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Monitoring of IWMP watershed project using geospatial technique-Sagar district, Madhya Pradesh

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Abstract
The Integrated Watershed Management Project (IWMP), which concentrates on integrated land, vegetation, and water resource management, is an important initiative aimed at sustainable development in rainfed areas. The project uses Geographic Information System (GIS) methods and satellite technology to efficiently plan, monitor, and evaluate IWMP activities, with the main objective of creating an extensive monitoring system for watershed resource management in the state.

The provision of crucial satellite data, GIS platforms, and software tools for planning is one of the project's main goals. It starts by providing all watersheds with baseline satellite images, which makes it easier to create Detailed Project Reports (DPRs) tailored to each watershed. The project incorporates regular satellite images to show temporal changes in these areas and also provides online Monitoring and Evaluation (M&E) for all identified watersheds. Resourcesa T_2 FMX and Cartosa T_1 PAN Satellite datasets were used in the IWMP project monitoring and evaluation processes. These sharp satellite images make it easier to monitor the changes brought on by the implementation of IWMP and accurately assess its effects. The project further improves its monitoring capabilities by utilizing mobile Smartphone technology to gather Point of Interest (POI) data. The acquisition of micro watershed and project boundaries from pertinent authorities, the preparation of Land Use Land Cover (LULC) maps for project areas, the creation of change area maps and change matrices, and finally the creation of a comprehensive summary report are the key steps in the monitoring and evaluation process.

The study area falls in Sagar district of Madhya Pradesh. The project area is 8981.14 ha. Activities done are trench (02), field bunds (09), farm ponds (03), check dam /stop dam (57), Nallah bunds (05) checks & plugs (03) etc. The LULC shows that increase in agriculture, water surface area and decrease in scrubland (based on available satellite data and field survey of this area). The major change is increase in cropland by 275.89 Ha, and water bodies by 60.73 Ha.

Keywords: IWMP, satellite image, watershed

Introduction
The Integrated Watershed Management Program (IWMP) was launched by the Ministry of Rural Development Government of India in 2009. It aimed to improve natural resource management, increase agricultural productivity, enhance rural livelihoods, and reduce poverty in India's rainfed and degraded areas. The program recognized the critical importance of watersheds in the overall development of rural regions. The IWMP was a significant step toward integrated watershed management in India and was part of a broader effort to address rural development challenges in the country's rainfed regions. The program aimed to strengthen local communities' ability to manage their natural resources sustainably while improving their socioeconomic conditions. Migration from villages to urban areas is a common occurrence in India nowadays due to the lack of means of subsistence in rural India. Thus they create so many problems in urban areas. Agriculture is a dominant means of livelihood in backward areas, and agricultural production depends on the monsoon. If we want develop agriculture and increase natural resource like ground water then we have to create a plan for develop an area. Watershed management program is one of the most popular practice for decrease dependency on monsoon for agriculture and also very helpful for natural resource management. So government take initiative and started IWMP program.

Objectives
This study find out the impact of this IWMP program result in the ground with the help of space technology. How much area conserve and which type of land decrease or increase.

There are some objectives

- Monitoring impact of IWMP activities using time series (5 year) high resolution satellite data.
- Observed transparency and accountability of Integrated Watershed Management Programme implemented work.
- Geospatial technology and mobile based data collection applying in watershed development monitoring.

Study Area

The watershed of our study area is fall under the Sagar district Shahgarh block Madhya Pradesh. The micro watershed Divided into 7 parts namely 2C2C1u2, 2C2C1u3, 2C2C1u4, 2C2C4a4, 2C1E6u3, 2C1E6u1, 2C1E6u2. The total area of these 7 micro watershed is 8981.14 ha. (Based on GIS tool) location Map of the study area is shown in Figure-1.

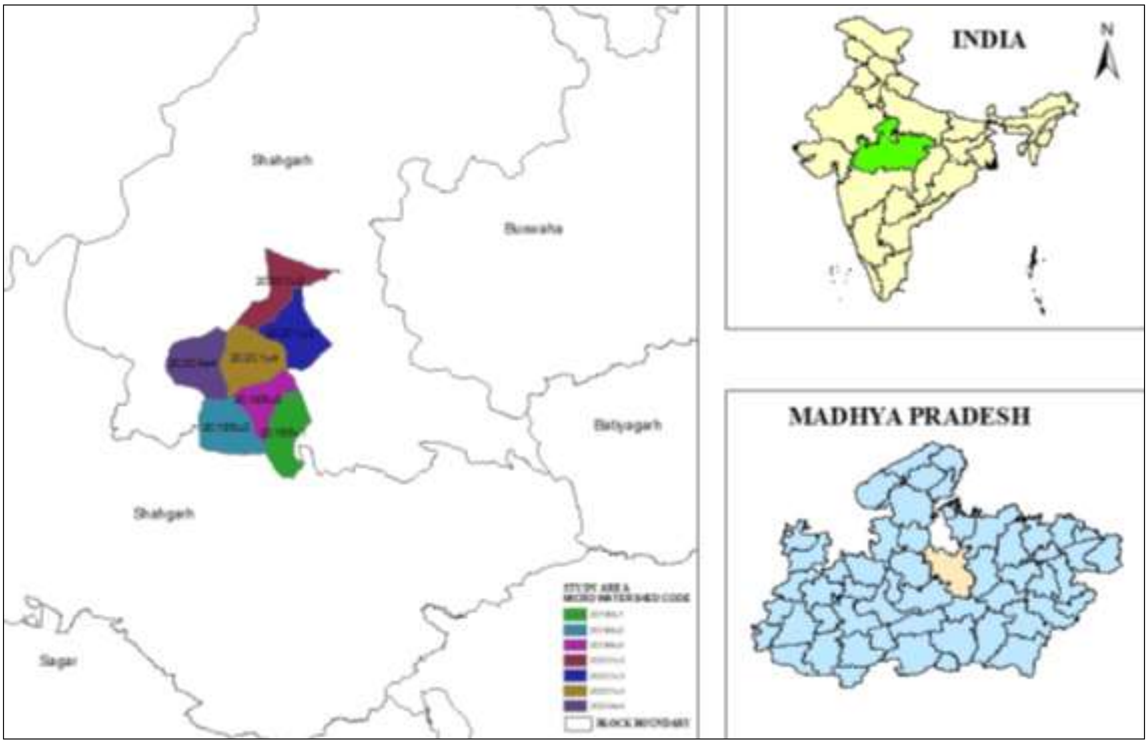


Fig 1: Location map of study area

Data and Methods

Monitoring for IWMP project result various data were used. Satellite image, watershed boundary, drainage, and field data used for different types of analysis. Like LULC, NDVI etc. The description of process of this study are below:

