Regenerative Production Landscape Collaborative: People, Nature, Economy

BASELINE STUDY REPORT

July 31, 2023

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Acronyms

1. ACZ: Agro-Climatic Zone
2. AKRSP-I: Agha Khan Rural Support Programme-India
3. APL: Above Poverty Line
4. ASA: Action for Social Advancement
5. CAPI: Computer-Assisted Personal Interviewing
6. CGWB: Central Ground Water Board
7. CH_4: Methane
8. CO_2eq: Carbon Dioxide Equivalent
9. CSL: Cognisphere Solutions Limited
10. CSO: Civil Society Organisation
11. DAY-NRLM: Deendayal Antyodaya Yojana - National Rural Livelihoods Mission
12. DFID: Department for International Development
13. DID: Difference-in-Difference
14. EC: Electrical Conductivity
15. FCC: False Colour Composite
16. FFS: Farmer Field Schools
17. FGD: Focussed Group Discussion
18. FIG: Farmers' Interest Group
19. FPC: Farmer Producers' Company
20. FPO: Farmer Producers' Organisation
21. FYM: Farmyard Manure
22. GCPs: Ground Control Points
23. GHG: Green House Gas
24. GIS: Geographic Information System
25. GMO: Genetically Modified Organism
26. GP: Gram Panchayat
27. GPS: Global Positioning System
28. Ha: Hectare
29. HFC23: Hydrofluorocarbon 23
30. HH: Household
31. ICAR: Indian Council of Agricultural Research
32. IFPRI: International Food Policy Research Institute
33. IFR: Individual Forest Rights
34. IPCC: Intergovernmental Panel on Climate Change
35. IPM: Integrated Pest Management
36. IPR: Institution, People, and Resources
37. IRRI: International Rice Research Institute
38. KCC: Kisan Credit Card
39. KII: Key Informant Interview
40. LDM: Land Degradation Mapping
41. LULC: Land Use Land Cover
42. MGNREGS: Mahatma Gandhi National Rural Employment Guarantee Scheme
43. MP: Madhya Pradesh
44. MPI: Multi-dimensional Poverty Index
45. N_2O: Nitrous Oxide

46. NDVI: Normalised Difference Vegetation Index
47. NDWI: Normalised Difference Water Index
48. NPK: Nitrogen, Phosphorous and Potassium
49. NRSC: National Remote Sensing Centre
50. OBC: Other Backward Classes
51. OPG: Organic Producers' Group
52. PDS: Public Distribution System
53. PG: Producer Group
54. PHH: Priority House Holder
55. PMAY: Pradhan Mantri Awas Yojana
56. PMFBY: Pradhan Mantri Fasal Bima Yojana
57. PMJJBY: Pradhan Mantri Jeevan Jyoti Bima Yojana
58. PMSBY: Pradhan Mantri Suraksha Bima Yojana
59. PMU: Project Management Unit
60. PPI: Production, Protection, and Inclusion
61. PRA: Participatory Research Approach
62. RPLC: Regenerative Production Landscape Collaborative
63. SC: Scheduled Caste
64. SHG: Self Help Group
65. SLF: Sustainable Livelihood Framework
66. SOC: Soil Organic Carbon
67. SPSS: Statistical Package for Social Sciences
68. SQKM: Square Kilometre
69. SRLM: State Rural Livelihood Mission
70. SRTM: Shuttle Radar Topography Mission
71. ST: Scheduled Tribe
72. ToR: Terms of Reference
73. UNFCCC: United Nations Framework Convention on Climate Change
74. USGS: United States Geological Survey
75. VLC: Village Level Committee
76. VO: Village Organisation
77. WEAI: Women's Empowerment in Agriculture Index
78. WWF: Worldwide Fund for Nature

1. Introduction

The Regenerative Production Landscape Collaborative (RPLC) is an innovative partnership model in Madhya Pradesh that aims to foster agricultural ecosystems which conserve and enhance natural resources, build community resilience, and enable responsible sourcing for businesses. The RPLC (People, Nature, Economy) – Compact 2 was launched in April 2022 to scale up regenerative and restorative agricultural practices. This collaborative effort is currently operational in eight districts of Western Madhya Pradesh. Knowledge partners IDH and Laudes Foundation, along with implementing partners ASA and AKRSP (I), are working together with the government and private sector to promote a system-level shift towards sustainable production landscape management.

The RPLC project follows IDH's Production, Protection, and Inclusion (PPI) Framework (Figure 1), which emphasises on sustainable production by increasing the adoption of regenerative practices, improving the income and livelihoods of vulnerable communities and women, and enhancing resource management and biodiversity. By implementing this framework, RPLC aims to create a more sustainable and resilient agricultural system that benefits both people and the environment.

Figure1: Production (P), Protection (P) and Inclusion (I) Framework (source IDH)



1.1. Objectives of the Study

The baseline study aims to provide a comprehensive snapshot of the project area and its defined fields of concern and interventions. It seeks to identify indicators that can be used to determine progress and suggest mitigation measures that are appropriate and feasible within the local context. The study focuses on six impact areas defined by the RLPC, namely,

- restoring and revitalising soil health and soil carbon content,
- improving access to and management of water as a resource,
- improving small holders' income towards a 'living income',

- preserving and enhancing biodiversity through nature-based solutions,
- reducing greenhouse gas (GHG) emissions from agricultural and allied activities, and
- improving gender equity and women empowerment in the community at both social and economic level.

The primary objective of the study is to establish a baseline for each of the above-mentioned impact areas and propose targets based on which the progress can be measured over time. The study also aims to provide practical and actionable recommendations to help RPLC project meet its outcomes in the project area. The recommendations made by the study will be tailored to the specific needs and context of the community and will be designed to be achievable within the project's timeframe. This study targets developing quantitative analytics on critical indicators, confirming the relevance of the already designed intervention pack, and recommending possible pathways, including investment needs. By conducting this baseline study, the collaborative seeks to lay the foundation for sustainable production landscape management that will benefit both people and the environment in the project area.

1.2. Geographical Coverage

Madhya Pradesh (MP) under the Compact II. Out of these eight districts, ASA will execute it in five districts i.e., Alirajpur, Barwani, Dhar, Jhabua, and Ratlam. Other three districts i.e., Burhanpur, Khandwa and Khargone, will be supported and saturated by AKRSPI. The project area is divided in three agro-climatic zones (ACZs) in Madhya Pradesh i.e., Jhabua Hills, Nimar Plateau, and the Malwa Plateau. Districts like Dhar and Jhabua fall in more than two ACZs. As seen in the table below, there is a concentration of tribal families in this area, where five districts have more than 50% tribal population. Districts like Alirajpur and Jhabua have almost 90% of the population belonging to scheduled tribe (ST) communities. According to Niti Aayog's Multi-dimensional Poverty Index (MPI) report, these two districts are also among the poorest districts of Madhya Pradesh. Table 1 provides a snapshot of the project's geographical area and the ACZs.

Table 1: A Snapshot of the Project Geographical Area

	District	Agro-climatic Zone (ACZ)	#Blocks	# Villages	ST Population	SC Population
1	Alirajpur	Jhabua Hills	6	552	89%	3.70%
2	Barwani	Nimar Plateau	7	717	69.40%	6.30%
3	Burhanpur	Nimar Plateau	2	277	30.40%	8.50%
4	Dhar	Jhabua Hills, Malwa Plateau, Nimar Plateau	13	1625	55.94%	6.65%
5	Jhabua	Jhabua Hills, Malwa Plateau	6	832	87%	1.70%
6	Khandwa	Nimar Plateau	7	725	35%	12%
7	Khargone	Nimar Plateau	9	1421	39%	11.20%
8	Ratlam	Malwa Plateau	6	1089	28.20%	13.60%

2. Baseline Study Methodology

The methodology adopted for the RPLC baseline study follows a three-pronged approach of Sustainable Production, Protection & Restoration and an Inclusion of landscape management in the project implementation area. The study focuses on gathering data around the current situation in alignment with these three aspects and project's key intervention areas.

2.1. Sample Size Selection

In this study, we have adopted a sampling design that includes both 'treatment' villages (where ASA/AKRSP actively implements project interventions) and 'control' villages (where ASA/AKRSP is not present, hence, unlikely to be included in the project) within the project intervening districts, along with the households residing in these villages. The primary purpose of selecting these groups is to ensure a robust analysis for the impact study. Moreover, data from the control group serves as a comparison (or reference) point, enabling the project to attribute changes in the treatment area vis-a-vis implemented interventions. Further, control villages are retained, considering the possibility of future work expansion by ASA/AKRSP.

This approach has facilitated us to determine the difference in project outcomes by comparing them to a counterfactual reference point. It has considered the possibility of other development partners implementing projects in both treatment and control villages, such as Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), the Forest Department, Department of Agriculture, and Deendayal Antyodaya Yojana - National Rural Livelihoods Mission (DAY-NRLM). By assuming the occurrence of these interventions in both groups, the project aims to isolate the specific impact resulting from its own interventions. Establishing a counterfactual reference point and utilising the Difference-in-Difference (DID) method has also helped us quantify the attributable impact.

