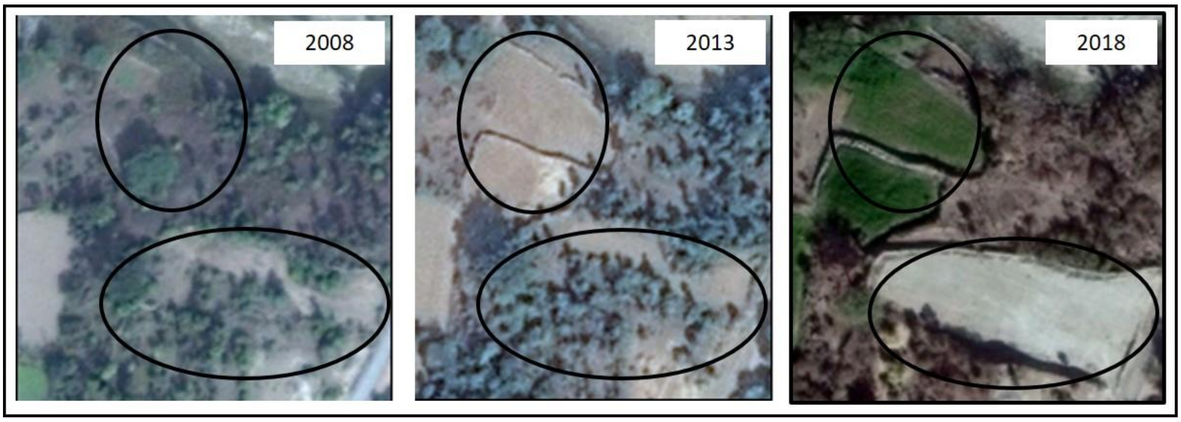


Figure 3-5 Area under Transformation as visualized on Google Earth Imagery of Vagda Watershed

The LULC maps were correlated with high resolution Google Earth imagery for validating the changes (Figure 3-6). Also, results were correlated with the photographs of geotagged assets. Geotagged photographs of Earthen Check Dam, one of the interventions in Hathniyawal Village, as seen on NABARD Bhuvan Portal and Google Earth is shown in Figure 3-6. The magnitude of change and annual rate was estimated for the period of study as shown in Table 3-4 below:

Figure 3-6 Earthen Check Dam, Hathniyawal Village (a) Geotagged Photographs (b) NABARD Bhuvan Portal (c) Google Earth of Vagda Watershed

Sr. No.	**LULC**	**LULC change from 2008 to 2018**	
		Magnitude of change (ha)	**Annual rate of change (ha/Year)**
1	Crop Land	(+) 83.63	(+) 8.363
2	Current Fallow	(-) 79.58	(-) 7.958
3	Scrub Land	(-) 5.44	(-) 0.544
4	Barren Land	0	0
5	Built-up Land	(+) 1.36	(+) 0.136

6	Waterbody	(+) 0.04	(+) 0.004
7	Forest	0	0

Table 3-4 LULC change assessment of Vagda watershed

3.1.3 Conclusion

The study was conducted to identify changes in land use and land cover in the Vagda watershed in the Udaipur district of Rajasthan.

The total area under cultivation in the study area was 152.22 ha (9.9% of total area) during the year 2008, which increased to 220.59 ha in the year 2013 and 235.85 ha (15% of total area) in the year 2018. Scrub land of around 6 ha was transformed to crop land. The other land use classes like built up land and waterbody underwent through marginal changes (increase) while area under barren land and forest cover remained same during the study period of 2008 to 2018.

The analysis of annual rate of change in LULC of Vagda watershed confirmed the similar trend of increase in area of cropland, built-up land and water body and decrease in area of current fallow land and scrubland.

The soil and water conservation measures like check dams, continuous contour trench, box trench were made near Hathinyawal village and stone gully plug, staggered contour trench etc. were carried out at Vagda village within the watershed. The significant increase in cropland area in the Vagda watershed is a positive aspect of development.

3.2 Gundalpur Watershed, Chittorgarh District of Rajasthan State

3.2.1 Study area

Gundalpur watershed is located in Chittorgarh district of Rajasthan state and covers an area of 1410.31 hectares. The watershed extents from 24° 20' 17'' to 24° 24' 21'' North latitude and from 74° 29' 48'' to 74° 31' 58'' East longitude (Figure 3-7). Gundalpur is hilly and undulating terrain with elevation varying between 480 m – 583 m from mean sea level. The watershed project is under IGWDP. Capacity Building Phase of the project was sanctioned in 2009 and the project completed in 2016 benefitting 427 households.

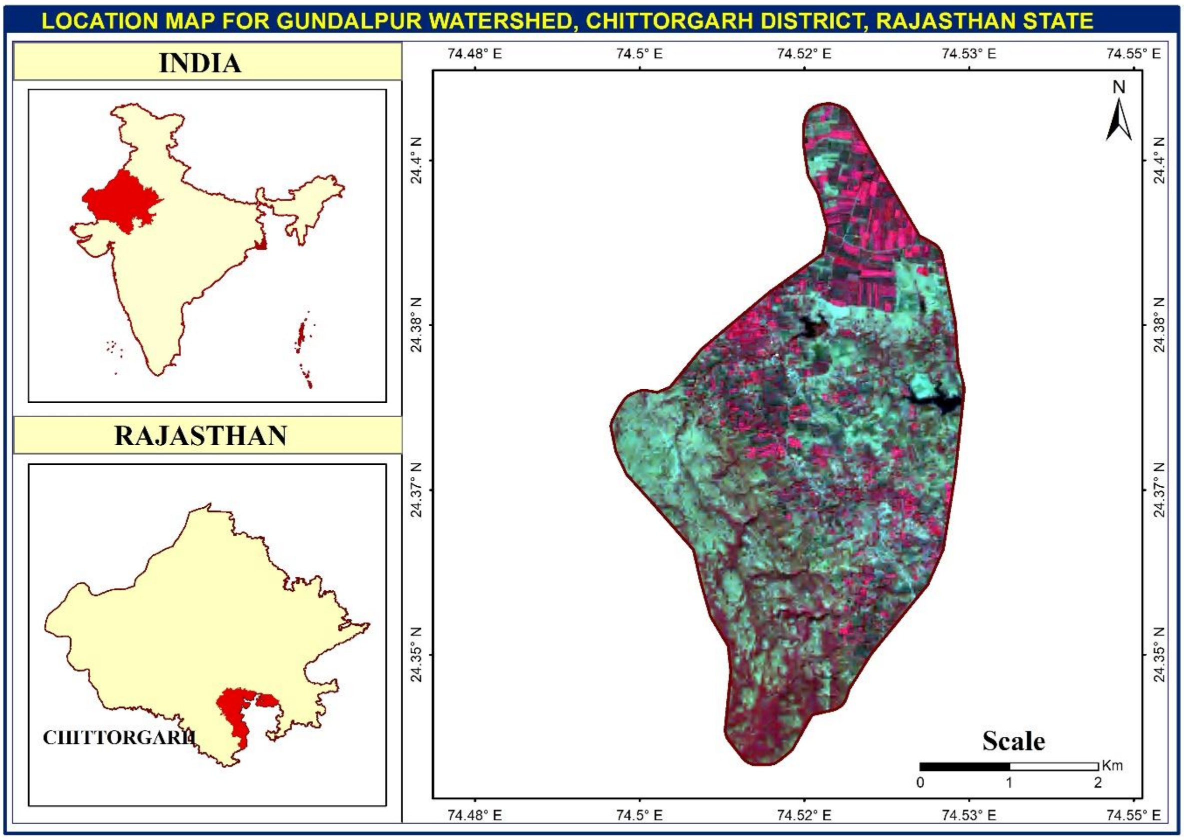


Figure 3-7 Location map of Gundalpur watershed

3.2.2 Comparative Assessment of Land Use Land Cover for Pre – During – Post Implementation

The study evaluated the Land Use Land Cover (LULC) changes in Gundalpur watershed occurred in pre-during-post implementation of NABARD assisted watershed development project. IRS-LISS-IV and Sentinel 2 multi-temporal satellite images were utilised to analyse and quantify the changes in land use land cover (Figure 3-8). To achieve the same, three satellite images pertaining to pre - during – post implementation stages were utilised. The details of satellite data used for change detection analysis are given in the Table 3-5 below:

Sr. No.	Satellite/Sensor	Date of Pass	Season
1	LISS IV	06-Nov-08	Rabi
2	Sentinel 2	25- Nov -15	Rabi
3	Sentinel 2	30- Nov -20	Rabi