- **Satellite Imagery Collection:** Acquire satellite imagery for the base year (2010-11) and the following five years (2014-15, 2015-16, 2016-17, 2017-18, and 2018-19). High resolution satellite image, Linear Imaging self-scanner-4 (LISS-4) used with cartosaT_1 pan merge. The spatial resolution of LISS-4 is 5.8 m and CartosaT_1 pan is 2.5 m. After pan merge final image resolution is 2.5 m.
- **LULC Map Generation (Visual Interpretation) and NDVI Index:** Utilize visual interpretation techniques to generate Land Use and Land Cover (LULC) maps for each of the specified years using the acquired satellite imagery. Additionally, calculate the Normalized Difference Vegetation Index (NDVI) for each time period to assess vegetation health and density. Mapping of Land Use and Land Cover (LULC) for each of the past five years has been carried out separately for each individual year. Starting from years 2014-2015 and end years 2017-2018. Assign name to every years as T_0, T_1, T_2, T_3, T_4, and T_5.
- **Comparative Analysis:** Compare the LULC maps from different years to identify changes and trends within the watershed area in GIS software. Union geo-processing tool apply for comparing LULC. There are five classes of LULC and calculated area of each class and compare how much area increase or decrease.
- **Matrix Analysis in Excel:** Utilize Excel sheets to perform quantitative calculations using change matrices. This analysis helps overall change trend within the watershed area.
- **Watershed Activity Mapping:** There are so many structures are made for watershed development, like Afforestation, Horticulture, stop dam, check dam, Tank etc. some activities are visible in satellite image and some are not., Srishti and Drishti are very useful tool for monitoring IWMP activities. Both tools are allow us to extract to field data like geo-tagging photographs of the IWMP activities.

Srishti is a Bhuvan Geo-ICT web portal which provide essential tools and techniques to decision makers related to IWMP. Srishti facilitate implementation & monitoring IWMP at different levels.

Drishti is an application for smartphone based platform. It is designed and developed for field data collection. This application capture geo-tagging pictures of field activities like field bund, check dam, Farm pond, trenching etc. and upload in Bhuvan

Concluding Results

Based on the findings from the change matrices, draw conclusions regarding the changes that have occurred in the watershed area over the five years.

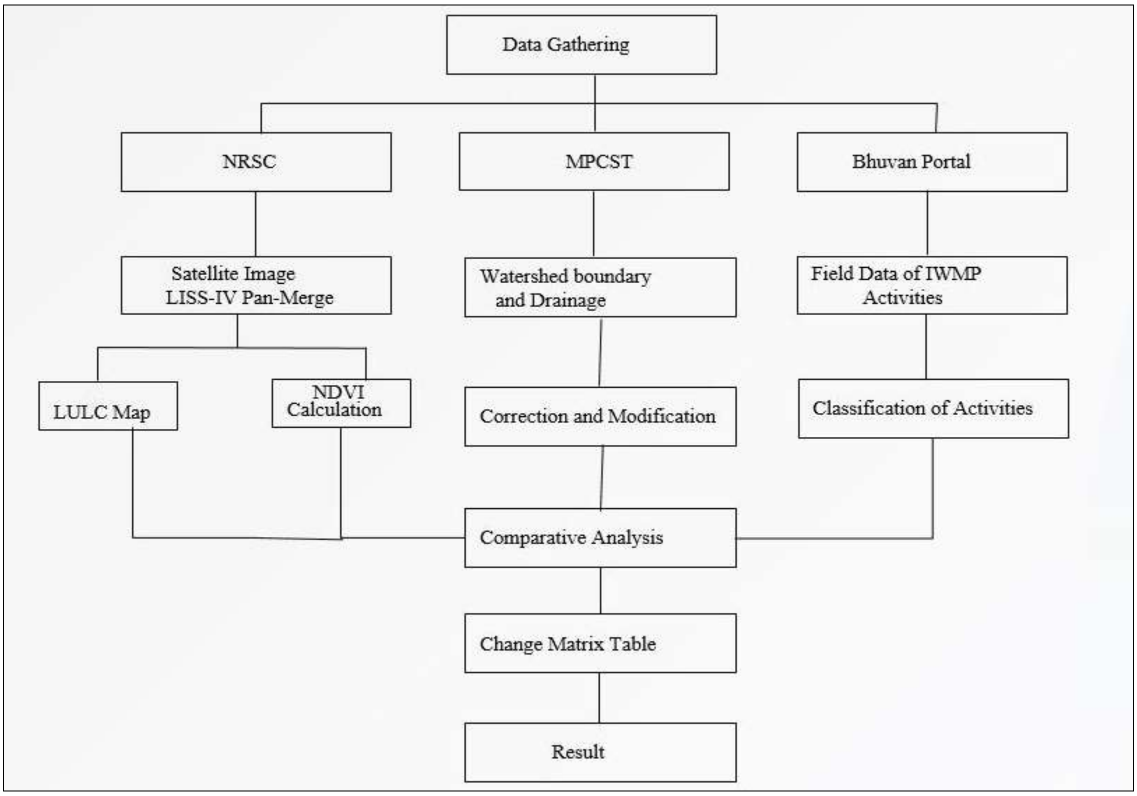


Fig 2: Methodology flowchart

Results and Discussion

Monitoring of IWMP program is very essential for transparency and accountability. Bhuvan geo portal play a crucial role in monitoring and evaluation this program. Because this geo portal provides geo-tagged photographs of the IWMP activities and help monitoring and evaluation. Satellite image provides LULC change assessment.