We have considered various factors to determine the appropriate sample size, such as setting the scenario at a 90% confidence level and 7% standard error. A design effect of two, statistical power of 80%, and maximum heterogeneity of 50% for the key characteristics are assigned, along with an expected nonresponse rate of 10% and potential entry errors. Based on these prerequisites, the study required a sample size of 864 to achieve our objectives efficiently. The selection of this sample size has accounted for the distinct agro-climatic zones and the extensive geographical spread while maintaining statistical significance and practicality to complete the survey within a specified timeframe and budget.

Selection of Districts and Blocks

To finalise the sample design, the first level of analysis has focused solely on the 21 intervened blocks (from the selected districts). Since the blocks in each district are segregated based on agro-climatic zones, the majority of blocks in a given district are concentrated in a specific agro-climatic zone, including Alirajpur, Barwani, Burhanpur, Khargone, and Ratlam. Only two districts (Dhar and Jhabua) have blocks spread across two or three agro-climatic zones (Dhar blocks across three ACZ and Jhabua blocks in two ACZ). Moreover, distributing the sample size evenly across all the blocks would not only have been impractical from a survey perspective but also expensive. Table 2 below further clarifies the district-wise distribution of intervened blocks across different ACZs.

Table 2: Distribution of Project Area as per the Agro-climatic Zones (ACZs)

ACZ	Geography (Outreach)	Alirajpur	Barwani	Burhanpur	Dhar	Jhabua	Khargone	Ratlam	Total
Jhabua Hills	Blocks	5			1	4			10
	Villages	105			24	50			179
	HHs	28,467			8,428	13,477			50,372
Nimar Plateau	Blocks		4	1	1		1		7
	Villages		106	20	9		44		179
	HHs		34,806	3,731	3,610		10,535		52,682
Malwa Plateau	Blocks				1	1		2	4
	Villages				13	7		47	67
	HHs				4,049	3,305		6,712	14,066

The block finalisation process has followed several design principles to ensure a robust and representative sample for the survey. Firstly, to streamline logistics during the survey, three blocks with the highest concentration of household outreach are chosen from each district. However, if a district has fewer than three blocks, all available blocks are automatically selected. Additionally, the selected blocks aim to represent different ACZs, although this does not apply to most districts since their blocks are concentrated in any single ACZ. Furthermore, the final selection of blocks has assessed the current or proposed outreach in each district, block, and ACZ, with a preference given to districts with a higher number of blocks. It is also ensured that the survey is conducted feasibly and cost-effectively. Based on these design principles, a total of 15 blocks from 7 districts (no block from Dhar is selected since all the regions are adequately represented) are shortlisted for inclusion in the survey sample for the Western MP Compact (please refer to Table 3).

A distinct strategy is employed to ensure representative village selection. Blocks are divided into agro-climatic zones (ACZs) for mapping treatment blocks. Household samples are proportionately divided among these zones, with more samples in high outreach areas. Each village has an average of 18 sample households. Following the block selection design, three (two treatment and one control) villages per block are chosen. It should be noted that the project follows a landscape approach, and the control villages would eventually transition into intervention villages. The intervention in these control villages could be carried out by the existing implementing agency or potentially taken over by other agencies.

Figure 2: Map of RPLC Project Districts

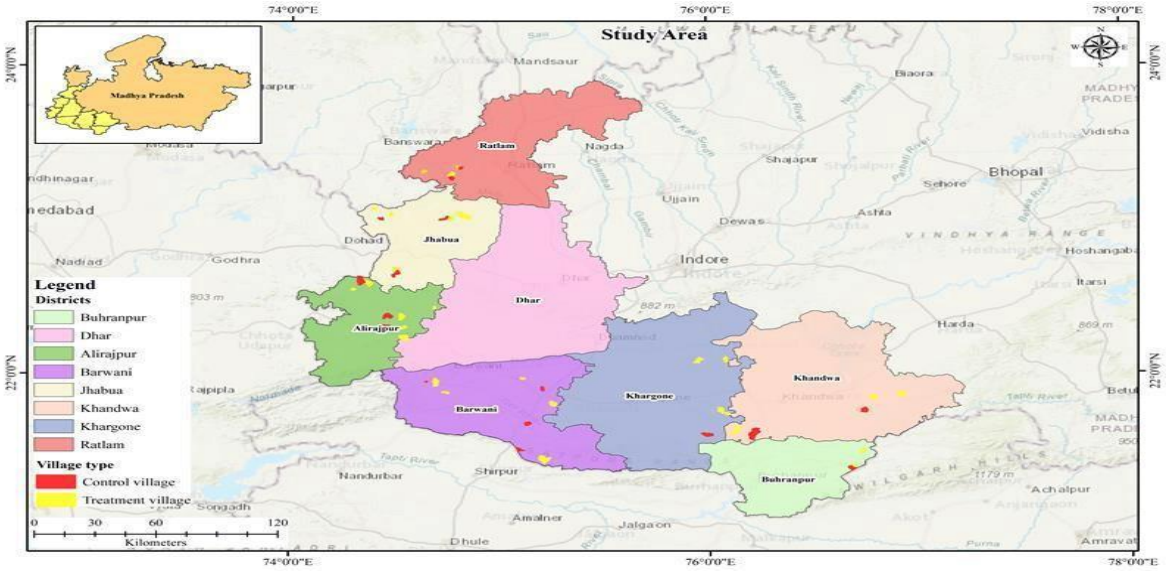


Table 3: Selected Districts and Blocks for the Baseline Study

District	# of blocks	# of Villages	# of HHs	Comments
Alirajpur	3	9	162	Three out of five blocks selected
Barwani	3	9	162	Three out of four blocks selected
Burhanpur	1	3	54	Only one intervening block in the district
Dhar	0	0	0	No block was selected as all regions were adequately represented
Jhabua	3	9	162	Three out of five blocks selected
Khargone	1	6	108	Only one intervening block in the district
Khandwa	2	6	108	Both blocks selected
Ratlam	2	6	108	Both blocks selected
Total	15	48	864	

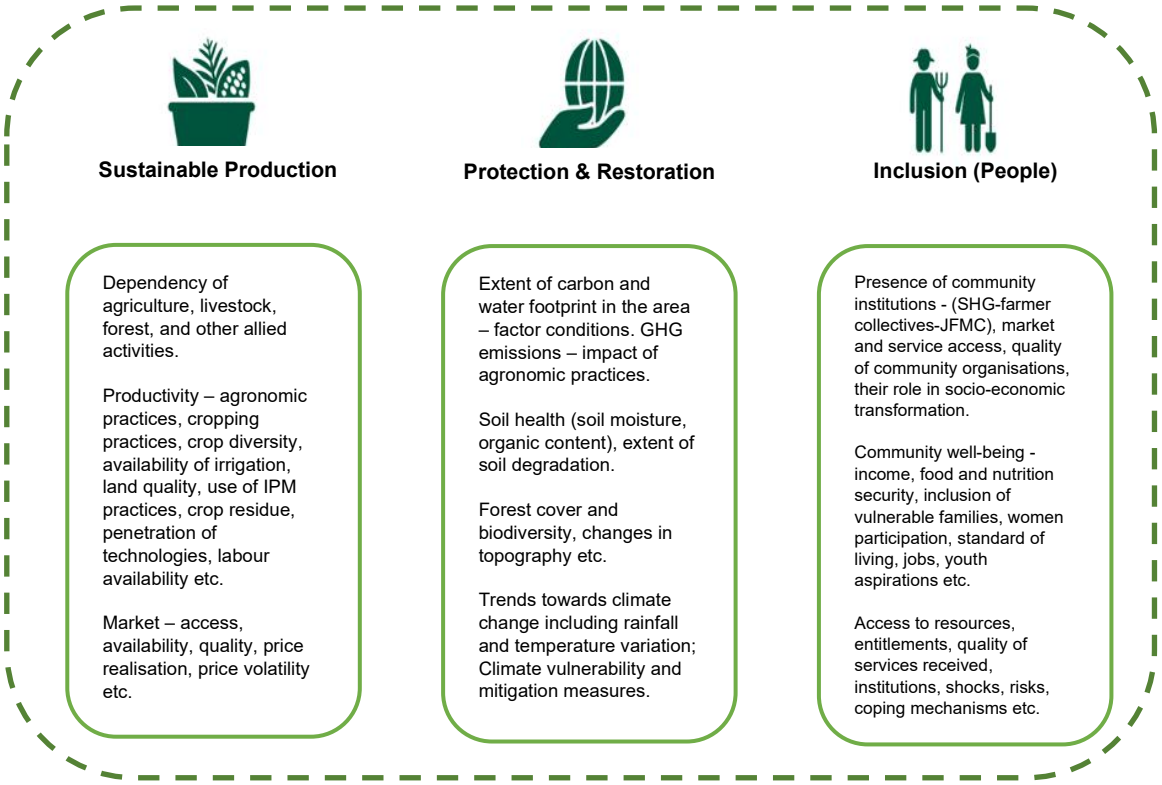
Table 4: Distribution of Villages and Household Samples across the ACZs

ACZ	Districts	Coverage	# of HH
Jhabua Hills	Alirajpur, Jhabua	Blocks	5
		Villages	15
		HHs	270
Nimar Plateau	Barwani, Burhanpur, Khargone, Khandwa	Blocks	7
		Villages	24
		HHs	432
Malwa Plateau	Jhabua, Ratlam	Blocks	3
		Villages	9
		HHs	162

2.2. Methods and Techniques of Data Collection

Given the critical areas of inquiry on sustainable production, protection & restoration, and inclusion, the survey instruments gather information around each of these aspects (Figure 3). The team has used mixed methods of data collection, including a judicious blend of qualitative and quantitative tools.