Table 3-5 Specifications of satellite data of Gundalpur watershed

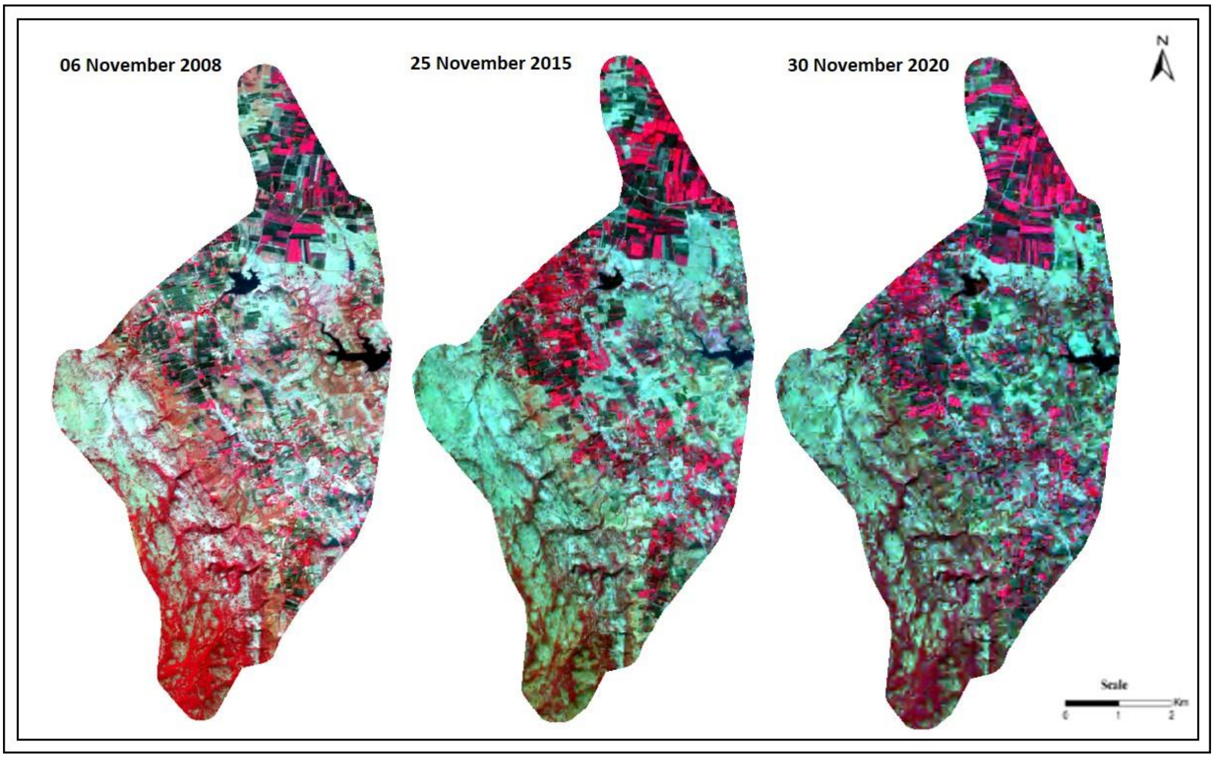


Figure 3-8 Temporal images of Gundalpur Watershed

The monthly rainfall data from the year 2008 to 2020 procured from India Meteorological Department (IMD) website as shown in Table 3-6 below:

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
2008	0	0	1.2	12	6.2	98.6	286.6	279.8	121.2	8.2	0	0	813.8
2009	0	0	0.9	0	8	49.8	313.3	197.1	61.9	9.8	6.1	0	646.9
2015	10.9	0.5	40.9	3.9	3.5	92.2	362.4	150.8	19.9	0	0	0	685
2016	0	0	1.3	0	3.8	75.8	394.7	781.1	55.8	39	0	0	1351.5
2017	4.5	0	6.8	4.4	14	80.6	419	134.7	53.8	0	0	6.8	724.6
2018	0	0	0	0.2	0	101.5	274	176.3	155.1	0	0	0	707.1
2019	1.7	0.2	0	23	7.5	116.6	252.7	530	277.9	27.9	14.8	0	1252.3
2020	0.3	0	20.6	4.9	10.8	87.5	146.7	301.6	111.1	20.5	6.5	0.2	710.7

Table 3-6 Monthly Rainfall (mm) of Gundalpur watershed

The land use land cover (LULC) maps were prepared by on-screen digitization through the visual interpretation method. LULC changes were identified in treated watershed area by comparing multi temporal data i.e. pre (2008), during (2015) and post (2020) as shown in Figure 3-9. Table 3-7 shows the area change statistics. Figure 3-10 highlights the gradual transformation of different land use to crop land. The area transformation as visualised in Google Earth Imagery is shown in Figure 3-11.

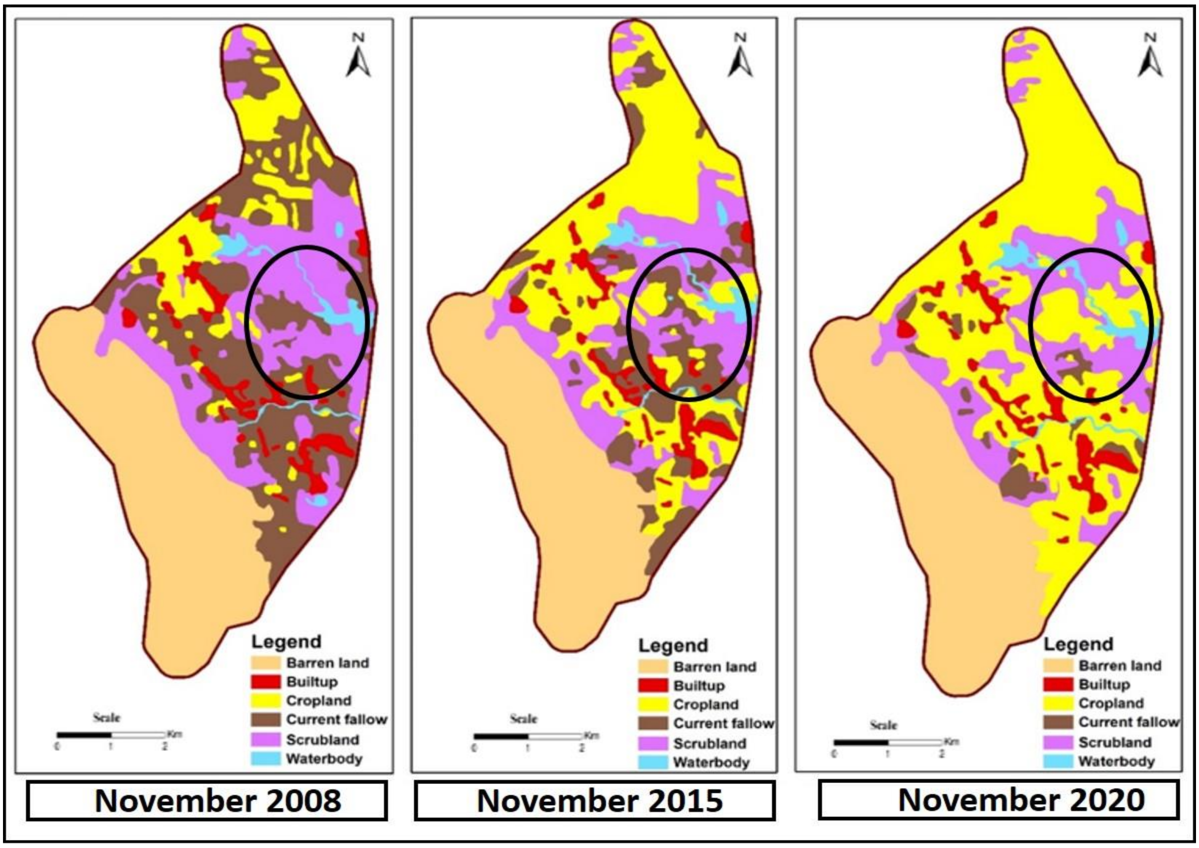


Figure 3-9 LULC Map of Gundalpur Watershed for 2008, 2015 and 2020

LULC	Area under different LULC (ha)		
	2008 (ha)	2015 (ha)	2020 (ha)
Crop Land	152.24	409.42	557.34
Current Fallow	393.67	194.82	70.53
Scrub Land	312.8	264.76	240.28
Barren Land	455.57	437.96	437.05
Builtup Land	66.41	71.71	72.05
Waterbody	29.62	31.64	33.06
Total Area (ha)	**1410.31**	**1410.31**	**1410.31**

Table 3-7 Distribution of LULC in Gundalpur watershed

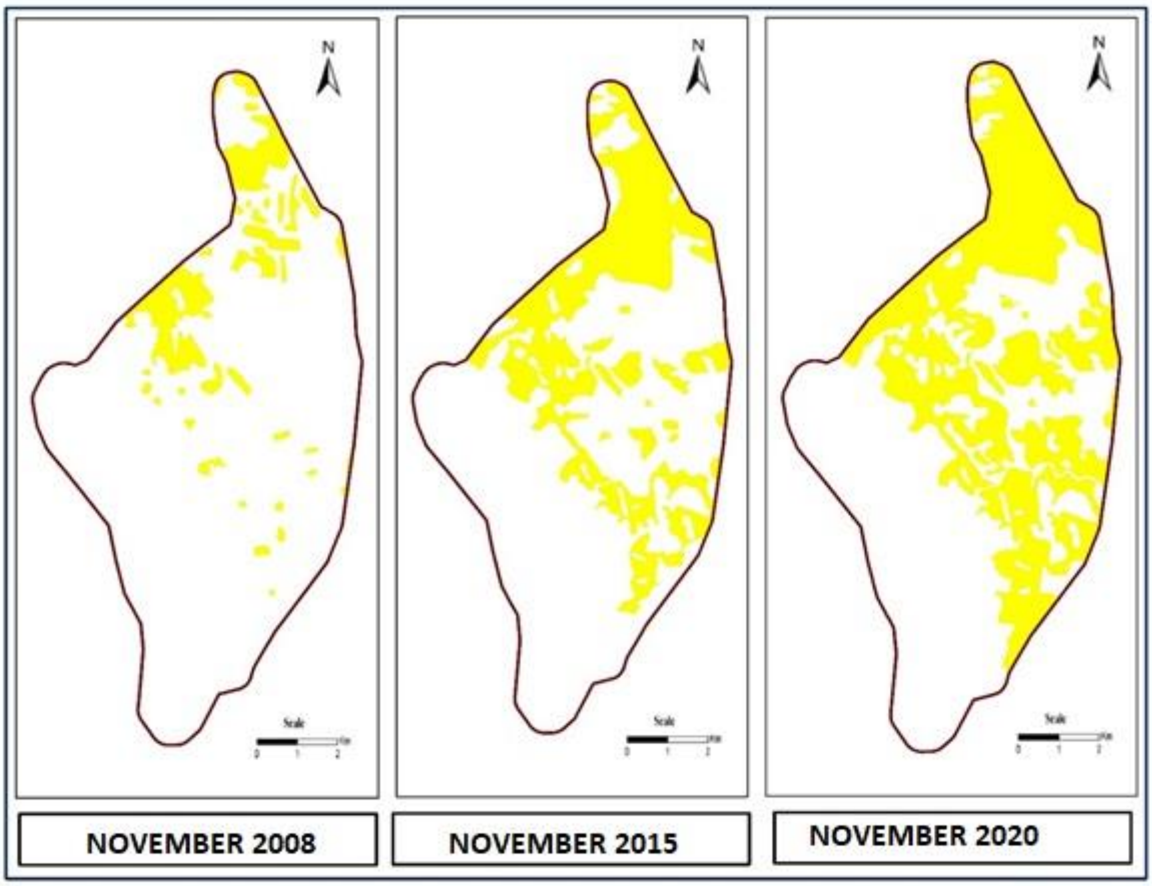


Figure 3-10 Transformation of different land-use to cropland of Gundalpur watershed

Figure 3-11 Transformation of current fallow to cropland of Gundalpur watershed

The LULC maps were correlated with high resolution Google Earth imagery for validating the changes (Figure 3-12). Also, results were correlated with the photographs of geotagged assets. Geotagged photographs of Cemented Check Dam, one of the interventions in Gundalpur Village, as seen on NABARD Bhuvan Portal and Google Earth is shown in Figure 3-12. The magnitude of change and annual rate was estimated for the period of study as shown in Table 3-8 below:

Figure 3-12 Cemented Check Dam, Gudalpur Village (a) Geotagged Photographs (b) NABARD Bhuvan Portal (c) Google Earth of Gundalpur watershed

Sr. No.	LULC	LULC change from 2008 to 2020	
		Magnitude of change (ha)	**Annual rate of change (ha/Year)**
1	Crop Land	(+) 405.1	(+) 33.76
2	Current Fallow	(-) 323.14	(-) 26.93
3	Scrub Land	(-) 72.52	(-) 6.04
4	Barren Land	(-) 18.52	(-) 1.54
5	Builtup Land	(+) 5.64	(+) 0.47
6	Waterbody	(+) 3.44	(+) 0.29

Table 3-8 LULC change assessment of Gundalpur watershed

3.2.3 Conclusion

The study was conducted to identify changes in land use and land cover in the Gundalpur watershed in the Udaipur district of Rajasthan.