LULC Change Assessment

LULC Change Assessment refers to the process of evaluating and analyzing changes in Land Use and Land Cover (LULC) patterns over a specific period of time. This assessment typically involves comparing LULC data from different time periods to identify trends, shifts, and alterations in land use types and land cover classes within a given area, such as a watershed. The aim is to understand the drivers of change, assess the impact on the environment and communities, and inform future land management and planning decisions. LULC Change Assessment, or Land Use and Land Cover Change Assessment, is a process of analyzing and understanding changes that occur in the distribution and characteristics of land use and land cover over time within a specific geographic area. This assessment typically involves comparing data from different time periods, often utilizing satellite imagery and geographic information systems (GIS), to identify and quantify changes in various land use and land cover categories such as agriculture, forests, urban areas, water bodies, and barren land. The goals of LULC change assessment include:

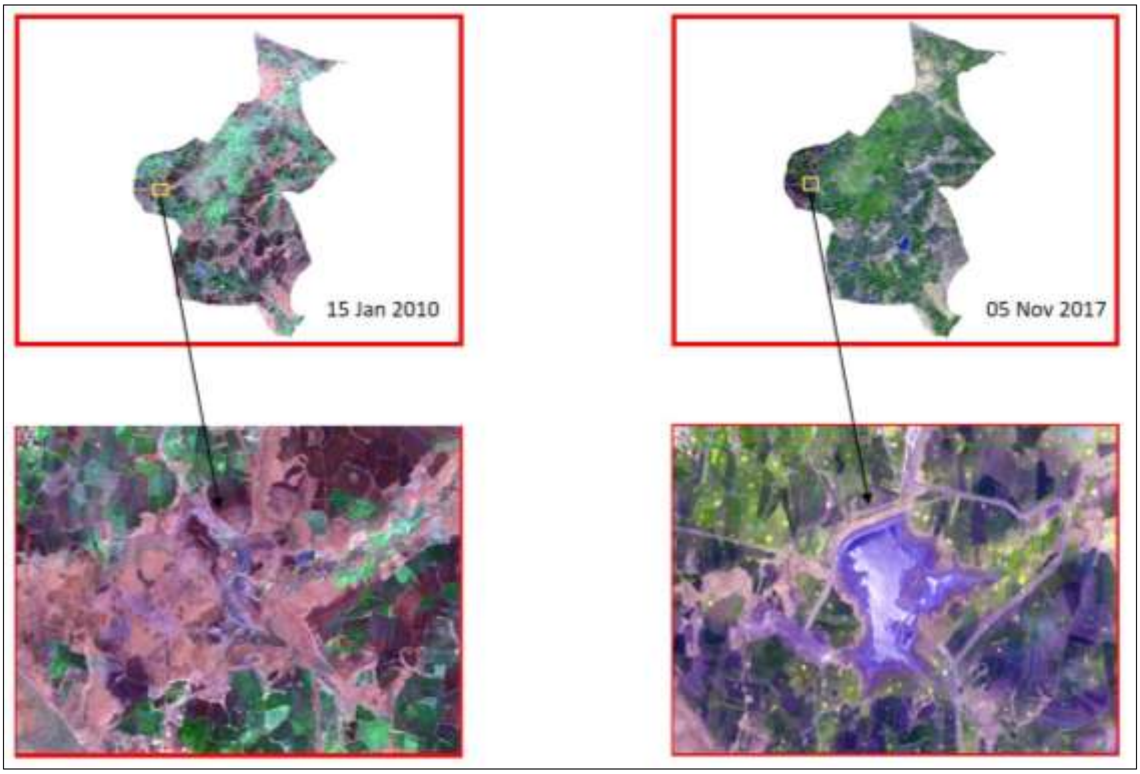
1. Understanding drivers of change: This initial phase involves examining the various factors and processes influencing alterations in land use and land cover. This includes studying phenomena such as urbanization, agricultural expansion, deforestation, and natural disasters. In the study area the main driver of change is increasing water bodies. The water bodies increase from 137.78 ha. To 192.68 in five years. There are 57 stop dam and check dam 10 farm pound found in the watershed area made which is increasing water bodies in the study area.

2. Identifying trends: Once the drivers of change are understood, the next step is to observe and analyze trends in land use and land cover categories. This involves determining whether these categories are experiencing growth, decline, or stability over time. The LULC divided into 8 categories. They are agriculture, built-up, canal, forest, mining/industrial, reservoir/tank, river/stream, and scrubland. The trend of this study is decreasing scrubland rapidly and agricultural land increasing. Reservoir, canal, built-up and mining are also expand. River/stream and forest are stable. There are no change in both forest and river over the years.