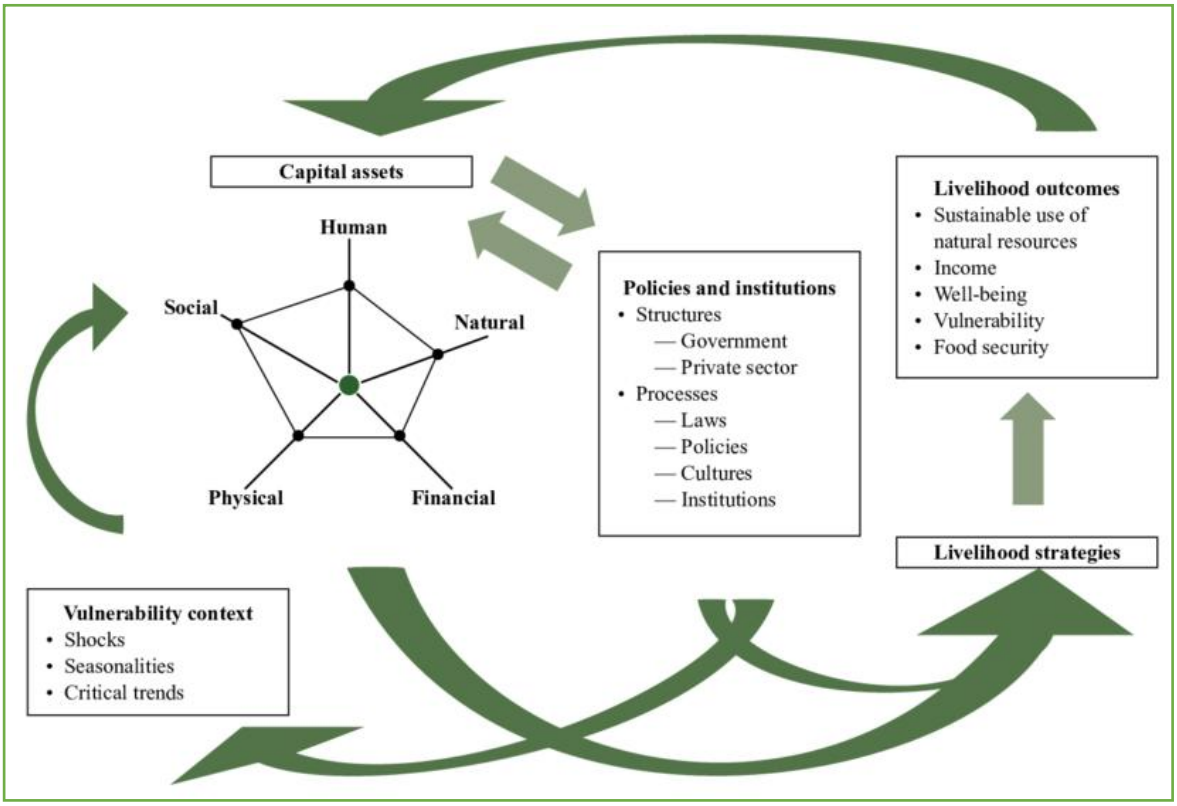
Figure 3: Critical Areas of Enquiry based on PPI Framework



Additionally, to ensure rigorous and widespread acceptance, the baseline study is designed with a broad international framework - the Sustainable Livelihood Framework (SLF) developed by UK Aid (formerly DFID). Since it is essential to understand the existing conditions of a target population before implementing development interventions, it becomes crucial to adopt a comprehensive framework that captures the multidimensional aspects of their livelihoods. The SLF, with its holistic approach, has been instrumental in guiding the development of questionnaires for this baseline study.

The SLF (Figure 4) provides a compendious and analytical framework for analysing and addressing the complexities of livelihoods. It recognises five critical assets - human, social, natural, physical, and financial capital - significantly influencing livelihood outcomes. Additionally, the SLF considers institutions and policies as cross-cutting elements that shape livelihood opportunities and constraints. By adopting this framework, baseline studies can effectively capture the nuances of households' livelihood contexts in the project area – both in treatment and control villages.

Figure 4: Sustainable Livelihood Framework (SLF)



The diverse tools designed for the baseline study have considered the framework principles as explained below:

Assessing Natural Capital: The questionnaire has included inquiries about land and water quality, soil type and soil quality, and availability issues, including access to these resources. The various questions focus on land ownership, land use patterns, land cover change, access to water sources, types of water resources, and the impact of environmental factors on agricultural productivity. This information enables us to understand the natural capital available to rural households and any environmental and climate challenges they may face.

Analysing Livelihood Strategies and Financial Capital: To understand the livelihood and income portfolio of tribal households, we have developed questions around information about diverse livelihood sources and their importance, such as agriculture, forestry, animal husbandry, or non-farm activities. Additionally, the questionnaire has explored income levels, expenditure patterns, savings, access to credit, the quantum of credit accessed and the variety of financial services available to the community, providing insights into the crucial components of financial capital.

Understanding Human and Social Capital: The questionnaire has included inquiries about education levels, skills, and health conditions, which reflect the human capital of tribal households. Exploring social networks, community organisations, and access to social services has also been essential to assess social capital. The inquiry also acknowledges that understanding social dynamics and support systems available to tribal households is vital in comprehending their livelihood contexts.

Examining Physical Capital: Physical capital includes infrastructure, tools, and equipment facilitating livelihood activities. The questionnaire has included questions about access to electricity, transportation, storage facilities, and availability of productive assets. This information has helped identify constraints and opportunities related to physical capital for the project households.

Assessing Institutional Dynamics: Institutional arrangements significantly influence livelihood opportunities and outcomes. The questionnaire has included the role of local governance structures, policies, and institutions in shaping households' livelihoods and the community's involvement and participation in all these institutions. Additionally, membership in community-based organisations, their functioning, and their relevance to the community are also explored. Inquiries about access to government schemes and services, land rights, and representation have shed light on the institutional dynamics and functioning affecting the community's livelihoods.

Agronomic Practices and Livelihood Outcomes: To understand agricultural practices adopted by tribal households, we have inquired about cropping patterns, organic or traditional methods, access to seeds and fertilisers, and irrigation practices. Additionally, questions are designed to measure the outcomes of livelihood activities, such as crop yields, food security, asset ownership, and overall well-being.

Since the DFID Sustainable Livelihood Framework offers a robust approach to developing questionnaires for baseline studies of tribal households' livelihoods, by integrating the SLF into the questionnaire design, an attempt has been made to gain a comprehensive understanding of the natural, financial, human, social, and physical capital available to households in the project area. Baseline data against each of these indicators are developed through rigorous analysis after triangulation from different sources. The Geographic Information System (GIS) and remote sensing data analytics are synthesized and triangulated against specific indicators like forest cover, stream flow, etc. A draft zero of the instruments is developed in English (later translated in Hindi accordingly) based on discussions held during preliminary meetings, literature review, project deliverables, and the results framework. Incorporating the feedback received on the draft zero from ASA, IDH, Laudes Foundation, the survey tools have undergone a pilot phase to verify their effectiveness and appropriateness. Table 5 provides details of the instruments utilised in the baseline survey. The survey instruments are included as annexes towards the end of this document.



Focused Group Discussion with the SHG/VO

Table 5: Survey Instruments Used in the Baseline Study and Data Collection Areas

Sl.#	Survey Tools	Areas of Data Collection
1	Individual HH Questionnaire	Data on HH socio-economic status, livelihood portfolio, cropping pattern, agronomic practices, gender and youth roles in agriculture, market integration, linkage with PRI and govt agencies, membership in community organisations, etc.
2	Village level Questionnaire	Data on village resources (5Js – Jan, Jal, Jameen, Janwar and Jangal), their quantification and assessing quality, climate variability and vulnerabilities, mitigation measures, integration with market and institutions etc.
3	FGD (women collectives – SHG/ VO)	Information on the quality of local organisations, role of women, the impact of SHG in livelihoods, wellbeing, gender issues, food and nutrition security, agriculture practices, access to credit etc.
4	FGD (PG/FIG, JFMG, FPC/FPO)	Understanding on the extent of agriculture interventions, existing cropping pattern, agronomic practices, market integration, agro-commodities value chain – issues and trends, issues related to forest, biodiversity etc.
5	Key Informant Interview	Individual interviews with one/ two of the best practitioners (farmer) of agriculture in the village and with govt officials to get their views on land-water-commodity integration and the challenges faced by famers.
6	Soil Sample collection	Soil sample and soil moisture data from selected villages in the block (keeping in mind the agro-ecological-topographical condition).
7	Remote Sensing and GIS mapping	Data gathering and analysis of Remote Sensing, and mapping and analysis of GIS data.
8	Deep Dive Study	In the Regenerative Production Landscape Initiative, a comprehensive "deep dive" process was undertaken to diagnose the current state of the landscape or selected parts of it. This involved making observations, predicting the impact of ongoing phenomena, and suggesting actions needed for desired ecosystem development. The team used PRA process such as transect walk and explored the village and farms with the community to understand the landscape, local resources, local dynamics of the community, including their social and economic activities.