The total area under cultivation in the study area was 152.24 ha (10.79% of total area) during the year 2008, which increased to 409.42 ha in the year 2015 and 557.34 ha (39.52% of total area) in the year 2020 (Table 3-7). The 323 ha of current fallow land and 73 ha of scrub land were transformed to crop land. The other land use classes went through marginal changes wherein barren land decreased by 18.52 ha while area under built up land and waterbody increased by 5.64 ha and 3.44 ha respectively during the study period of 2008 to 2020. The analysis of annual rate of change in LULC of Gundalpur watershed confirmed the similar trend of increase in area in cropland, built-up land and water body and decrease in area of current fallow land and scrubland.

The soil and water conservation structures like stone gully plug, staggered contour trench etc. were made in Gundalpur village within the watershed. Total 15 activities were implemented and geotagged. The significant increase in cropland area in the Gundalpur watershed is a positive aspect of development.

3.3 Motihandi Watershed, Dahod District of Gujarat State

3.3.1 Study area

Motihandi watershed is located in Dahod district of Gujarat state and covers an area of 1888.18 hectares. The watershed extents from 22° 55' 14'' to 22° 58' 37'' North latitude and from 74° 08' 46'' to 74° 11' 13'' East longitude (Figure 3-13). Motihandi is hilly and undulating terrain with elevation varying between 286 m – 373 m from mean sea level. The watershed project was supported under IGWDP. Capacity Building Phase of the project was sanctioned in 2008 and the project completed in 2016 benefitting 778 households.

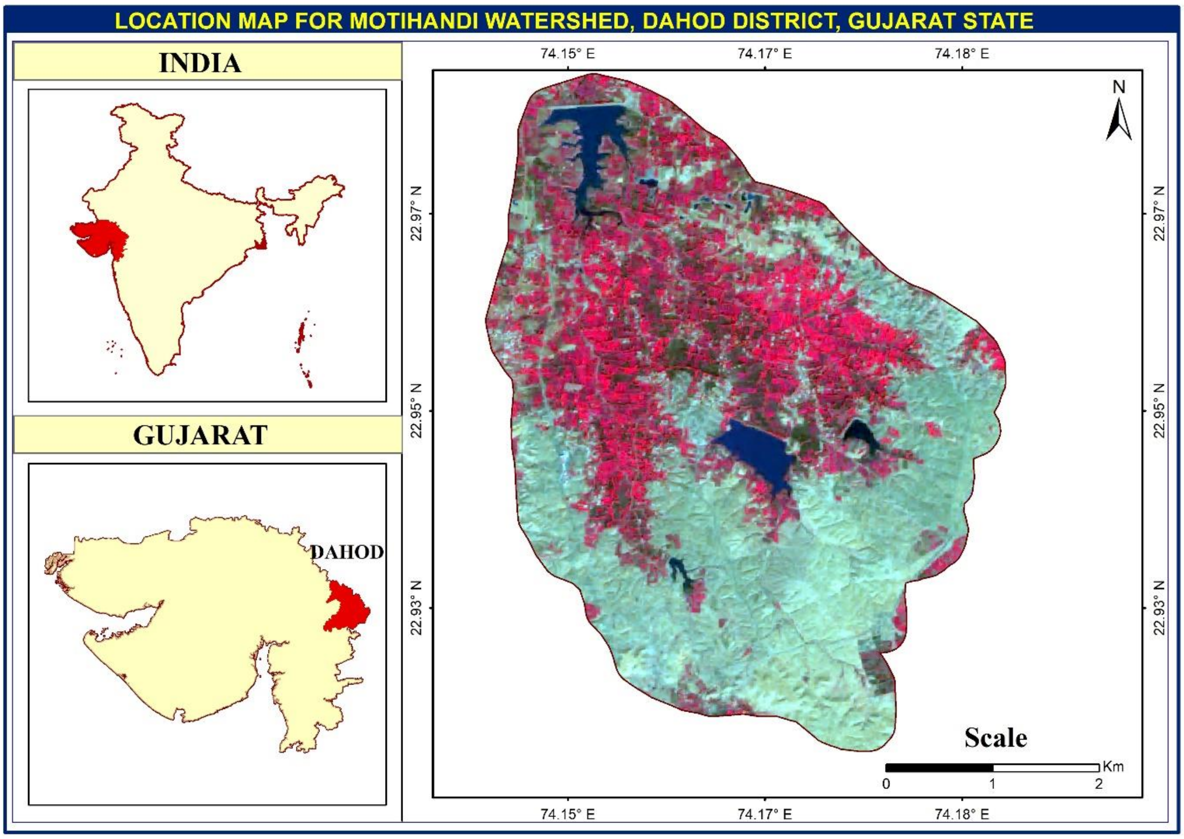


Figure 3-13 Location map of Motihandi watershed

3.3.2 Comparative Assessment of Land Use Land Cover for Pre – During – Post Implementation

The study evaluated the Land Use Land Cover (LULC) changes in Motihandi watershed occurred in pre-during-post implementation of NABARD assisted watershed development project. IRS-LISS-III multi-temporal satellite images were utilised to analyse and quantify the changes in land use land cover (Figure 3-14). To achieve the same, three satellite images pertaining to pre - during – post implementation stages were utilised. The details of satellite data used for change detection analysis are given in the Table 3-9 below:

Sr. No.	Satellite/Sensor	Date of Pass	Season
1	LISS III	13-Oct-08	Rabi
2	Sentinel 2	07-Dec-15	Rabi
3	Sentinel 2	10-Dec-20	Rabi

Table 3-9 Specifications of satellite data of Motihandi watershed

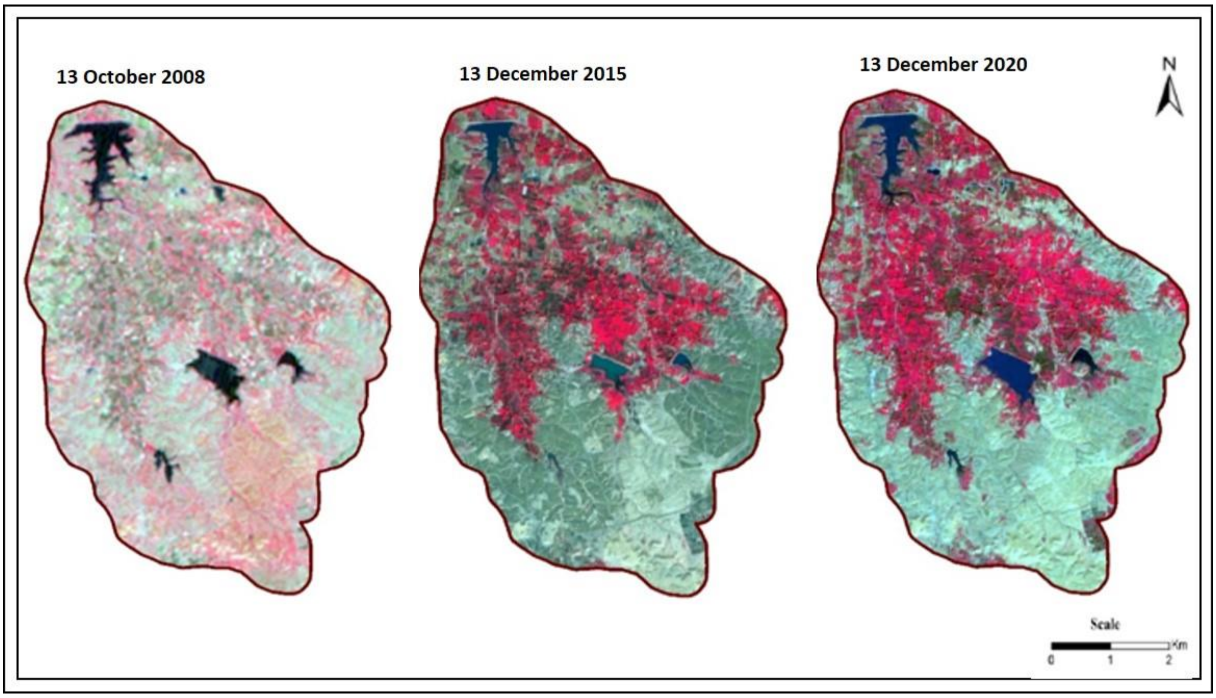


Figure 3-14 Temporal images of Motihandi Watershed

The monthly rainfall data from the year 2008 to 2020 procured from India Meteorological Department (IMD) website as shown in Table 3-10 below:

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
2008	0	0	0	0	0	35.7	163.8	267.7	120.3	5.4	0	0	592.9
2009	0	0	0	0	0	20	221	103.9	56.3	26.9	11.1	0	439.2
2014	18.8	0.4	0	0	0	0.6	194	136.3	206.8	5.4	0	0	562.3
2015	1.4	0	7.5	2.5	0	127.3	227	35.1	37.4	1.1	0	0	439.3

2016	0	0	0	0	0	44.9	230.5	341.7	113.9	48.9	0	0	779.9
2017	0	0	0	0	1	111.2	363.2	113	58.7	1.2	0	6.2	654.5
2018	0	0	0	0	0	77.1	230.8	199.3	64.5	0	0	0	571.7
2019	0	0	0	0	0	65	155.9	350.3	277.4	44.4	3	0	896
2020	0	0	0	0	0	59.7	79.6	360.1	79.6	3.8	0	5.7	588.5

Table 3-10 Monthly Rainfall (mm) of Motihandi watershed

The land use land cover (LULC) maps were prepared by on-screen digitization through the visual interpretation method. LULC changes were identified in treated watershed area by comparing multi temporal data i.e. pre (2008), during (2015) and post (2020) as shown in Figure 3-15. Table 3-11 shows the area change statistics. Figure 3-16 highlights the gradual transformation of different land use to crop land. The area transformation as visualised in Google Earth Imagery is shown in Figure 3-17.