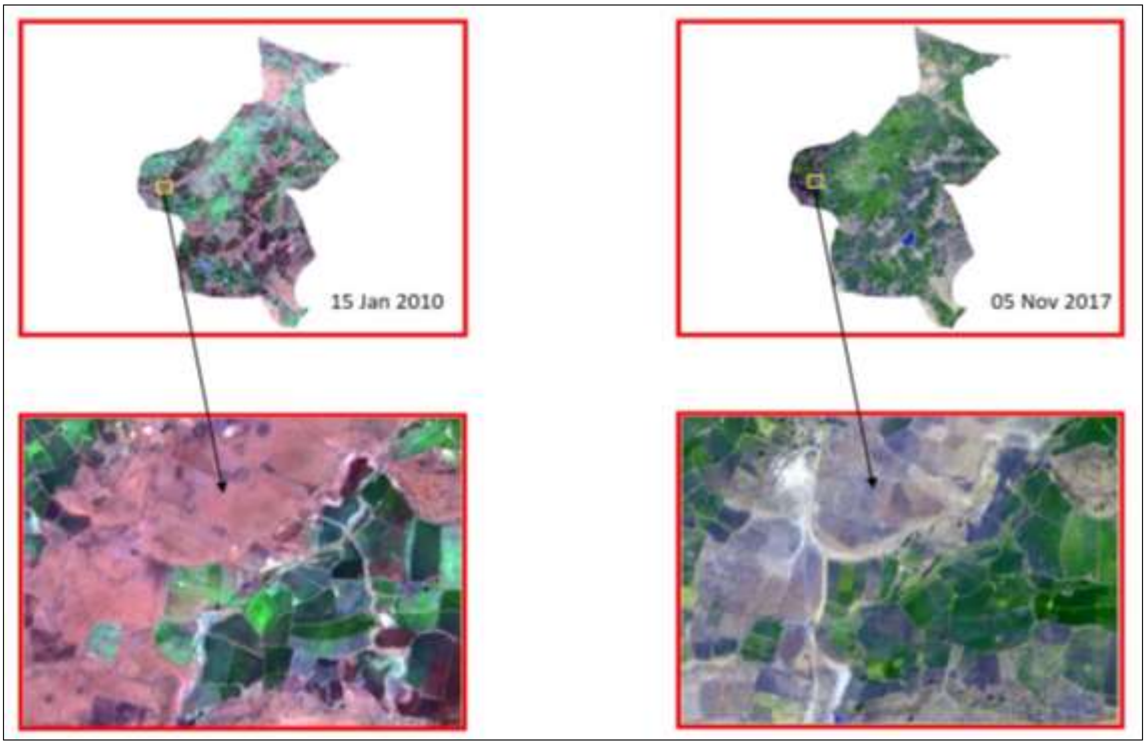
3. Assessing impacts: Following the identification of trends, it's crucial to evaluate the consequences of these changes. This assessment encompasses examining the environmental, social, and economic implications associated with alterations in land use and land cover. It involves understanding effects on biodiversity, water resources, climate, and human communities. Due to increase water bodies found progress in agriculture, vegetation, ground water.

4. Informing decision-making: Based on the insights gathered from understanding drivers, identifying trends, and assessing impacts, the final objective is to provide actionable information. This information aims to support informed decision-making processes related to land management, land-use planning, conservation efforts, and initiatives geared towards sustainable development. LULC change assessment is a valuable tool for policymakers, land managers, researchers, and other stakeholders to better understand landscape dynamics, anticipate future changes, and develop effective strategies for managing land resources and mitigating potential negative impacts.

In this paper analyze 5 years of change assessment and 2010-11 was a base year. The monitoring duration of this time period start from 2014-15 to 2018-19. In the watershed area in the base year 2010-11, the agricultural land covered 6239.83 hectares, built-up areas totaled 219.76 hectares, mining/industrial have 3.40 hectares, forests occupied 840.13 hectares, water bodies spanned 137.77 hectares, and wasteland encompassed 1540.24 hectares. The monitoring year 2014-15, the LULC classes occupied area as agriculture 6300.60 hectares, built-up 220.24, canal 10.79 hectares, forest 840.13 hectares, mining/industry 6.56 hectares, reservoir/tank 101.62 hectares, river/stream/drain 70.47 hectares, and scrubland 1430.72 hectares.