2.3. Data Gathering and Analysis through GIS and Remote Sensing

Land Use Land Cover Mapping: Mapping of land use land cover (LULC) for selected districts over three time-periods is done using moderate and high-resolution satellite images (Landsat 5, Landsat 8, Sentinel 2A, and 2B). Six LULC classes are identified: Forestland, Cropland, Grassland, Wetland, Settlements, and other land. The classification algorithm, such as maximum likelihood or random forest, is trained using ground control points, and classified images are visually adjusted. Accuracy is assessed for individual classes and the entire district. If accuracy is unsatisfactory, the process is iterated with refined training sites and further adjustments until the desired accuracy is achieved. This methodology is employed for LULC and change detection.

Slope and Aspect Mapping: We have generated slope layers using Carto DEM. The resolution of this DEM is 30 m., and height (Z) values of the DEM are used for spatial averaging using an appropriate spatial filter. The output slope layer thus generated is represented in degrees. Similarly, the aspect layer is also generated from the raw DEM image as well.

NDVI & NDWI Analysis: Normalised Difference Vegetation Index (NDVI) and Normalised Difference Water Index (NDWI) is generated for the multiple time-periods to indicate vegetation growth and water-related information.

Land Degradation Mapping: The delineating of degraded areas is done using Land Degradation datasets from the National Remote Sensing Centre (NRSC) for 2015-16. If the current degradation data are unavailable from NRSC, Landsat images from different seasons are used to create False Colour Composite (FCC) images for visual interpretation. The interpretation involved analysing texture, tone, shape, location, and pattern of ground features to identify degraded areas. Qualitative assessment of soil erosion is conducted using Landsat data, slope data, land use/land cover, and soil characteristics. Three soil erosion classes (Sheet Erosion, Gullied, and Stony Waste) are mapped. Representative ground truth data collection is done at selected sample sites, including topography and soil profile analysis. Field data and soil chemical analysis are used to modify preliminary interpreted maps, and final maps are prepared with appropriate legends.

Forest Cover Change Mapping: Fractional cover is estimated for the three time points using Sentinel 2A/2b, and Landsat 5/8; once fractional cover images has been estimated; they are compared to detect forest cover changes across the three time-period.

Mapping cropping pattern, intensity, and growth over seasonality: High-resolution Sentinel 2A and 2B are acquired for the current year to create a comprehensive annual time series. The time series Sentinel data are utilised for mapping cropping patterns for three cropping seasons (Zaid, Kharif and Rabi; images are acquired during individual peak growing seasons). The mapping is conducted by combining Sentinel images with in-situ data on crop types collected during field data collection. The intensity and seasonal growth are estimated using NDVI time series generated from the Sentinel time series data.

Change in course of Water Bodies and enhancement of Water Table

Change in the course of water bodies is estimated by comparing LULC across three time points already generated. Water table or groundwater level information is significant as a geospatial layer from the Central Ground Water Board (CGWB).

2.4. Quantification of Soil Carbon Sink and Estimation of GHG Emissions

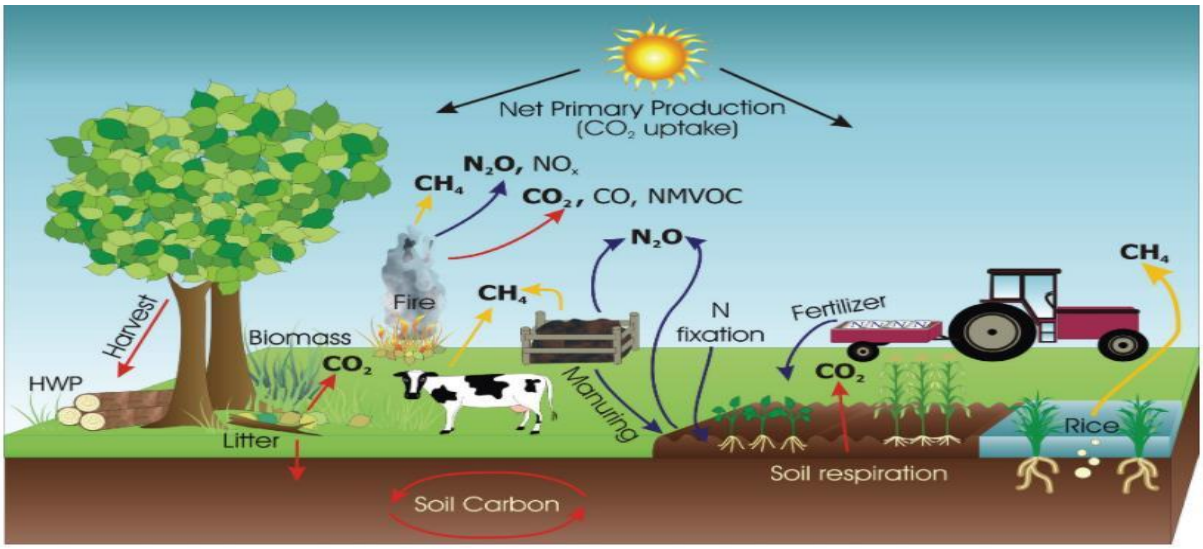
According to India's Third Biennial Update Report to UNFCCC, Methane (CH4) and Nitrous Oxide (N2O) are two major greenhouse gases (GHGs) contributing to emissions from the agriculture sector. Livestock rearing (enteric fermentation and manure management) and rice cultivation are the two major causes of CH4 emission, whereas the application of synthetic fertilisers is the primary cause of N2O emission. In 2016, the agriculture sector emitted 407,821 Gg Carbon dioxide equivalent (CO2eq), which amounted to around 14% of total emissions, i.e., 2.25% less than 2014. This was the first time a reduction was seen in India's inventory for any sector between two consecutive inventory years[1]. Table 6 shows GHG emissions from the agriculture sector in India in 2016. Methane and Nitrous Oxide account for 74% and 26%, respectively, of the total GHG emissions for the sector year.

Table 6: GHG Emissions from Agriculture Sector in India, 2014

CO_2 emission	CO_2 removal	CH_4	N_2O	HFC23	CF_4	C_2F_6	SF_6	CO_2 equivalent
-	-	14,423	339	-	-	-	-	407,821

While various agricultural activities contribute to GHG emissions, the sector also sequesters carbon in soils and in biomass (Figure 6). Although emissions from this sector are mainly attributed to crop cultivation, livestock management and deforestation, it is important to note that this estimate does not include carbon sequestration, which is estimated to offset approximately 20% of the emissions.[2]

Figure 1: On-farm GHG emissions[3]



[1] MoEFCC. (2021). *Third Biennial Update Report to the United Nations Framework Convention on Climate Change.* Retrieved from the Ministry of Environment, Forest and Climate Change, Government of India: https://unfccc.int/sites/default/files/resource/INDIA%20SECOND%20BUR%20High%20Res.pdf

[2] United States Environmental Protection Agency. (2014). *Global Greenhouse Gas Emissions Data.* Retrieved from https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data#Sector

[3] IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds.) Published: IGES, Japan.

At a farm level, the size of different sources of emissions varies depending on crops grown, farming practices employed, inputs used, and natural factors such as weather, topology and hydrology. Farm-level GHG emissions include:

- CO2 from changes in biomass, dead organic matter and mineral soils,
- CO2 and non-CO2 emissions from crop burning,
- N2O emissions from nutrient use on agricultural soils,
- CO2 emissions associated with liming and urea application to the agricultural soil,
- CH4 emissions from rice cultivation,
- CO2 and N2O emissions from cultivated organic soils,
- CH4 emission from livestock (enteric fermentation) and
- CH4 and N2O emissions from manure management.

Given that agriculture significantly contributes to GHG emissions, the present study proposes mitigation measures towards promoting low-carbon farming by estimating emissions from cultivation and livestock management. Additionally, the study has mapped the potential opportunities for carbon sequestration and has assessed current soil organic carbon levels.