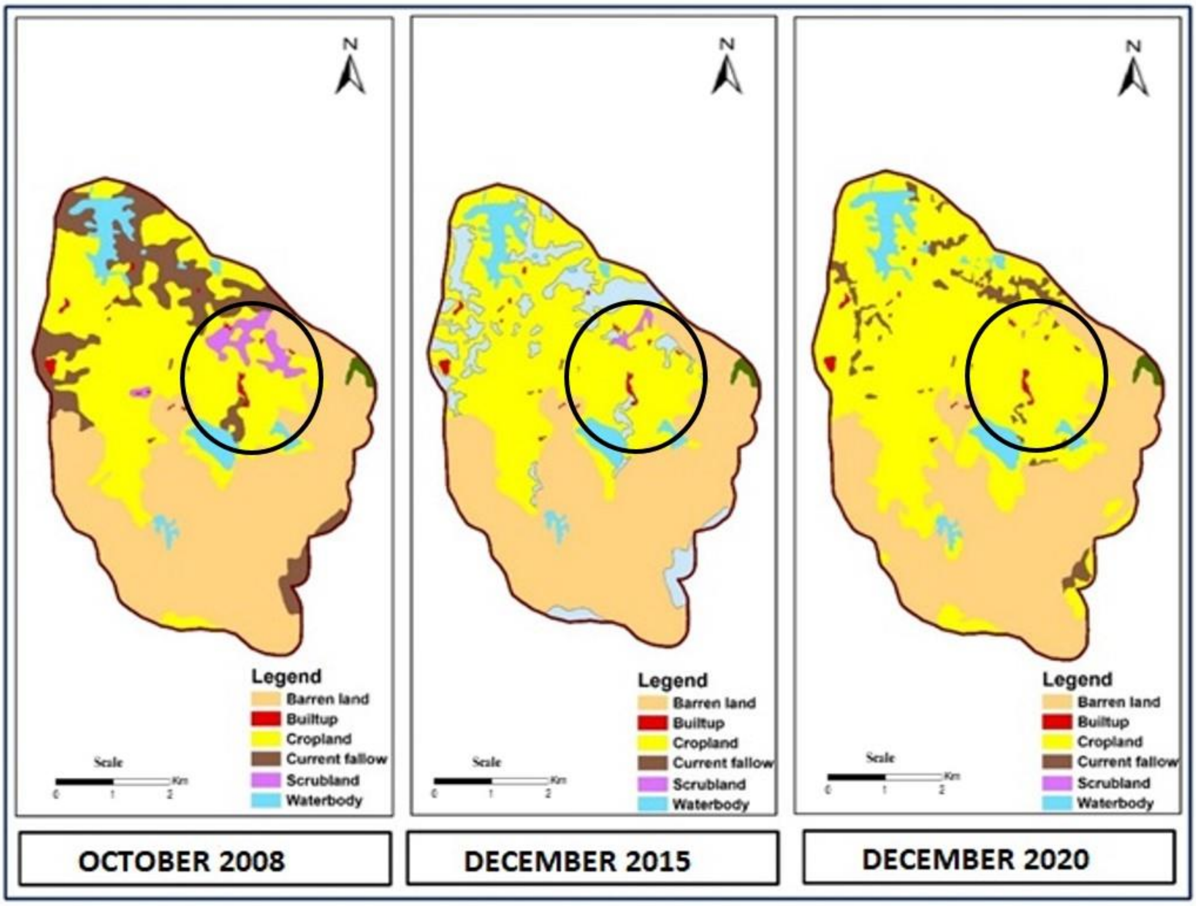


Figure 3-15 LULC Map of Motihandi Watershed for 2008, 2015 and 2020

LULC	Area under different LULC (ha)		
	2008 (ha)	**2015 (ha)**	**2020 (ha)**
Crop Land	654.27	756.89	978.92
Current Fallow	235.73	214.37	63.7
Scrub Land	41.68	7.8	1.46
Barren Land	860.89	857.66	764.93
Builtup Land	9.88	10.21	10.33
Waterbody	78.12	33.64	61.25
Forest	7.6	7.6	7.6
Total Area (ha)	**1888.18**	**1888.18**	**1888.18**

Table 3-11 Distribution of LULC in Motihandi watershed

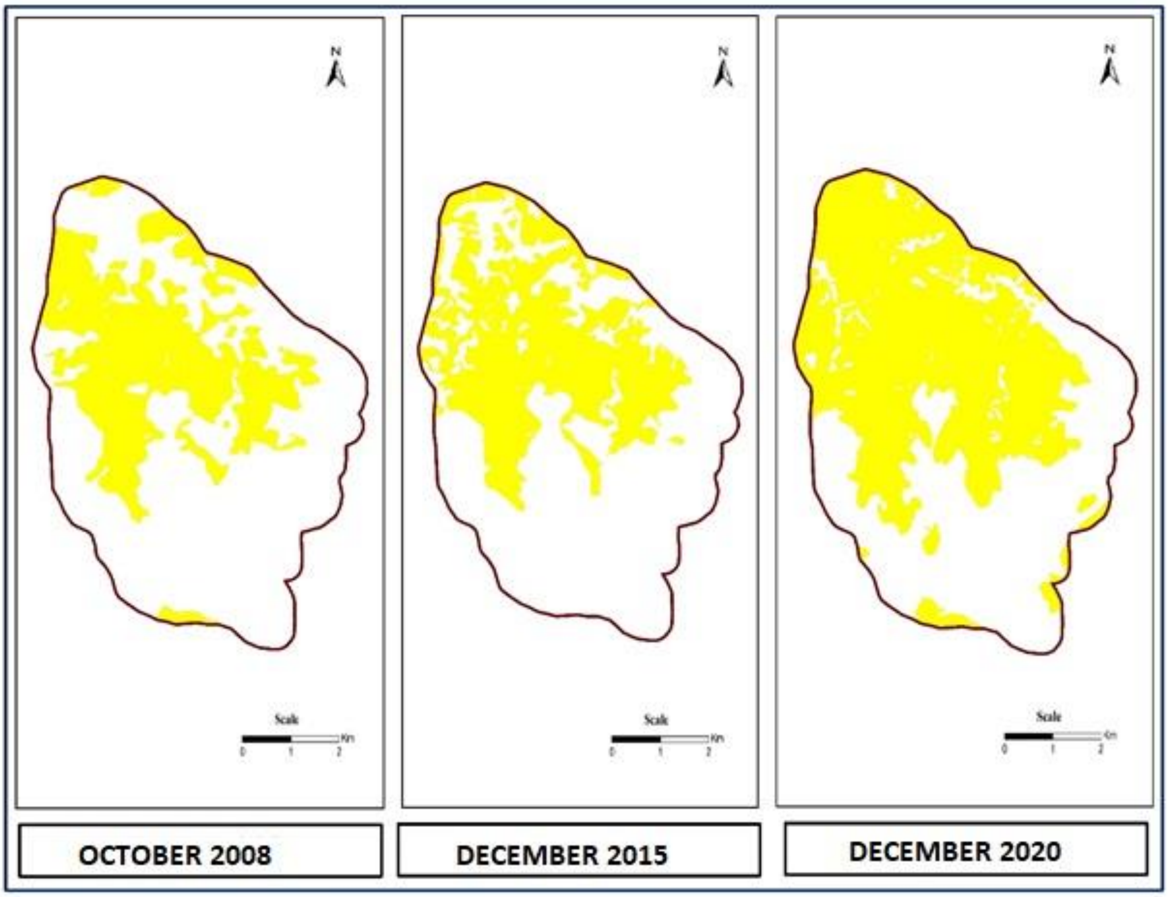


Figure 3-16 Transformation of different land-use to cropland of Motihandi watershed

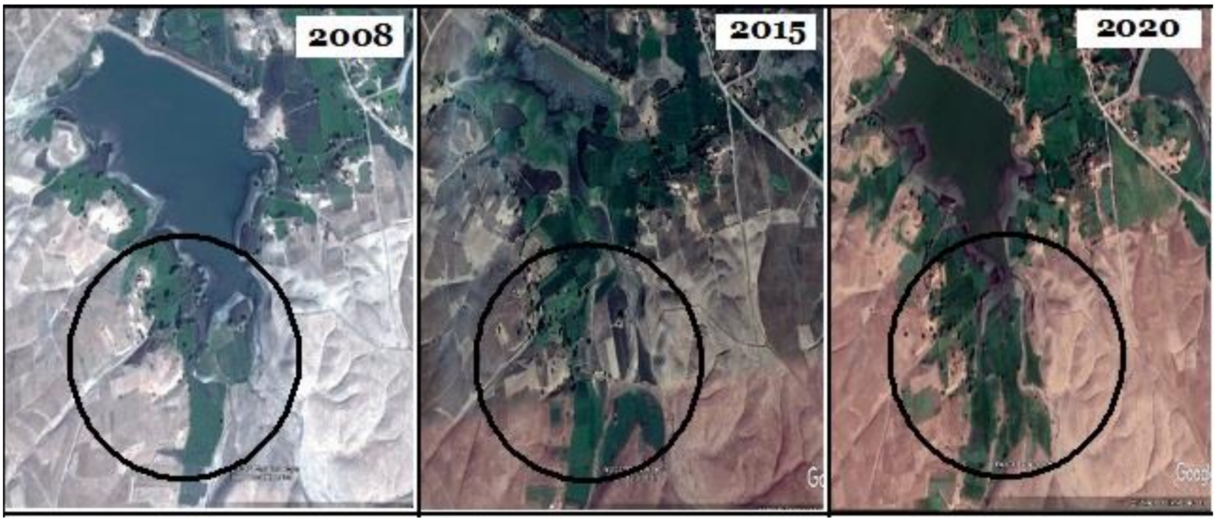


Figure 3-17 Area under Transformation as visualized on Google Earth Imagery of Motihandi watershed