Conversion of Scrubland to Water body



Conversion of Scrubland to Cropland

Fig 3: Land use Land cover change

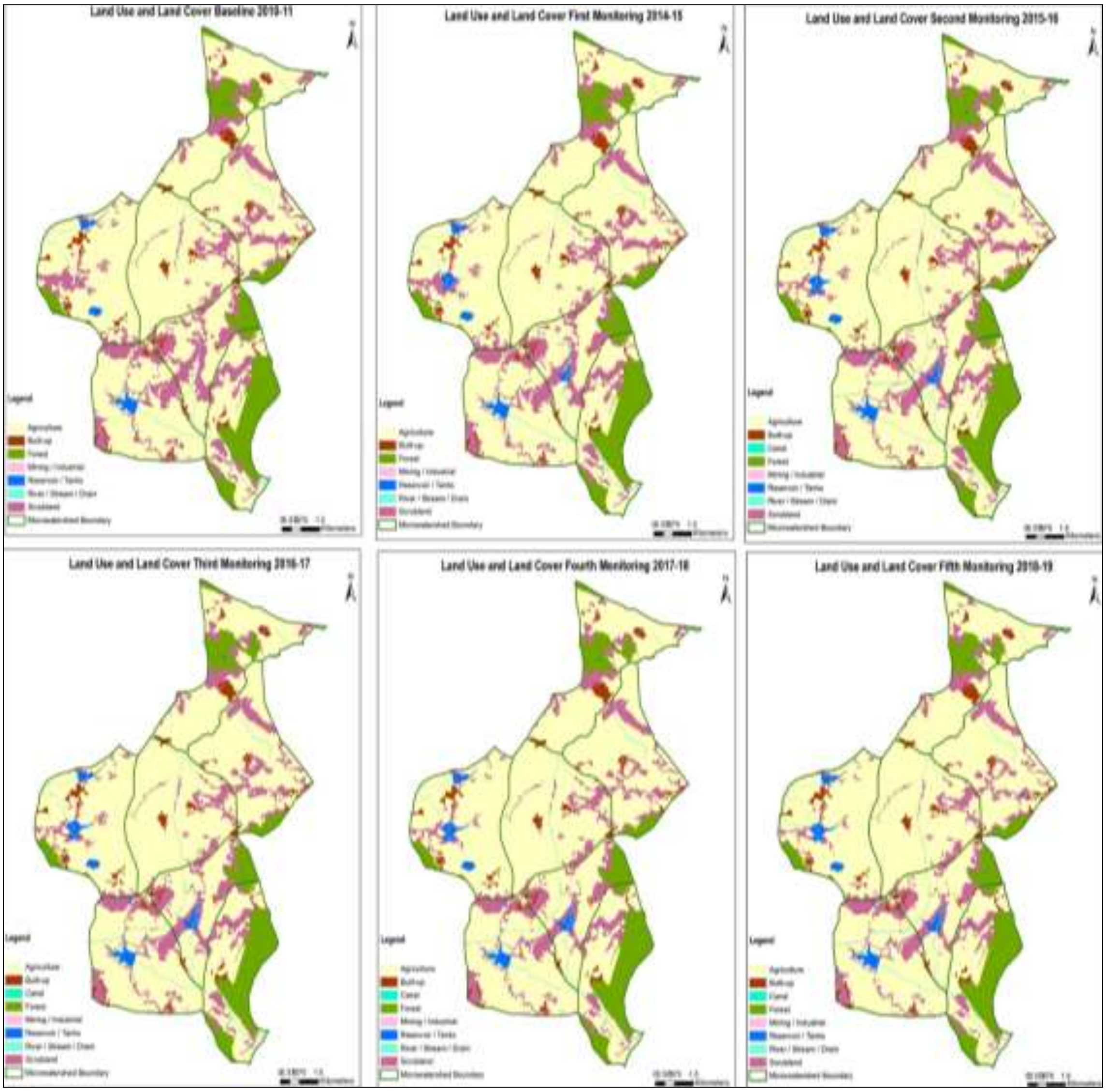


Fig 4: Land Use Land Cover Map 2010-11 to 2018-19

Change Matrix Analysis

Change Matrix Analysis is a method used to quantify and understand the changes that have occurred between two or more time periods in a specific geographic area, often in the context of land use and land cover (LULC) change assessment. This analysis involves comparing thematic maps or datasets representing different time periods and constructing a matrix to summarize the transitions between land cover categories.

Here's how the process typically works

1. Creation of Transition Matrix: The first step is to create a transition matrix, also known as a change matrix or conversion matrix. This matrix usually consists of rows and columns representing land cover classes or categories for two consecutive time periods. Each cell in the matrix indicates the number or percentage of pixels or areas that transitioned from one land cover class to another.

2. Quantifying Changes: Once the transition matrix is established, quantitative measures such as the total area of change, net change, gain, loss, persistence, and transition probabilities can be calculated. These measures provide insights into the magnitude and direction of changes in different land cover classes over time.

3. Interpretation and Analysis: The change matrix and associated metrics are then analyzed to identify patterns, trends, and drivers of land cover change. This analysis helps in understanding factors such as urbanization, agricultural expansion, deforestation, and reforestation influencing landscape dynamics.

4. Visualization: Visual representations such as thematic maps, bar charts, and graphs are often used to present the results of change matrix analysis in a clear and understandable manner, facilitating communication and decision-making.

Change Matrix Analysis is a powerful tool for monitoring and assessing land cover dynamics, identifying areas of concern or opportunity, and guiding land management and planning decisions. It provides valuable information for policymakers, land managers, researchers, and other stakeholders involved in natural resource management and environmental conservation efforts. The table of change matrix of monitoring years are below.

Table 1: Change matrix table of the year 2010-11 to 2014-15

2014-15	Monitoring Period T_0-T_1								
2010-11	**Agriculture**	**Built-up**	**Canal**	**Forest**	**Mining/Industrial**	**Reservoir/Tanks**	**River/ Stream/Drain**	**Scrubland**	**Total**
Agriculture	6204.40	-	8.81	-	3.16	23.47	-	-	6239.83
Built-up	-	219.76	-	-	-	-	-	-	219.76
Canal	-	-	0.00	-	-	-	-	-	0.00
Forest	-	-	-	840.13	-	-	-	-	840.13
Mining/Industrial	-	-	-	-	3.40	-	-	-	3.40
Reservoir/Tanks	-	-	-	-	-	67.31	-	-	67.31
River/Stream/Drain	-	-	-	-	-	-	70.47	-	70.47
Scrubland	96.21	0.49	1.98	-	-	10.84	-	1430.72	1540.24
Total	6300.60	220.24	10.79	840.13	6.56	101.62	70.47	1430.72	8981.14

Table 2: Change matrix table of the year 2014-15 to 2015-16

2015-16	Monitoring Period T_1-T_2 (Area in hectares)								
2014-15	**Agriculture**	**Built-up**	**Canal**	**Forest**	**Mining/Industrial**	**Reservoir/Tank**	**River/Stream/Drain**	**Scrubland**	**Total**
Agriculture	6294.87	0.42	-	-	-	4.85	-	-	6300.60
Built-up	-	220.24	-	-	-	-	-	-	220.24
Canal	-	-	10.79	-	-	-	-	-	10.79
Forest	-	-	-	840.13	-	-	-	-	840.13
Mining/Industrial	-	-	-	-	6.56	-	-	-	6.56
Reservoir/Tank	-	-	-	-	-	101.62	-	-	101.62
River/Stream/Drain	-	-	-	-	-	-	70.47	-	70.47
Scrubland	82.88	0.35	-	-	-	8.52	-	1338.97	1430.72
Total	7377.75	221.02	10.79	840.13	6.56	114.99	70.47	1338.97	8981.14