Soil Sampling

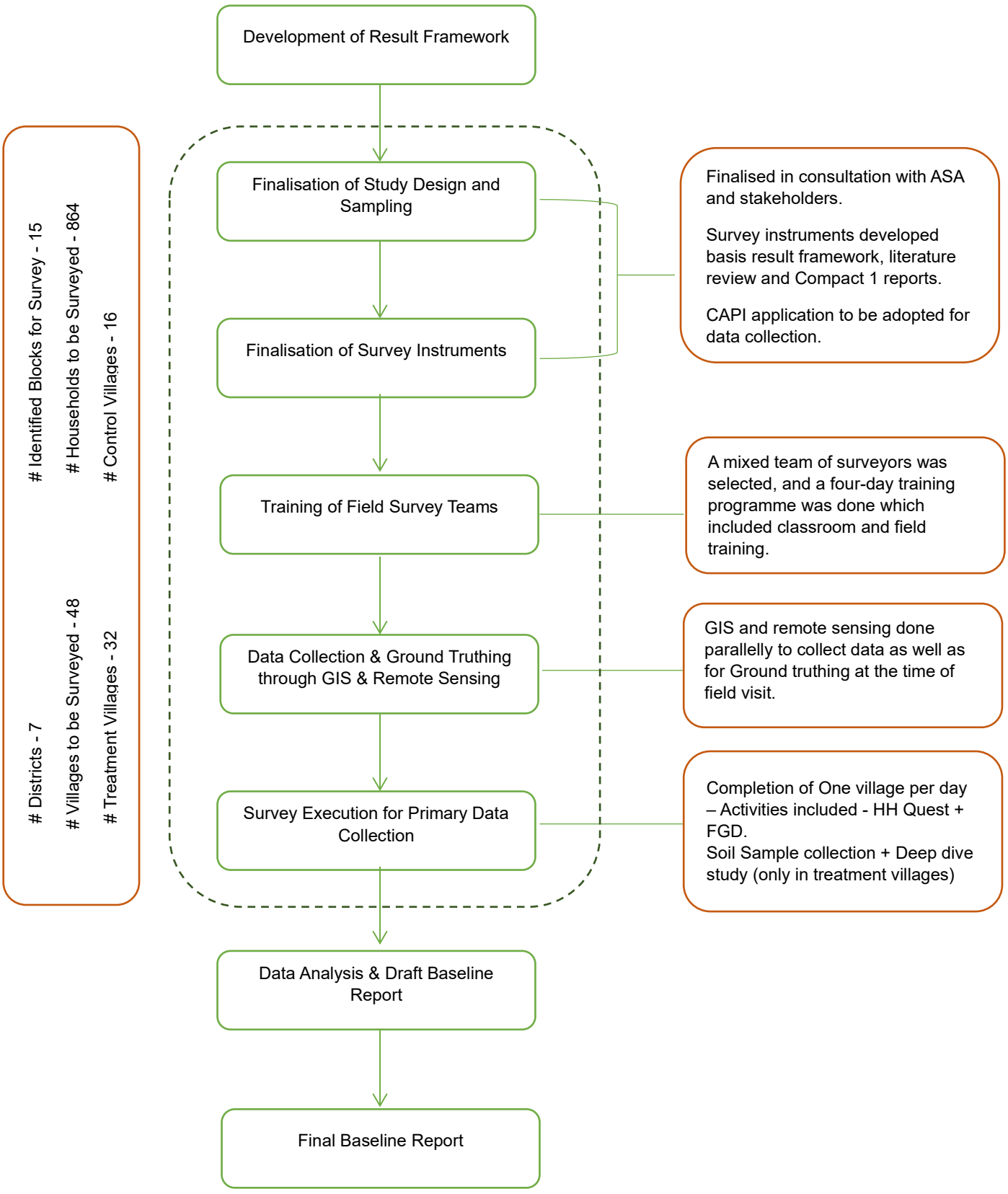
We have conducted soil testing at multiple locations to assess the current soil carbon content in project landscapes. Manual sampling time points are correlated with the Remote Sensing data gathering time points. In general, sampling is done at the rate of one sample for every two-hectare area, and for larger regions, at least one sample is collected for a maximum area of five hectares. For soil survey work, samples are collected from a soil profile representative of the soil of the surrounding area.

- 114 soil samples are collected (3 samples per village for 38 treatment villages),
- Three sites (1 ha each) are selected in each village,
- Three plots (10×10 m) are established at each sampling site,
- Triplicate soil samples are collected after removing litter (if any) using soil auger of 3 cm diameter at three soil depths – 0-10cm, 10-20cm and 20-30cm,
- Samples are collected from the three plots, and depths (total 27 soil cores) are pooled and analysed as one sample.

The collected soil samples are tested on the following parameters:

- Soil pH and Cation Exchange Capacity: to assess the capacity of the soil to supply nutrient cations to soil solution for plant uptake),
- Soil Organic Carbon: to assess the water and nutrient holding capacity of the soil and its physical stability,
- Presence of macro elements needed for plant growth and development - Available Nitrogen, Phosphate and Potash.

2.5. Study Methodology – Process Flow



3. Study Findings

3.1. Socio-Economic Profile of the Households

3.1.1. Geographic Distribution

A total of 864 households are interviewed in MP including 589 (68%) from treatment villages and 275 (32%) from control villages.

Table 7: District-wise Disaggregated Data of Sample Households, MP

Districts	ACZ	HH Sample Achieved		
		Treatment	Control	Total
Alirajpur	Jhabua Hills	113	49	162
Barwani	Nimar Plateau	109	53	162
Burhanpur	Nimar Plateau	36	18	54
Khargone	Nimar Plateau	77	31	108
Jhabua 1[4]	Jhabua Hills	72	36	108
Jhabua 2[5]	Malwa Plateau	36	18	54
Ratlam	Malwa Plateau	72	36	108
Khandwa	Nimar Plateau	74	34	108
Total		589	275	864

Agro climatically the sample is concentrated in Nimar Plateau (50%) as the project has the largest concentration in that belt. Jhabua Hills has 31% of the sample share and the remaining 19% is in Malwa Plateau.

3.1.2. Caste Profile

The baseline study reveals that a significant majority, approximately 97%, of the surveyed households belong to the ST community, which is slightly higher than the ST population recorded in the census data for the same blocks (80.3% in 2011)[6]. Notably, in Alirajpur, Jhabua, Khargone, and Ratlam districts, nearly 100% of the sample households are STs.

Table 8: Caste Category of the Sample Households in MP (in percentage)

Village Category	Scheduled Caste (SC)	Scheduled Tribe (ST)	Other Backward Class (OBC)	General
Treatment	0.6	96.3	2.4	0.7
Control	0	97.5	1.4	1.1
All Villages	0.3	96.9	1.9	0.9

[4] Jhabua 1 is the area under the ACZ Jhabua Hills and includes villages in the blocks of Ranapur and Thandla.
[5] Jhabua 2 is the area under ACZ Malwa Plateau and includes the villages in the Petlawad block.
[6] Source Census of India, 2011

3.1.3. Education Profile

The survey data suggests that a large majority of the population are not educated in both treatment and control villages across the districts of MP. Over 60% of the respondents have yet to receive formal education. Among those who have, only 18% have received primary education, while 19% have completed secondary or higher secondary education. A mere 2% of the respondents hold a graduation or post-graduation degree. Alirajpur, Barwani, and Jhabua districts show the highest percentage of uneducated individuals, consistent with the secondary data. Table 9 presents the education profile of the survey respondents, along with the corresponding district-wise literacy rates from the 2011 Census.

Table 9: Education Status of the Households in MP (in percentage)

District	Village	Not literate	Primary	Secondary	Graduation +	Literacy Rate*
Alirajpur	Treatment	66.04	16.14	16.14	1.7	36.10
	Control	77.88	12.38	7.95	1.77	
Barwani	Treatment	67.89	14.68	17.42	0	49.08
	Control	64.15	20.75	15.09	0	
Burhanpur	Treatment	33.33	38.9	24.99	2.78	64.36
	Control	61.11	16.68	22.23	0	
Jhabua 1	Treatment	75	12.51	12.11	1.39	43.3
	Control	86.11	8.34	5.56	0	
Jhabua 2	Treatment	75	11.11	13.89	0	
	Control	38.89	22.22	33.33	5.56	
Khandwa	Treatment	51.35	22.96	25.38	1.35	66.39
	Control	32.35	26.47	32.42	8.82	
Khargone	Treatment	70.13	23.39	5.2	1.3	62.7
	Control	67.74	16.14	16.13	0	
Ratlam	Treatment	58.33	12.5	23.61	5.56	66.78
	Control	58.33	13.89	25.01	2.78	

*Source: Census of India, 2011

3.1.4. Access to Bank/Insurance Services:

The study findings reflect that 99% of the surveyed households in both treatment and control villages have bank accounts. However, the percentage of Kisan Credit Cards (KCC) possession is relatively low, with only 14% of respondents in both groups having them. Interestingly, none of the surveyed respondents reported having a post office account.

Table 10: Percentage of Sample Households with Access to Bank Accounts

Village Type	Bank Account	Post-office Account	Both bank & Post-office Account	No Savings Account	HH with KCC
Treatment	99.0	0.0	0.0	0.7	14.0
Control	99.3	0.0	0.0	0.7	13.7
All villages	99.1	0.0	0.0	0.7	13.8

The availability of insurance schemes among the surveyed HHs shows mixed results. The data indicated that 83% of HHs in treatment villages possess Ayushman Bharat cards[7], whereas in control villages, this percentage is 76. However, the data varies across different regions. In the Jhabua 1 region, 86.1% of HHs have Ayushman Bharat cards in the treatment villages, while the figure drops to 47.2% in the control villages. Similarly, in Burhanpur, all HHs in the treatment villages (100%) possess Ayushman Bharat cards, whereas only 66.7% of HHs report having them in the control villages.

The accessibility to insurance schemes like PM Jeevan Jyoti Bima Yojana[8] (PMJJBY for life insurance), PM Suraksha Bima Yojana[9] (PMSBY for accident and disability), and PM Fasal Bima Yojana[10] (PMFBY for crop insurance) is found to be extremely low in all the treatment and control villages.