The LULC maps were correlated with high resolution Google Earth imagery for validating the changes (Figure 3-18). Also, results were correlated with the photographs of geotagged assets. Geotagged photographs of Cemented Check Dam, one of the interventions in Motihandi Village, as seen on NABARD Bhuvan Portal and Google Earth is shown in Figure 3-18. The magnitude of change and annual rate was estimated for the period of study as shown in Table 3-12 below:

Figure 3-18 Cemented Check Dam, Motihandi Village (a) Geotagged Photographs (b) NABARD Bhuvan Portal (c) Google Earth of Motihandi watershed

Sr. No.	LULC	LULC change from 2008 to 2020	
		Magnitude of change (ha)	**Annual rate of change (ha/Year)**
1	Crop Land	(+) 324.65	(+) 27.05
2	Current Fallow	(-) 172.03	(-) 14.34
3	Scrub Land	(-) 40.22	(-) 3.35
4	Barren Land	(-) 95.96	(-) 8
5	Builtup Land	(+) 0.45	(+) 0.04
6	Waterbody	(-) 16.87	(-) 1.41
7	Forest	0	0

Table 3-12 LULC change assessment of Motihandi watershed

3.3.3 Conclusion

The study was conducted to identify changes in land use and land cover in the Motihandi watershed in the Dahod district of Gujarat.

The total area under cultivation in the study area was 654.27 ha (34.65% of total area) during the year 2008, which increased to 756.89 ha in the year 2015 and 978.92 ha (51.84% of total area) in the year 2020. Scrub land of around 40 ha and current fallow land of around 172 ha were transformed to crop land. The other land use classes like barren land, built up land, and waterbody underwent through marginal changes during the study period of 2008 to 2018.

The analysis of annual rate of change in LULC of Motihandi watershed confirmed the similar trend of increase in area of cropland, built-up land and water body and decrease in area of current fallow land and scrubland.

The soil and water conservation structures like stone gully plug, check dam, field bund, farm pond, stone gully plug and continuous contour trench were made in Motihandi village within the watershed. Total 22 activities were implemented and geotagged. The significant increase in cropland area in the Motihandi watershed is a positive aspect of development.

3.4 Lathibari Watershed, Godda District of Jharkhand State

3.4.1 Study area

Lathibari watershed is located in Godda district of Jharkhand state and covers an area of 915.98 hectares. The watershed extents from 24° 41' 57'' to 24° 44' 03'' North latitude and from 87° 13' 31'' to 87° 15' 26'' East longitude (Figure 3-19). Lathibari is hilly and undulating terrain with elevation varying between 128 m – 182 m from mean sea level. The watershed project was supported under WDF. Capacity Building Phase of the project was sanctioned in 2014 and the project completed in 2020 benefitting 962 households.

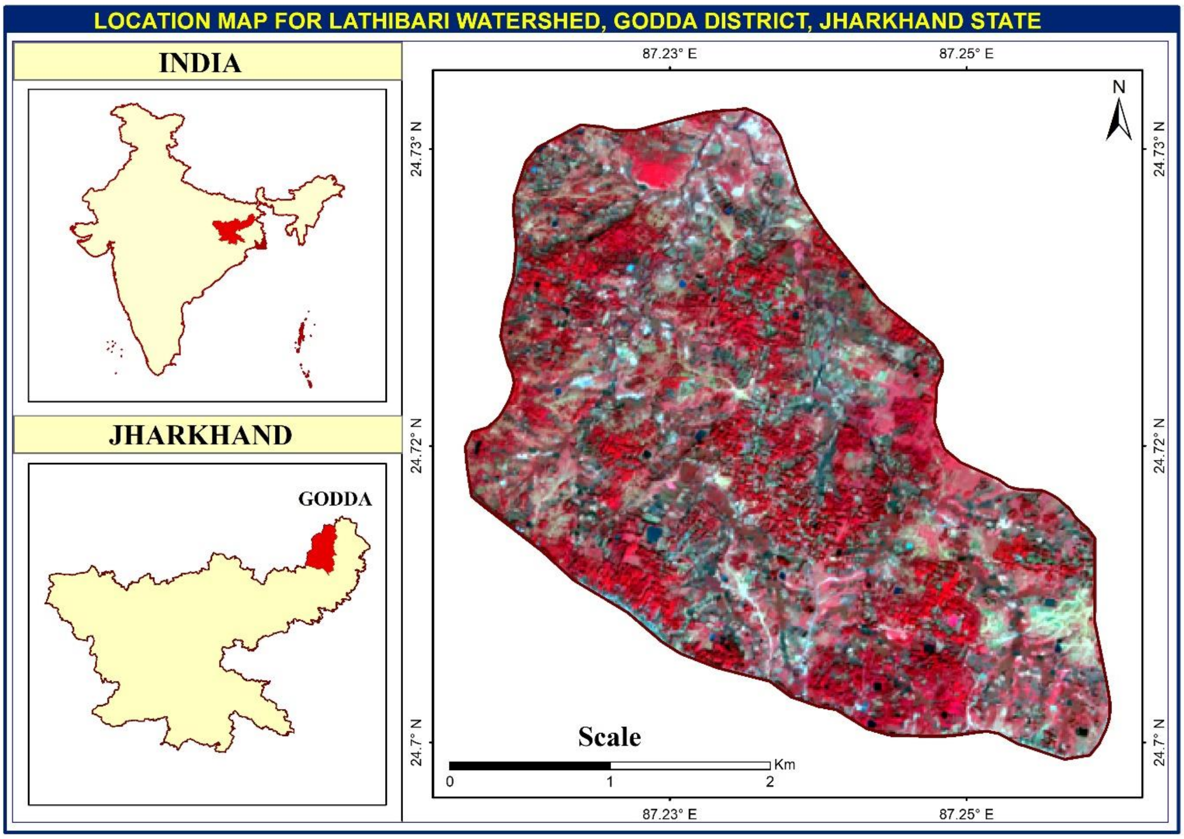


Figure 3-19 Location map of Lathibari watershed

3.4.2 Comparative Assessment of Land Use Land Cover for Pre – Post Implementation

The study evaluated the Land Use Land Cover (LULC) changes in Lathibari watershed occurred in pre-post implementation of NABARD assisted watershed development project. IRS-LISS-III and sentinel 2 multi-temporal satellite images were utilised to analyse and quantify the changes in land use land cover (Figure 3-20). To achieve the same, two satellite images pertaining to pre - post implementation stages were utilised. The details of satellite data used for change detection analysis are given in the Table 3-13 below:

Sr. No.	Satellite/Sensor	Date of Pass	Season
1	LISS III	04-Nov-14	Rabi
2	Sentinel 2	10-Nov-20	Rabi

Table 3-13 Specifications of satellite data of Lathibari watershed

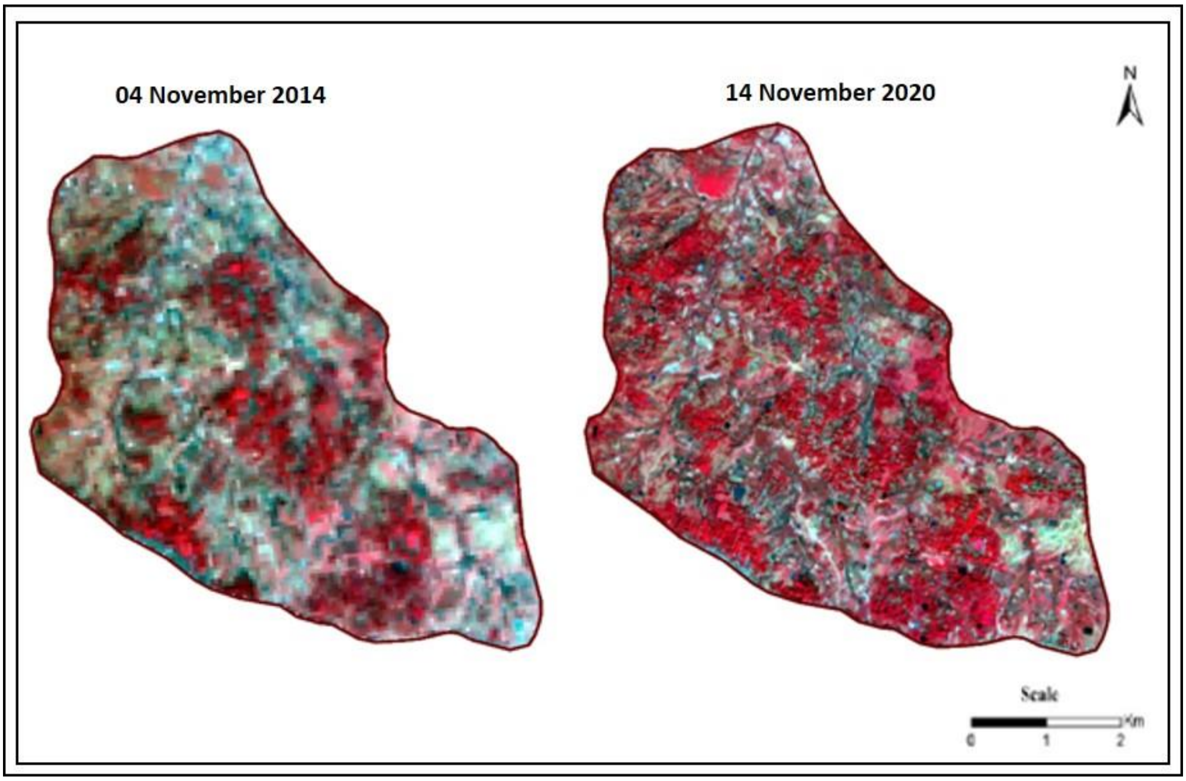


Figure 3-20 Temporal images of Lathibari Watershed

Monthly rainfall data from the year 2016 to 2020 procured from India Meteorological Department (IMD) website as shown in Table 3-14 below:

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
2016	9.1	3.4	0.3	2.3	60.2	100.9	299.5	151.1	255.5	27.2	0	0	909.5
2017	1.4	0	5.2	0	21.4	36.7	340	136.5	167.8	202.2	0	1.2	912.4
2018	0	1.7	0	34.2	44.9	124.4	254.6	196.4	65.7	53.9	0	8.3	784.1

2019	0	0	0	32.4	87.3	23.3	179	63.9	290.2	91.5	0	3.9	771.5
2020	1.2	29.4	36.8	48.9	88	202.3	239.6	109.3	268.3	37.7	0	0	1061.5

Table 3-14 Monthly Rainfall (mm) of Lathibari watershed

The land use land cover (LULC) maps were prepared by on-screen digitization through the visual interpretation method. LULC changes were identified in treated watershed area by comparing multi temporal data i.e. pre (2014) and post (2020) as shown in Figure 3-21. Table 3-15 shows the area change statistics. Figure 3-22 highlights the gradual transformation of different land use to crop land. The area transformation as visualised in Google Earth Imagery is shown in Figure 3-23.