Table 3: Change matrix table of the year 2015-16 to 2016-17

2016-17	Monitoring Period T_2-T_3 (Area in hectares)								
2015-16	**Agriculture**	**Built-up**	**Canal**	**Forest**	**Mining/Industrial**	**Reservoir/Tank**	**River/Stream/Drain**	**Scrubland**	**Total**
Agriculture	6376.51	-	-	-	-	1.24	-	-	7377.75
Built-up	-	221.02	-	-	-	-	-	-	221.02
Canal	-	-	10.79	-	-	-	-	-	10.79
Forest	-	-	-	840.13	-	-	-	-	840.13
Mining/Industrial	-	-	-	-	6.56	-	-	-	6.56
Reservoir/Tank	-	-	-	-	-	114.99	-	-	114.99
River/Stream/Drain	-	-	-	-	-	-	70.47	-	70.47
Scrubland	20.84	-	-	-	-	4.24	-	131436	1338.97
Total	6397.35	221.02	10.79	840.13	6.56	120.46	70.47	131436	8981.14

Table 4: Change matrix table of the year 2016-17 to 2017-18

2017-18	Monitoring Period T_3-T_4 (Area in hectares)								
2016-17	**Agriculture**	**Built-up**	**Canal**	**Forest**	**Mining/Industrial**	**Reservoir/Tank**	**River/Stream/drain**	**Scrubland**	**Total**
Agriculture	6396.40	-	-	-	0.32	0.63	-	-	6397.35
Built-up	-	221.02	-	-	-	-	-	-	221.02
Canal	-	-	10.79	-	-	-	-	-	10.79
Forest	-	-	-	840.13	-	-	-	-	840.13
Mining/Industrial	-	-	-	-	6.56	-	-	-	6.56
Reservoir/Tank	-	-	-	-	-	120.46	-	-	120.46
River/Stream/Drain	-	-	-	-	-	-	70.47	-	70.47
Scrubland	74.27	3.35	-	-	-	1.11	-	1235.63	131436
Total	6470.67	224.37	10.79	840.13	6.88	122.21	70.47	1235.63	8981.14

Table 5: Change matrix table of the year 2017-18 to 2018-19

2018-19	Monitoring Period T_4-T_5 (Area in hectares)								
2017-18	**Agriculture**	**Built-up**	**Canal**	**Forest**	**Mining/Industrial**	**Reservoir/Tank**	**River/Stream/Drain**	**Scrubland**	**Total**
Agriculture	6463.30	1.77	1.29	-	-	4.31	-	-	6470.67
Built-up	-	224.37	-	-	-	-	-	-	224.37
Canal	-	-	10.79	-	-	-	-	-	10.79
Forest	-	-	-	840.13	-	-	-	-	840.13
Mining/Industrial	-	-	-	-	6.88	-	-	-	6.88
Reservoir/Tank	-	-	-	-	-	122.21	-	-	122.21
River/Stream/Drain	-	-	-	-	-	-	70.47	-	70.47
Scrubland	52.43	2.88	0.32	-	-	1.52	-	1178.49	1235.63
Total	6515.73	229.01	12.40	840.13	6.88	128.03	70.47	1178.49	8981.14

Assets for watershed development under IWMP in the watershed area

Currently there are 18 types of activities listed on Bhuvan portal under IWMP. The list of activities shown in the table. These assets are field data in the form of geotagged photographs. The field data collected through Drishti which is smart phone-based application. Drishti facilitate taken geotagged photographs and upload in Bhuvan portal. Geo-tagged photo is very important for maintain transparency and accountability. Because we can easily monitor the asset if they are geo-tagged.

Spatial distribution of geo tagged IWMP activities

There are 10 types of assets and total 101 activities found in the study area. They are: Trench-2, field bunds/marginal bunds: 9, check and plugs: 3, farm pounds: 3, check dam/stop dam: 57, nallah bunds: 5, entry point activity: 8, others: 14. There are only 29 assets visible on satellite image. The spatial distribution of geo tagged asset taken from Srishti Bhuvan ICT Geo portal. Srishti facilitate the download geo-tagged photographs which is uploaded by Drishti application. Every photographs have unique ID No. With the help of these photographs easily monitoring the activity of IWMP. The geotagged photo provides us with the exact location of the assets and indicates their condition, whether it's good or bad. Srishti and Drishti help in decision making for monitoring the IWMP activities.