Table 11: Percentage of Sample Households with Access to Insurance Schemes

Districts	Village Type	Ayushmaan Bharat	PMJJBY	PMSBY	PMFBY
Alirajpur	Treatment	60.2	1.8	1.8	2.7
	Control	75.5	0.0	0.0	2.0
Barwani	Treatment	83.5	6.4	2.8	2.8
	Control	96.2	11.3	5.7	1.9
Burhanpur	Treatment	100.0	5.6	8.3	0.0
	Control	66.7	0.0	0.0	0.0
Khargone	Treatment	97.4	11.7	5.2	11.7
	Control	90.3	3.2	0.0	16.1
Jhabua 1	Treatment	86.1	19.4	19.4	5.6
	Control	47.2	0.0	5.6	0.0
Jhabua 2	Treatment	91.7	5.6	5.6	2.8
	Control	83.3	0.0	0.0	5.6
Ratlam	Treatment	48.6	11.1	8.3	4.2
	Control	72.2	2.8	5.6	0.0
Khandwa	Treatment	100.0	5.4	4.1	4.1
	Control	76.5	2.9	5.9	17.7
Mean	Treatment	83.4	8.4	6.9	4.2
	Control	76.0	2.5	2.8	5.4

[7] Ayushman Bharat PM-JAY is India's national health insurance scheme providing free coverage to low-income individuals, ensuring access to healthcare.
[8] PM Jeevan Jyoti Bima Yojana is an affordable government life insurance scheme in India offering Rs. 2 lakh on death.
[9] PM Suraksha Bima Yojana is an affordable government personal accident insurance scheme in India, providing coverage for death and disability.
[10] PM Fasal Bima Yojana is an Indian government scheme offering crop insurance coverage to farmers against losses caused by natural calamities.

3.1.4. Food Sufficiency from Own Production

It is observed in the findings that none of the surveyed districts demonstrated food sufficiency[11] for 12 months. The average food security for both treatment, as well as control villages is found to be nine months. However, in the Jhabua Hills region of the Jhabua district, specifically the Ranapur and Thandla blocks, both villages demonstrated food security between seven to eight months. The HHs reported that they depend on the Public Distribution System (PDS) for meeting food security. Some also buy grains from the market as the PDS supply is insufficient to support the family. The control villages of Jhabua (Malwa Plateau) are the only exception where HHs reported almost yearlong food sufficiency (11.38 months). It is observed that a vast majority of HHs both in treatment and control villages (98%) possess ration cards[12] (access to PDS). Among HHs with ration cards, 85.9% in the treatment villages possess Priority Householder (PHH) cards[13]; same is around 84% in control villages. Additionally, 4.2% of households in the treatment village possessed Antyodaya[14] cards, while the corresponding figure for control villages is 5.1%.

Table 12: Food Security of the Sample Households and Access to PDS in MP

Village Type	Food Security (in months)	HHs with Ration Card (in %)	Type of Ration Card (in %)			
			PHH	Antyodaya	BPL	APL
Treatment	9.5	98.8	85.9	4.3	8.6	1.2
Control	9.2	97.8	84.0	5.2	7.4	3.4
All villages	9.3	98.3	84.9	4.7	7.9	2.3

3.1.5. Quality of House

The survey findings indicate that 99% of the surveyed households in treatment and control villages have electricity connections. Further, 98% of the HHs reported owning their house in both treatment and control villages.

Table 13: Percentage of Sample Households with Own House and Access to Electricity

Village Type	HHs with Electricity Connection	HHs with Own House	Type of House			HH received PM Awas Yojana
			Kuchcha	Semi-Pucca	Pucca	
Treatment	99.0	98.3	37.1	23.0	39.9	39.9
Control	99.2	97.7	45.2	29.0	25.8	31.1
All villages	99.1	98.0	41.1	26.0	32.9	35.5

Sixty-three percent of the HHs in the treatment villages reported better quality houses (pucca and semi pucca) against 54% of the HHs in the control villages. Almost 46% of the HHs in control villages live in kuccha houses. Jhabua 1 is the lowest, where 61% of the surveyed HHs live in kuccha houses. In Jhabua 2, 55% of households reported having a kuccha house, while

[11] Food Sufficiency from own food production
[12] Ration cards are issued by Indian state governments, enabling eligible households to buy subsidised food grains from the PDS.
[13] PHH cards are issued to eligible households (based on socio-economic condition), granting them access to subsidised food grains through the Public Distribution System.
[14] Antyodaya cards, issued under the Antyodaya Anna Yojana (AAY), provide higher quantity of subsidised food grains to economically disadvantaged households in India.

66% from the control villages reported the same. Around 35% of the surveyed HHs own a house built under PM Awas Yojana[15] (PMAY); however, the HHs in the treatment villages have higher access to the scheme.



A typical house in the surveyed village where access to piped water supply is absent.

3.1.6. Occupation Profile

Agriculture is the dominant occupation among the surveyed households in Alirajpur, Barwani, Khargone, Khandwa, and Ratlam (i.e., both the treatment and control villages). A significant portion (approximately 35%) of these households rely on casual labour as an additional source of income. However, only a minor proportion, merely 0.9%, consider permanent wage employment as their primary occupation, while 1% of households are engaged in salaried jobs, and another 1% are involved in business enterprises.

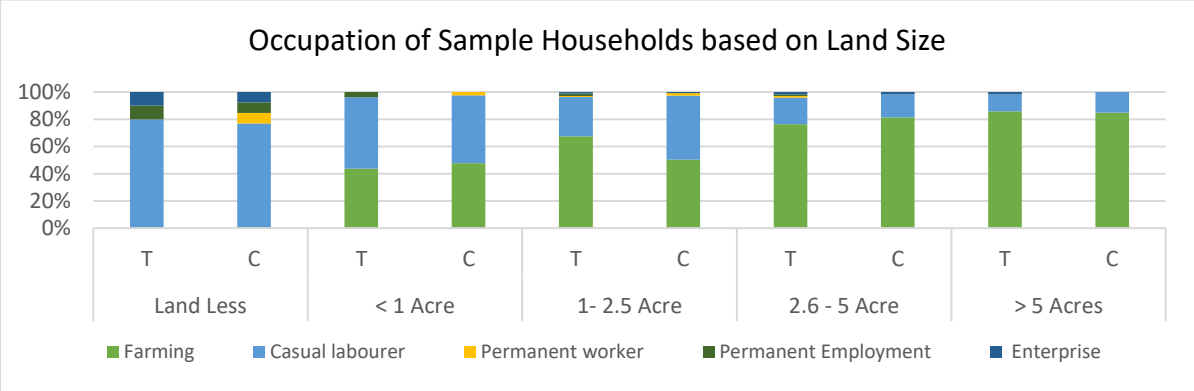
Table 14: Occupation of the Sample Households (in percentage), MP

Village type	Farming (Self-employed in Agriculture)	Casual Labourer (agri + non)	Permanent worker	Private Employment /Salaried Worker	Business/ Own Enterprise
Treatment	65.2	30.7	0.6	2.0	2.0
Control	59.1	38.7	1.3	0.0	0.0
All Villages	62.1	34.7	0.9	1.0	1.0

[15] PM Awas Yojana is a government housing scheme in India that provides financial assistance for affordable housing to eligible beneficiaries. The scheme aims to achieve the goal of "Housing for All" by 2022.

While analysing the occupation patterns concerning land ownership, it is observed that landless farmers and those with less than one acre of land heavily depend on casual labour for livelihood. Surprisingly, 10% of landless households in the treatment village hold permanent jobs; this figure stands at 8% in the control villages. On the other hand, smallholder farmers (owning land between 2.6 to 5 acres) and large farmers (holding more than 5 acres) primarily engage in farming activities as their primary source of income. Agriculture plays a central role in the livelihoods of surveyed households who have land, with casual labour being a common supplement to their income. Landless farmers show some interesting patterns, with a notable percentage holding permanent jobs, while large landholders focus predominantly on farming.

Figure 2: Occupation of Sample Households based on Land Size



3.1.7. Employment under MGNREGS

Only 56.8% of the households had access to job cards, with noticeable variations across districts. In Alirajpur, the lowest percentage of households (25.9%, 26.5% in treatment and 24.5% in control villages) reported having job cards. Conversely, in Khargone, the highest percentage of households (75%, 75.6% in treatment and 71% in control villages) had access to MGNREGS cards. A significant difference is observed in Burhanpur, with 83.3% of households in treatment villages having access compared to 55.6% in control villages. In other districts, the difference in MGNREGS card accessibility among households is insignificant.

Out of the households with MGNREGS cards, only 30.5% reported working in MGNREGS. In Alirajpur, only 10% of households in treatment villages and 8.3% in control villages with MGNREGS job cards worked for a project. The data presented in Table 15 indicate a meager percentage of families with job cards participating in MGNREGS work.

On an average, households that worked under MGNREGS received 43 days of work out of 100 working days. Interestingly, Alirajpur reported the highest number of working days, with households receiving 61 days of work. However, treatment villages received 77 days of work, while households in control villages received only 15 days of work. The lowest number of working days is reported in Ratlam, with only 26 days out of 100 days.