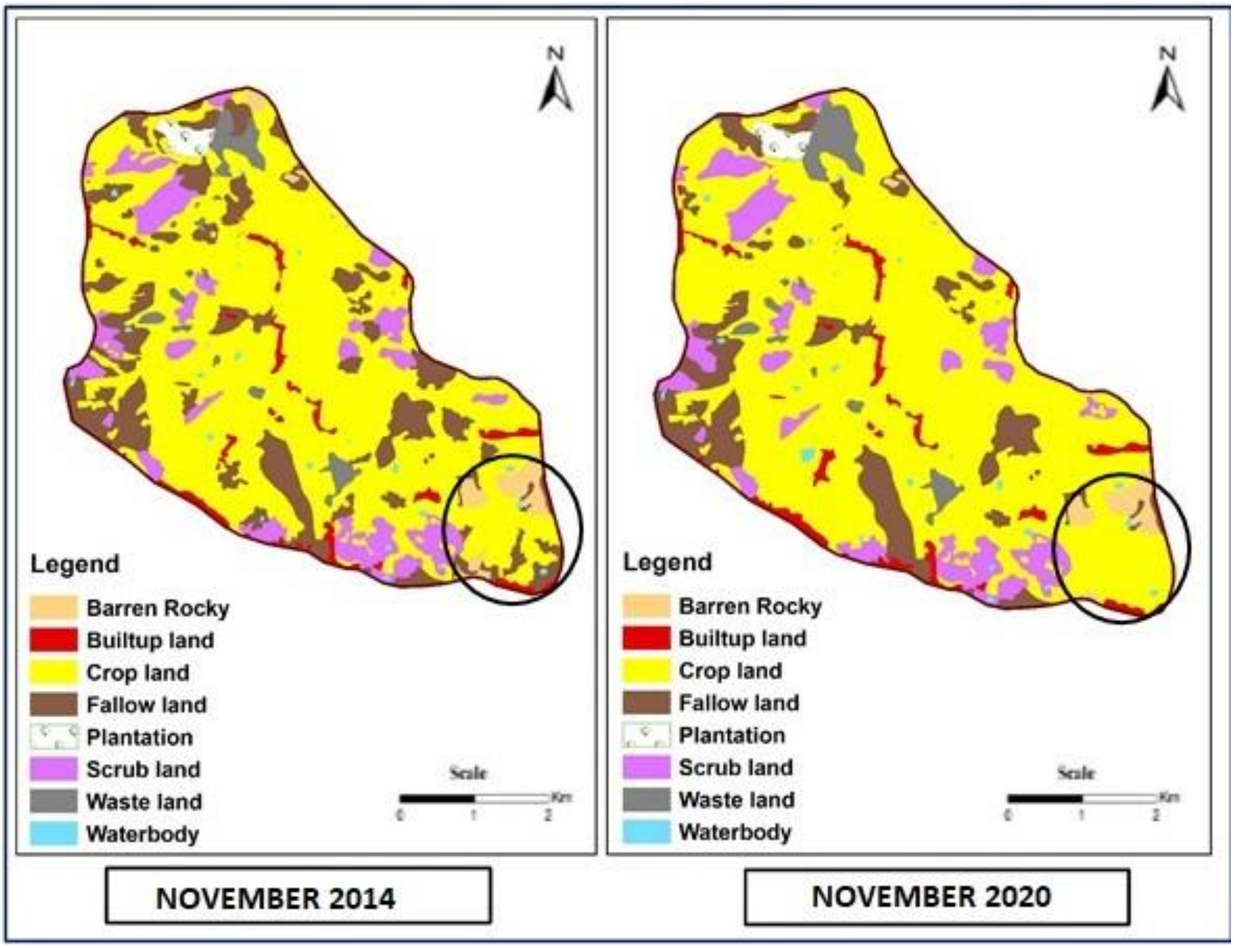


Figure 3-21 LULC Map of Lathibari Watershed for 2014 and 2020

LULC	**Area under different LULC (ha)**	
	2014 (ha)	**2020 (ha)**
Crop Land	589.67	641.37

Current Fallow	160.49	111.3
Scrub Land	85.59	83.31
Barren Land	19.23	15.69
Builtup Land	25.75	29.8
Waterbody	4.57	5.36
Waste Land	22.3	20.79
Plantation	8.37	8.37
Total Area (ha)	**915.98**	**915.98**

Table 3-15 Distribution of LULC in Lathibari watershed

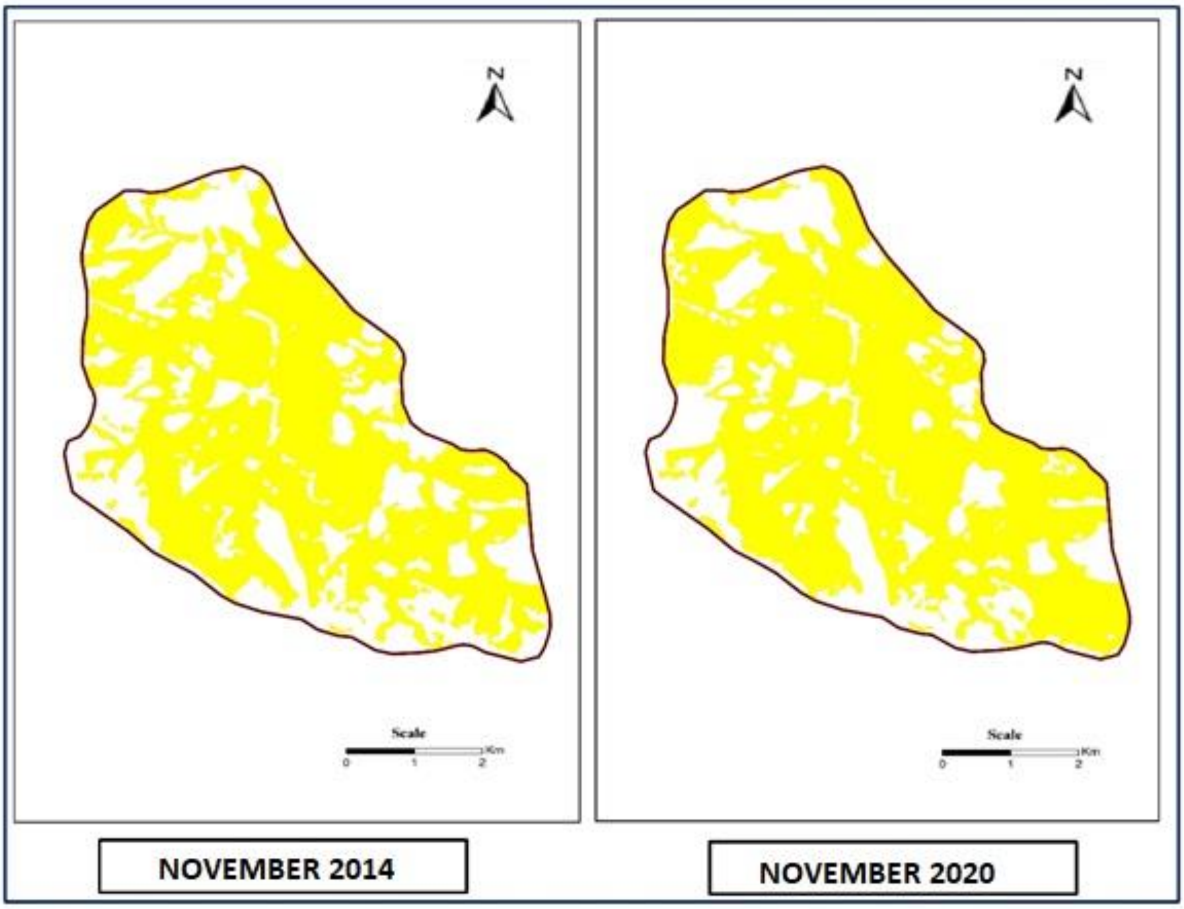


Figure 3-22 Change in crop pattern from year 2014 to 2020 of Lathibari watershed

Figure 3-23 Area under Transformation as visualized on Google Earth Imagery of Lathibari watershed

The LULC maps were correlated with high resolution Google Earth imagery for validating the changes (Figure 3-24). Also, results were correlated with the photographs of geotagged assets. Geotagged photographs of Cemented Check Dam, one of the interventions in Lathibari Village, as seen on NABARD Bhuvan Portal and Google Earth is shown in Figure 3-24. The magnitude of change and annual rate was estimated for the period of study as shown in Table 3-16 below:

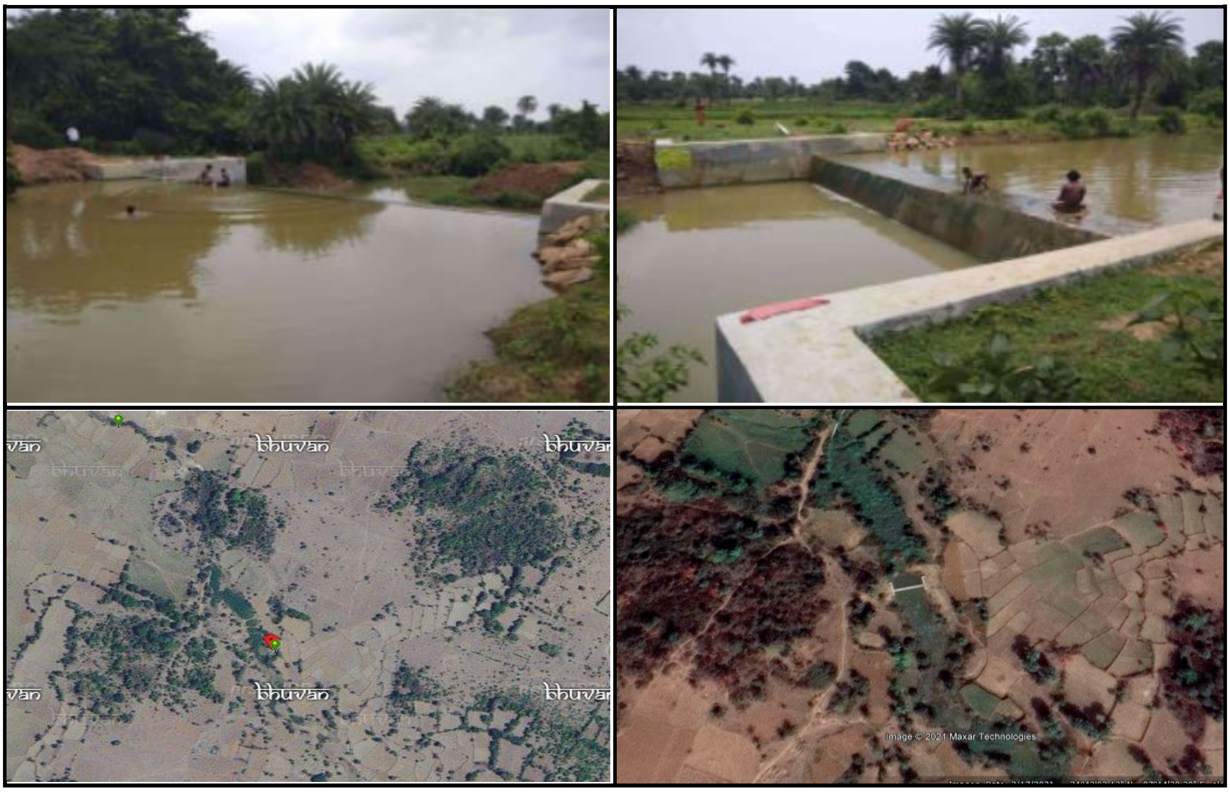


Figure 3-24 Cemented Check Dam, Lathibari Village (a) Geotagged Photographs (b) NABARD Bhuvan Portal (c) Google Earth of Lathibari watershed

Sr. No.	LULC	LULC change from 2014 to 2020	
		Magnitude of change (ha)	Annual rate of change (ha/Year)
1	Crop Land	(+) 51.7	(+) 8.62
2	Current Fallow	(-) 49.19	(-) 8.20
3	Scrub Land	(-) 2.28	(-) 0.38
4	Barren Land	(-) 3.54	(-) 0.59
5	Builtup Land	(+) 4.05	(+) 0.68
6	Waterbody	(+) 0.79	(+) 0.13
7	Waste Land	(-) 1.51	(-) 0.25
8	Plantation	0	0

Table 3-16 LULC change assessment of Lathibari watershed

3.4.3 Conclusion

The study was conducted to identify changes in land use and land cover in the Lathibari watershed in the Godda district of Jharkhand.

The total area under cultivation in the study area was 589.67 ha (64.37% of total area) during the year 2014, which increased to 641.37 ha (70.02% of total area) in the year 2020. Current fallow land of around 49 ha and scrub land 2 ha were transformed to crop land. The other land use classes like barren land, built up land, plantation and waterbody underwent through marginal changes during the study period of 2014 to 2020.

The analysis of annual rate of change in LULC of Lathibari watershed confirmed the similar trend of increase in area of cropland, built-up land and water body and decrease in area of current fallow land and scrubland.

The soil and water conservation measures like water resource development - farm pond, drum check dam, cemented check dam, NRM plantation and horticulture - vegetable cultivation, dryland horticulture, agroforestry, NRM soil conservation – gabion, loose boulders, field bund, earthen gully plugs, stone gully plug etc. were carried at lathibari village within the watershed. Total 62 activities were implemented and geotagged. The significant increase in cropland area in the lathibari watershed is a positive aspect of development.

3.5 Bayyaram Watershed, Karimnagar District of Telangana State

3.5.1 Study area

Bayyaram watershed is located in Karimnagar district of Telangana state and covers an area of 2427.4 hectares. The watershed extents from 18° 33' 16'' to 18° 35' 52'' North latitude and from 79° 54' 28'' to 79° 58' 22'' East longitude (Figure 3-25). Bayyaram is hilly and undulating terrain with elevation varying between 130 m – 171 m from mean sea level. The watershed project was supported under IGWDP. Capacity Building Phase of the project was sanctioned in 2009 and the project completed in 2014 benefitting 530 households.

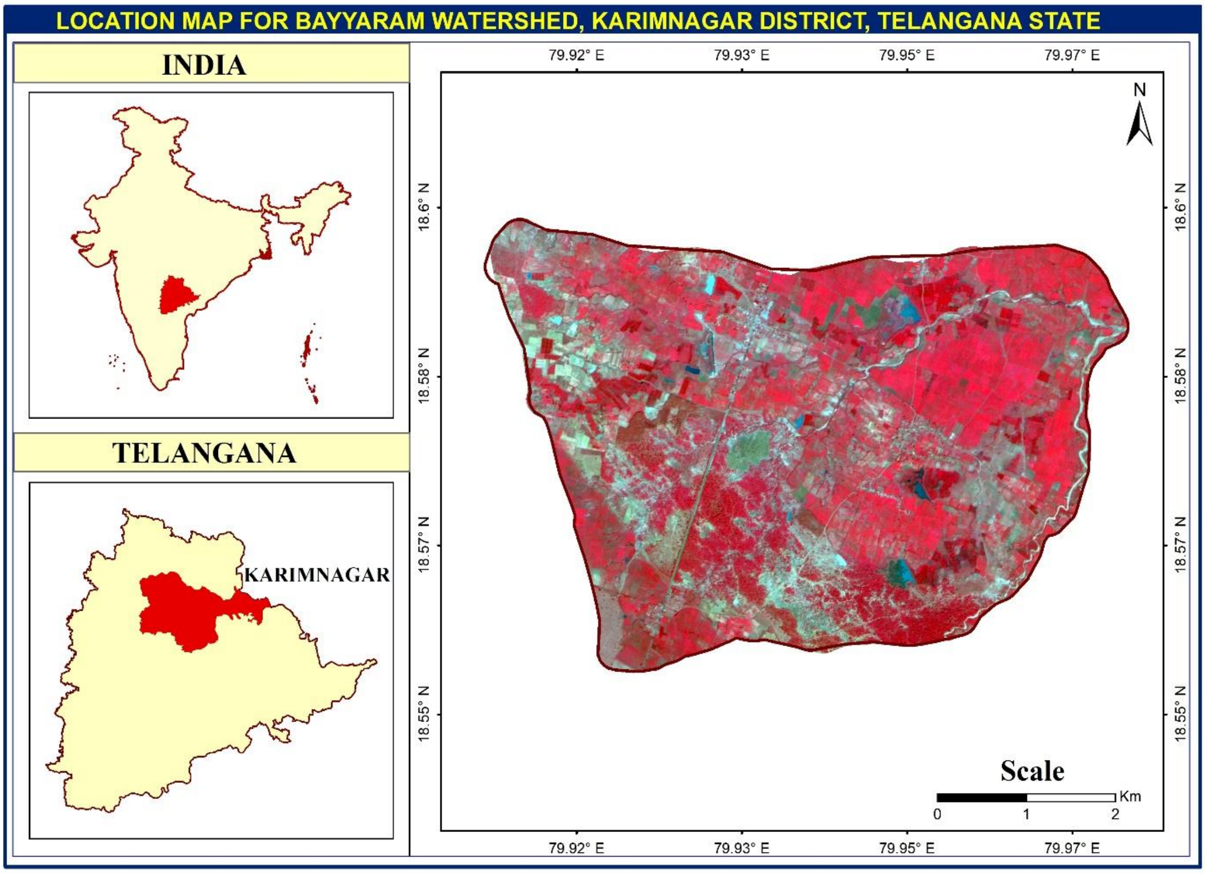


Figure 3-25 Location map of Bayyaram watershed

3.5.2 Comparative Assessment of Land Use Land Cover for Pre – During – Post Implementation

The study evaluated the Land Use Land Cover (LULC) changes in Bayyaram watershed occurred in pre-during-post implementation of NABARD assisted watershed development project. IRS-LISS-IV and Sentinel 2 multi-temporal satellite images were utilised to analyse and quantify the changes in land use land cover (Figure 3-26). To achieve the same, three satellite images pertaining to pre - during – post implementation stages were utilised. The details of satellite data used for change detection analysis are given in the Table 3-17 below:

Sr. No.	Satellite/Sensor	Date of Pass	Season
1	LISS IV	24-Oct-09	Rabi
2	LISS IV	29-Oct-14	Rabi
3	Sentinel 2	07-Feb-21	Rabi