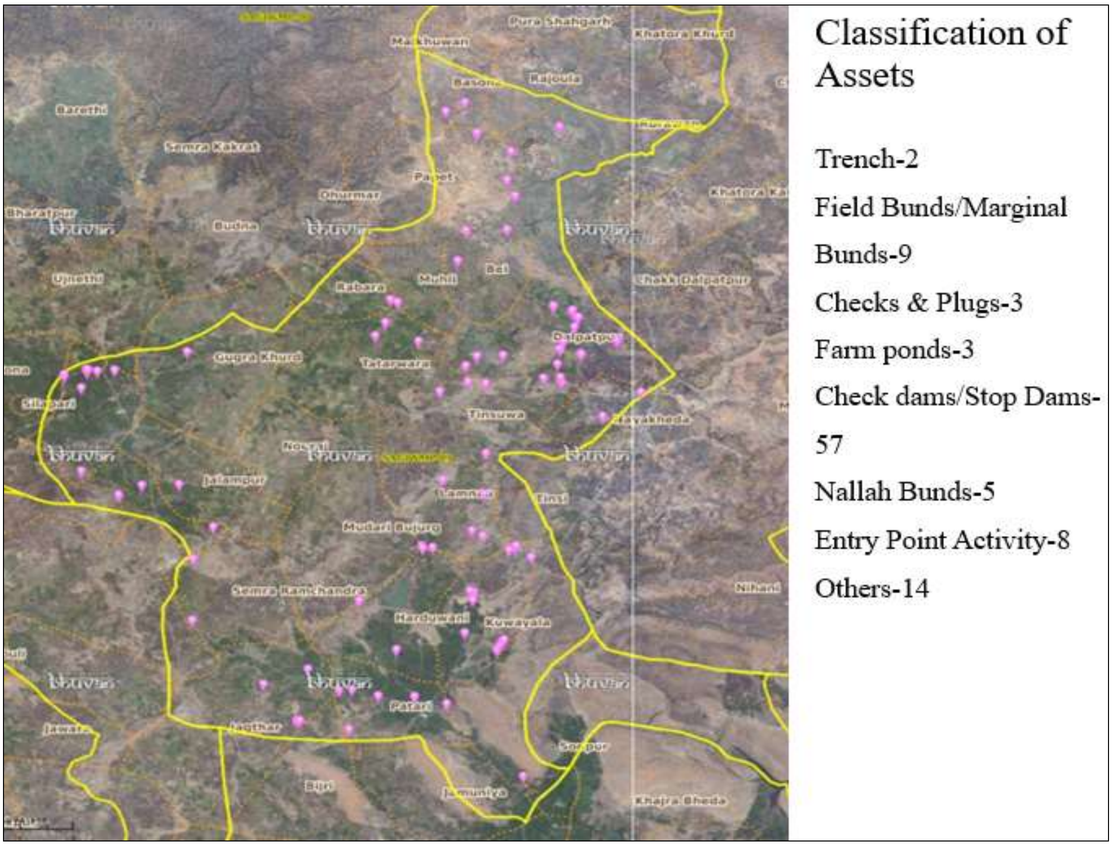


Fig 5: Spatial distribution of geo tagged IWMP activities

Table 6: List of IWMP activities

Sr. No.	Activity	Drishi Photo	Visible on Satellite Image
1	Afforestation	-	-
2	Horticulture	-	-
3	Agriculture	-	-
4	Pasture	-	-
5	Trench	2	2
6	Field Bunds/Marginal Bunds	9	3
7	Terrace	-	-
8	Checks & Plugs	3	3
9	Gabion structure	-	-
10	Farm ponds	3	3
11	Check dams/Stop Dams	57	17
12	Nallah Bunds,	5	-
13	Percolation tanks/Ground water recharge structure	-	-
14	Production System and Micro-Enterprises	-	-
15	Livelihood Activities	-	-
16	Capacity Building Activities	-	-
17	Entry Point Activity	8	-
18	Others	14	1
	Total	101	29

The spatial distribution of assets and geo-tagged photographs shown in Figures 5 and 6. The pictures depict three different structures: a check dam, a stop dam, and a farm pond. These structures are constructed for the conservation of soil and water. The photographs show there were no constructions until 2016 and 2017 when the check dam was constructed in Figure 5. Same things happen with Figure 6 stop dam and farm pound appear in year 2017. These photographs indicate the change the over time.