Table 15: Employment Status in MGNREGS in Last One Year in MP

District	Village Type	Households with MGNREGS Cards (%)	HHs with MGNREGS Card worked in MGNREGS (%)	Working days/ Year (#)
Alraijpur	Treatment	26.5	10.0	77
	Control	24.5	8.3	15
Barwani	Treatment	63.3	49.3	62
	Control	54.7	34.5	33
Burhanpur	Treatment	83.3	33.3	39
	Control	55.6	10.0	13
Khargone	Treatment	76.6	23.7	36
	Control	71.0	9.1	65
Jhabua	Treatment	69.4	25.3	42
	Control	68.5	18.9	35
Ratlam	Treatment	47.2	26.5	25
	Control	44.4	31.3	26
Khandwa	Treatment	63.5	61.7	35
	Control	61.8	28.6	43
Total	Treatment	58.4	34.3	45
	Control	53.5	21.8	35
	Total	56.8	30.5	43

3.1.8. Access to Government Subsidies/Schemes

According to the baseline survey, government subsidies these households receive are relatively low in both the treatment and control villages. In the treatment village, 11.61% of the households receive subsidies compared to only 5.75% in the control villages. In all the treatment villages, except for Alirajpur, the percentage of households receiving subsidy in treatment villages is higher than in the control villages. In Alirajpur, 12% HHs in treatment villages receive subsidy against 16% in control villages, mostly for house construction from the Tribal Development Department. The average subsidy received per household in the treatment villages is Rs 100,000, which is much higher compared to Rs 72,000/- per household in control villages.

The highest number of subsidies are reported in treatment villages of Khargone, where out of the 77 households surveyed, 16 households received subsidies, mostly for housing loans with a maximum subsidy of Rs. 300,000 and the minimum subsidy received is Rs. 8,000. However, it is noteworthy that none of the surveyed households in Khandwa have received any subsidy, neither in the treatment nor control villages.

Most of the subsidies received are for the construction of houses, while a few subsidies are granted for irrigation purposes, and one subsidy is received for purchasing a tractor. The maximum subsidy received by any household is Rs 300,000 in the treatment village of Khargone, while the minimum subsidy received is Rs 2,000 in the treatment village of Ratlam. The subsidies are primarily received from the Tribal Development Department, while some subsidies from Pradhan Mantri Awas Yojana (PMAY) and the Agriculture Department are also reported.

Table 16: Percentage of Sample Households receiving Government Subsidies in MP

Village Type	% HHs received Govt. Subsidy	Subsidy Amount (in INR)		
		Average	Minimum	Maximum
Treatment	11.6	106,540	63,375	144,625
Control	4.2	47,037	30,875	57,500
All villages	7.9	76,788	47,125	101,063

3.1.9. Participation in Gram Sabha

Based on the findings, one can infer that the participation of households and women in Gram Sabhas varies across the surveyed districts in Madhya Pradesh. The survey reveals that 73% of the households in the treatment villages have attended at least one Gram Sabha during the last year, while this participation is slightly less at 69.8% for the control villages. However, district-wise data suggests that in Barwani, Burhanpur, Jhabua, Khargone, and Khandwa, more than 75% of the households in both control and treatment villages have attended at least one Gram Sabha meeting in the last year; the numbers are proportionately less in other districts.

Regarding the participation of women in Gram Sabhas, it is noteworthy to find that 40.7% of the women in treatment villages attended Gram Sabha last year. In comparison, it is much less (25.7%) in control villages.

Table 17: Participation of Sample Households in Gram Sabha (GS)

Districts	Village Type	% HH attended the GS meeting	Numbers of GS meeting attended	% Women attended the GS meeting	Numbers of GS meeting attended by women
Alirajpur	Treatment	38.9	44	11.5	13
	Control	59.2	29	10.2	5
Barwani	Treatment	87.2	95	50.5	55
	Control	73.6	39	37.7	20
Burhanpur	Treatment	83.3	30	55.6	20
	Control	77.8	14	33.3	6
Khargone	Treatment	83.1	64	40.3	31
	Control	74.2	23	9.7	3
Jhabua 1	Treatment	70.8	51	58.3	42
	Control	58.3	21	44.4	16
Jhabua 2	Treatment	88.9	32	50	18
	Control	94.4	17	44.4	8
Ratlam	Treatment	47.2	34	20.8	15
	Control	47.2	17	8.3	3
Khandwa	Treatment	82.4	61	37.8	28
	Control	73.5	25	17.7	6
Mean	Treatment	73.4	47.3	40.8	40.3
	Control	69.8	23.1	25.7	8.4
	All villages	71.6	35.2	33.3	24.3

3.1.10. Status of Credit/Loan

The data analysis shows that the percentage of surveyed households who have taken a loan in the last year is 32.6% for the treatment village, whereas the same is 30% in the control villages. In the control villages of Burhanpur and Jhabua, more than 50% of the HHs surveyed have taken a loan. While the average amount of loan taken is highest in Alirajpur for both the treatment and control villages, which is > Rs 100,000, the percentage of families taking a loan is lesser, amounting to 17.7% and 4.08% for treatment and control households, respectively. There might be an increase in the average loan taken per HHs as the number of loans are less, but the amount of loan taken is high.

On average, the loan taken by HHs both in treatment and control villages is almost the same, i.e., 70%. However, when we look at the loan sources, 41% of the households had taken a loan from SHGs/VOs, while in control villages, it is at 31%. The loan taken from money lenders is higher in control villages at 30%, while in the case of treatment, it is only 14%. The loan from formal institutions is almost at par in control and treatment villages at 23.1% and 21.2%, respectively. Loan from community groups/friends is 23% for treatment villages and 15% for control villages. Notably, in Khargone and Khandwa, all HHs in control villages have yet to take a loan from formal institutions. However, in other districts, the loan amount taken from formal institutions is higher for control villages than treatment villages.

Table 18: Household Loan Status in MP

Districts	Village Type	HHs taken loan (Yes%)	Average Amount of Loan (In INR)	Average Loan Outstanding (In INR)
Alirajpur	Treatment	17.7	110,850	80,450
	Control	4.1	125,000	95,000
Barwani	Treatment	13.8	33,667	29,933
	Control	22.6	85,846	76,430
Burhanpur	Treatment	52.8	82,000	64,021
	Control	50.0	27,889	22,555
Khargone	Treatment	16.9	33,214	26,821
	Control	16.1	50,000	18,800
Jhabua 1	Treatment	52.8	111,106	64,538
	Control	41.7	47,222	24,550
Jhabua 2	Treatment	50.0	48,869	27,739
	Control	66.7	96,538	75,770
Ratlam	Treatment	29.2	77,820	45,544
	Control	30.6	36,818	18,173
Khandwa	Treatment	28.4	61,742	44,033
	Control	8.8	93,333	76,667
Mean	Treatment	32.7	69,909	47,885
	Control	30.1	70,331	50,993
	All villages	31.4	70,120	49,439

Table 19: Credit Sources for Sample Households (in percentage)

Village Type	Formal Institutions	Relatives/ Neighbours	Money Lender	Local Informal Committees	SHG/ VO/ CLF
Treatment	21.2	14.2	14	9.4	41.2
Control	23.2	6.7	30.5	9	30.6
All Villages	22.2	11.1	23.7	9.2	35.9

When we analyse the interest rates (Table 20), it is evident that money lenders impose the highest interest rate, amounting to 31.2% per annum, compounded annually. In contrast, the interest rate offered by Self-Help Groups (SHGs) is 10.3% per annum, and loans from banks had the lowest interest rate, set at 9.5% per annum.

Table 20: Source wise Interest Rates on Loan taken by Sample Households (INR/ Annum)

Village Type	Formal Institutions	Relatives/ Neighbours	Money Lender	Local Informal Committees	SHG/ VO/ CLF
Treatment	9.1	23.9	35.9	18.1	11.2
Control	10.5	34.1	22.9	8.3	7.2
All Villages	9.5	26.2	31.2	15.6	10.3

Regarding the purpose of the loan (Table 21), in both control and treatment villages, it is found that 42% of the loans taken in the past year were for agricultural purposes. In Khargone, 78% of the families in treatment villages have taken a loan for agricultural purposes, whereas 100% of the families in control villages have taken a loan for agricultural purposes. In Barwani and Burhanpur, almost 50% have taken a loan for agriculture purposes. The reason for high loans in agriculture could be that the data is taken only for one year.

Seventeen per cent of families in treatment villages and 19% in control villages have taken a loan for marriage or to meet household expenses. Furthermore, 8% of families in treatment villages and 5% of families in control villages have taken a loan to construct/repair a house or buy an asset.

Table 21: Productive vs. Consumption Loans taken by Sample Households (in percentage)

Loan Type		Treatment Villages	Control Villages	All villages	
Productive Loan	High-cost debt redemption	0.7	0	0.4	50.1
	Agriculture activity	42.3	42.1	42.2	
	Livestock rearing	4.4	1	2.7	
	Purchase of asset	3.6	2.4	3	
	To start/ sustain an enterprise	2.8	1	1.9	
Consumption Loan	To marry a family member/ acquaintance	14.4	23.9	19.1	49.9
	To repair/ construct house or other infrastructure	12.3	8	10.2	
	To meet household expenses	19	15.4	17.2	
	To help someone else in need	0.5	6.3	3.4	

3.2. Land Profile of the Sample Households

The land is mostly undulating in the survey area, constituting upland, medium upland, and medium lowland. Household survey data, as well as remote sensing data, provide similar analysis. Further, the field observations during FGD and deep dive study corroborated this analysis. As per HH survey data, most of the land in both treatment and control villages is medium upland (53% and 55%, respectively), followed by upland (31% and 30%). The treatment villages have a higher share of medium lowland (15.1%) than the control villages (14.5%).