Table 3-17 Specifications of satellite data of Bayyaram watershed

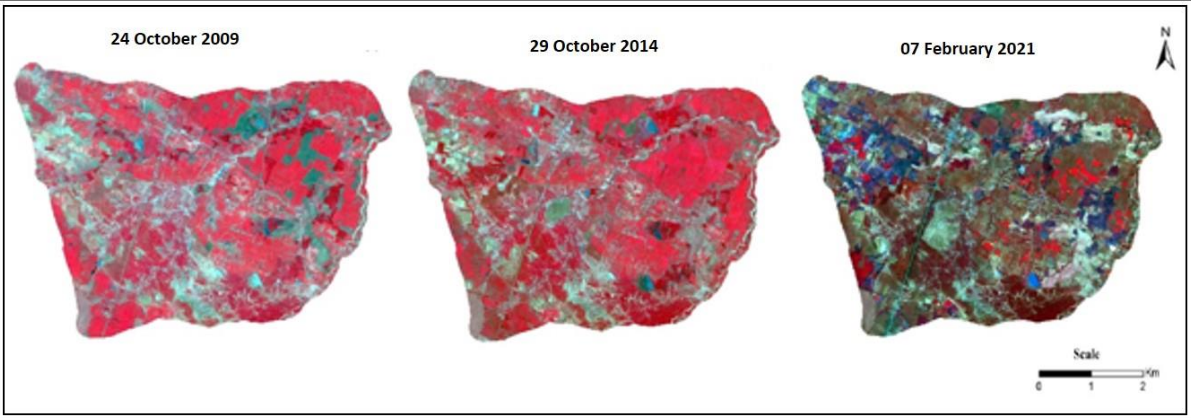


Figure 3-26 Temporal images of Bayyaram Watershed

Monthly rainfall data from the year 2008 to 2020 procured from India Meteorological Department (IMD) website as shown in Table 3-18 below:

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
2008	0	0	0	0	0	35.7	163.8	267.7	120.3	5.4	0	0	592.9
2009	0	0	0	0	0	20	221	103.9	56.3	26.9	11.1	0	439.2
2014	18.8	0.4	0	0	0	0.6	194	136.3	206.8	5.4	0	0	562.3
2015	1.4	0	7.5	2.5	0	127.3	227	35.1	37.4	1.1	0	0	439.3
2016	0	0	0	0	0	44.9	230.5	341.7	113.9	48.9	0	0	779.9
2017	0	0	0	0	1	111.2	363.2	113	58.7	1.2	0	6.2	654.5
2018	0	0	0	0	0	77.1	230.8	199.3	64.5	0	0	0	571.7
2019	0	0	0	0	0	65	155.9	350.3	277.4	44.4	3	0	896
2020	0	0	0	0	0	59.7	79.6	360.1	79.6	3.8	0	5.7	588.5

Table 3-18 Monthly Rainfall (mm) of Bayyaram watershed

The land use land cover (LULC) maps were prepared by on-screen digitization through the visual interpretation method. LULC changes were identified in treated watershed area by comparing multi temporal data i.e. pre (2009), during (2014) and post (2021) as shown in Figure 3-27. Table 3-19 shows the area change statistics. Figure 3-28 highlights the gradual transformation of different land use to crop land. The area transformation as visualised in Google Earth Imagery is shown in Figure 3-29.

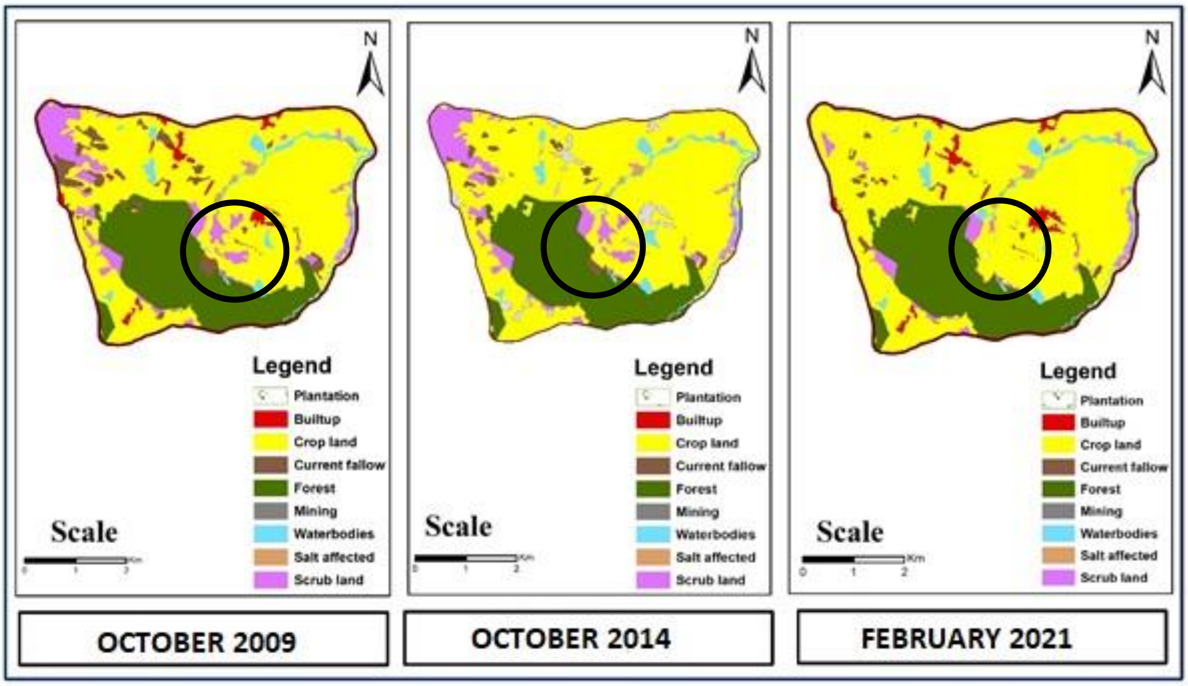


Figure 3-27 LULC of Bayyaram Watershed for 2009, 2014 and 2021

LULC	Area under different LULC (ha)		
	2009 (ha)	2014 (ha)	2021 (ha)
Crop Land	1432.2	1588.4	1622.1
Current fallow	96.5	40.3	26.4
Scrub land	208.2	101.2	75.3
Built up	43.1	48.8	52.1
Waterbody	76.6	77.8	80.5
Forest	560.4	560.4	560.4
Mining	0.8	0.8	0.8
Salt affected	8.6	8.6	8.6

Plantation	1.0	1.0	1.0
Total Area (ha)	**2427.4**	**2427.4**	**2427.4**

Table 3-19 Distribution of LULC in Bayyaram watershed

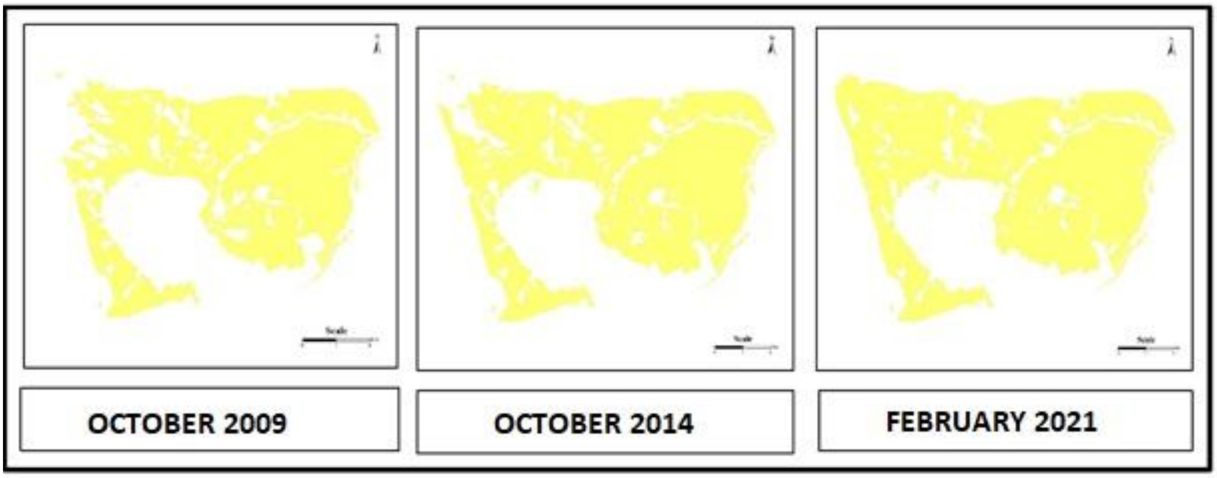


Figure 3-28 Transformation of different land-use to cropland of Bayyaram watershed

Figure 3-29 Current fallow land transformation into the Crop land of Bayyaram watershed

The LULC maps were correlated with high resolution Google Earth imagery for validating the changes (Figure 3-30). Also, results were correlated with the photographs of geotagged assets. Geotagged photographs of Farm Pond, one of the interventions in Bayyaram Village, as seen on NABARD Bhuvan Portal and Google Earth is shown in Figure 3-30. The magnitude of change and annual rate was estimated for the period of study as shown in Table 3-20 below:

Figure 3-30 NRM soil conservation activity at field of Bayyaram watershed

Sr. No.	LULC	LULC change from 2009 to 2021	
		Magnitude of change (ha)	**Annual rate of change (ha/Year)**
1	Crop Land	(+) 189.9	(+) 15.83
2	Current Fallow	(-) 70.1	(-) 0.37
3	Scrub Land	(-) 132.9	(+) 1.90
4	Builtup Land	(+) 9	(-) 0.07
5	Waterbody	(+) 3.9	(+) 0.43

Table 3-20 LULC change assessment of Bayyaram watershed

3.5.3 Conclusion

The study was conducted to identify changes in land use and land cover in the Bayyaram watershed, Karimnagar district of Telangana.

The total area under cultivation in the study area was 1432.2 ha (59% of total area) during the year 2009, which increased to 1588.4 ha in the year 2014 and 1622.1 ha (66% of total area) in the year 2021. Scrub land of around 133 ha and 70 ha of current fellow were transformed to crop land. The other land use classes like built up land, and waterbody went through marginal changes while area under forest cover and mining remained same during the study period of 2009 to 2021.

The analysis of annual rate of change in LULC of Bayyaram watershed confirmed the similar trend of increase in area of cropland, built-up land and water body and decrease in area of current fallow land and scrubland.

The soil and water conservation measures like farm pond, bund plantation, field bund, grass seed were made at Rudraram village within the watershed. LWD livelihood activities - goat - sheep rearing, embroidery - tailoring activities, kirana – cutlery, trail auto, barbershop, dairy animals, formation of SHGs, flour mill etc. were carried out at Bayyaram village within the watershed. Total 167 activities were implemented and geotagged. The significant increase in cropland area in the Bayyaram watershed is a positive aspect of development.