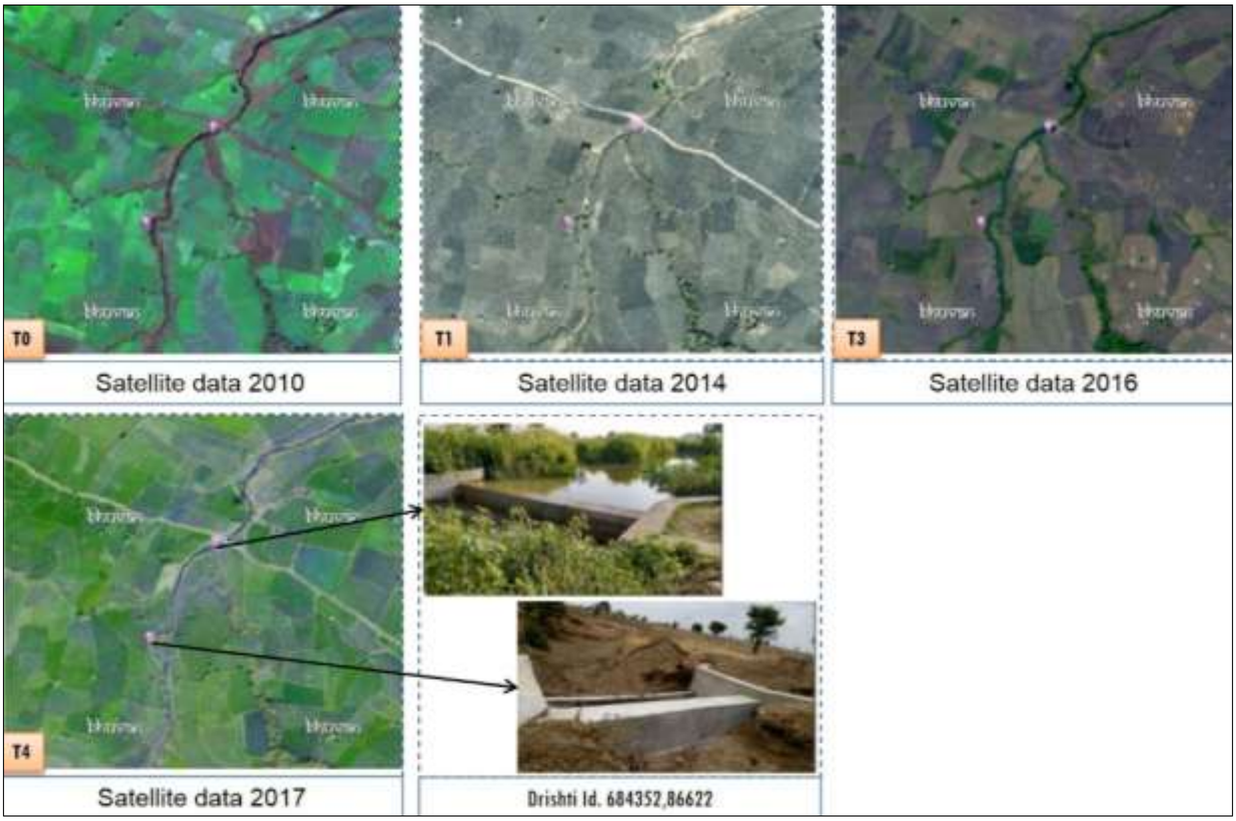


Fig 6: Check dams

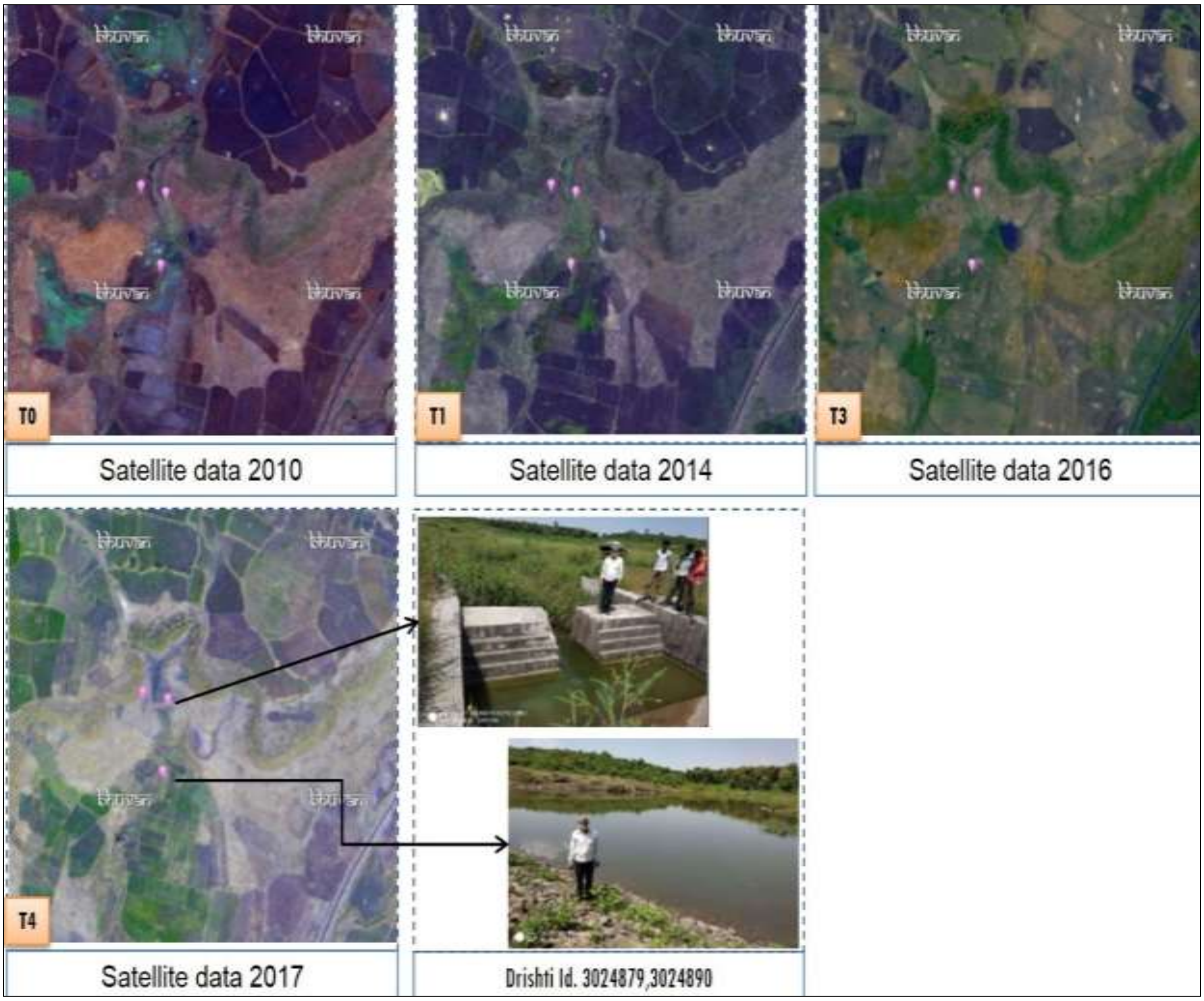


Fig 7: Stop dam & Farm Pond

Conclusion

The LULC change assessment and Change Matrix Analysis provide valuable insights into the dynamics of land use and land cover within the study area. These insights are essential for promoting transparency, accountability, and informed decision-making in the context of the IWMP and other natural resource management and conservation initiatives. The remote sensing and GIS technology analyzed the impact of integrated watershed program in Sagar district shahgarh block Madhya Pradesh. The total watershed area is 8981.14 ha based on the GIS tool. Dynamic changes have occurred in land use and land cover (LULC) within this area over the span of five years.

The analysis of Land Use and Land Cover (LULC) reveals a notable increase in Crop land, Built-up area, and Reservoir/Tanks, alongside a decrease in Scrubland, as depicted in the change matrix for different years. Specifically, there has been a 60.73-hectare increase in Reservoir/Tanks area between the baseline LU/LC data of 2010-11 (T_0) and 2018-19 (T_5). Moreover, there has been an overall increase of 275.89 hectares in Crop land area over the same period, with increases of 60.77, 77.62, 19.59, 73.32, and 45.06 hectares observed between consecutive time intervals (T_0-T_1, T_1-T_2, T_2-T_3, T_3-T_4, and T_4-T_5). Conversely, there has been an overall decrease of 361.75 hectares in Scrubland area between 2010-11 (T_0) and 2018-19 (T_5). Notably, various structures such as Check dams/Stop Dams (17), Trenches (2), Field Bunds (3), Checks & Plugs (3), Farm ponds (3), and Others (1) are visible on the IWMP Bhuvan Srishti portal, although the numbers are fewer than those verified from the Bhuvan Drishti photos of these structures (57 Check dams/Stop Dams, 2 Trenches, 14 Field Bunds, 3 Checks & Plugs, 3 Farm ponds, and 14 Others).

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