A high incidence of upland is observed in the control villages of Ratlam district and treatment villages of Barwani and Jhabua districts. In contrast, an insignificant percentage of low land is observed in control villages of Alirajpur, Barwani, Khandwa, Khargone and treatment villages of Barwani, Khargone and Ratlam districts. Except for the districts of Barwani, Jhabua and Khargone, no clear picture emerges regarding land types in the rest of the districts. Average landholding is significantly lesser in the treatment villages (2.8 acres) compared to the control villages (3.3 acres).

Table 22: Land Type Classification as per the Household Survey

Districts	Village Type	*Upland* %	Medium Upland %	Medium Lowland %	Total Land (acre)	Average Land Ownership per HH (acre)
Alirajpur	Treatment	40	43	17	280	2.5
	Control	26.9	63.4	9.7	166	3.5
Barwani	Treatment	43.9	48.3	7.8	303	2.9
	Control	32.8	57	10.2	172	3.5
Burhanpur	Treatment	17.8	39.3	42.9	127	3.5
	Control	59.0	17.3	23.7	70	3.9
Khargone	Treatment	12.3	84.9	2.8	269	3.5
	Control	16.6	80.8	2.6	153	5.5
Jhabua	Treatment	42.1	29.7	28.2	178	1.6
	Control	30.7	25.2	44.2	120	2.2
Ratlam	Treatment	37.5	49.8	12.7	159	2.2
	Control	46.8	33.9	19.3	80	2.2
Khandwa	Treatment	22.1	59.4	18.5	305	4.4
	Control	5.2	94.8	0	106	3.8
Mean	Treatment	31.4	53.4	15.1	1621	2.8
	Control	30.4	55.1	14.5	868	3.3
	All Villages	31.1	54.0	14.9	2490	3.0

The agroclimatic zone level disaggregated data shows that the Jhabua Hills ACZ district has an equal distribution of land types across the treatment and control villages. In contrast, the land type in the Nimar Plateau is more skewed towards medium land. However, such broad characteristics have yet to evolve for the Malwa Plateau.

Table 23: Classification of Land Types by Agro-climatic Zones

ACZ	Village Type	Upland (%)	Medium Upland (%)	Medium Low Land (%)	Total Land (%)
Jhabua Hills	Treatment	41.5	30.6	30.1	100.0
	Control	27.5	45.0	26.2	100.0
Nimar Plateau	Treatment	28.1	57.2	17.5	100.0
	Control	21.4	63.8	8.8	100.0
Malwa Plateau	Treatment	2.5	95.7	1.3	100.0
	Control	74.9	33.9	19.3	100.0

An effort is made to understand the land classification through RS-GIS for the entire landscape of the surveyed villages. This is an additional effort to corroborate the findings from the HH survey. However, the data from HH survey is only limited to agricultural land and does not consider built-up land, forests, wetlands or barren land. Moreover, the HH data set is only for a small % of the villages and may not give a broader view of the situation.

As per the RS-GIS data, 12% of the total land in the surveyed villages is upland, 42% is medium upland, and the remaining 46% is lowland – though significant district-wise variations exist.

Table 24: Classification of Land Types for Sample Households as per RS-GIS

District	Village Type	Total Land (acre)	Upland (%)	Medium Upland (%)	Medium Low Land (%)
Alirajpur	Treatment	4,012	6.1	38.1	55.8
	Control	3,061	5.2	62.1	32.7
Barwani	Treatment	4,181	3.7	43.5	52.8
	Control	1,395	22.5	63.9	13.5
Burhanpur	Treatment	977	1.7	35.5	62.8
	Control	622	5.5	22.5	71.9
Jhabua	Treatment	3,933	22.4	31.5	46
	Control	1,470	26.6	56.4	17
Khandwa	Treatment	2,878	17.3	39.9	42.8
	Control	3,297	3	33.2	63.8
Khargone	Treatment	2,715	9.3	39	51.7
	Control	423	3.3	31.4	65.4
Ratlam	Treatment	1,142	16.8	56.2	27.1
	Control	716	54.8	22.6	22.6
Mean	Treatment	2,834	11.3	39.2	49.5
	Control	1,569	12.8	46.9	40.3
	All villages	2,201	11.8	42	46.2

3.2.1. Land Ownership

Our analysis shows that the overall average landholding per HH is slightly higher in control villages (2.6 acres) than in treatment villages (2.2 acres). There is a significant district-wise variation with the average HH landholdings. For instance, the control villages of Alirajpur reported 5 acres of landholding, while those in the treatment villages of Alirajpur have 1.1 acres.

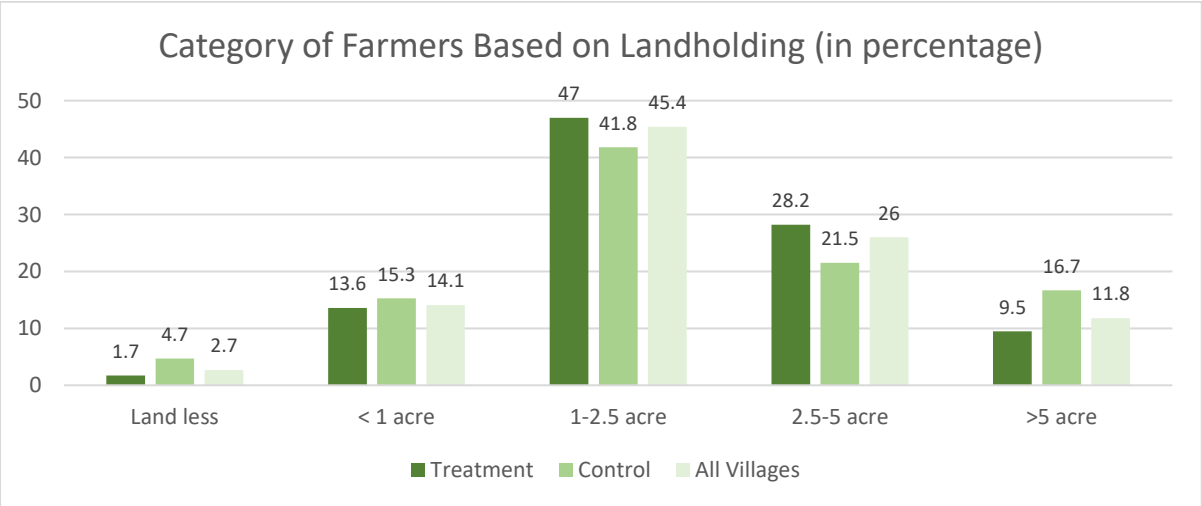
From the caste-wise analysis, SC HHs are at the bottom of the ownership hierarchy with only 0.1 acre/ HH. The ST HHs, which comprise a significant portion of the surveyed HHs have an average holding of 2.9 acres (3.2 acres in control and 2.8 acres in treatment villages). The OBC HHs top the land ownership hierarchy with 5.7 acres of land per HH (10.2 acres in control and 2.8 in treatment villages), and the HHs from other castes have an average of 4.1 acres (3.6 and 4.5 in control and treatment groups, respectively). The maximum landholding of 24 acres is reported from control villages of Barwani district.

When farmers are categorised according to the size of their landholdings, the majority of them (41.8%) fall into the marginal category, owning land ranging from 1 to 2.5 acres. Additionally, small farmers, owning land between 2.5 to 5 acres, comprise a significant portion of the farming population (21.5%); 4.7% do not own any land, 15.3% are categorised as nano farmers with less than one acre of land, and 16.7% of surveyed households are large farmers, possessing more than five acres of land.

Table 25: Average Land Holdings of Sample Households and Landholdings by Caste in MP

Village Type	SC HH	ST HH	OBC HH	Others HH	Max holding (acres/HH)	Min holding (acres/HH)	Mean of all HHs (acres/HH)
Treatment	0.1	2.8	2.8	3.6	17	0.1	2.8
Control	0.0	3.2	10.2	4.5	24	0.3	3.3
All Villages	0.1	2.9	5.7	4.1	24	0.1	3.0

Figure 3: Category of Farmers Based on the Landholding Size (N = 864, Treatment = 589; Control = 275)



3.2.2. Individual Forest Rights (IFR), Landholding and Usage

A few HHs across all surveyed villages and districts reported access to IFR land, except for Jhabua and Ratlam, where the access is very high. In the treatment villages of Jhabua and Ratlam, 38.9% and 81.9% households reported access to IFR land. The pattern emerges that treatment villages are better off in IFR land access.

Table 26: Classification of Sample HHs with IFR Land and its Usage Across Districts in MP

Districts	Village Type	HHs with IFR land (%)	IFR Land Use Detail
Alirajpur	Treatment	1.13	Fallow land
	Control	4	Pulses/oilseeds
Barwani	Treatment	10	Fallow land
	Control	0	NA
Burhanpur	Treatment	11.1	Cereal Crops
	Control	0	NA
Jhabua	Treatment	38.9	Cereal Crops
	Control	10.9	Cereal Crops
Khandwa	Treatment	0	NA
	Control	0	NA
Khargone	Treatment	7.8	Cereal Crops
	Control	9.7	Cereal Crops
Ratlam	Treatment	81.9	Cereal Crops, pulses, oilseeds, plantation
	Control	19.3	Cereal Crops

3.2.3. Land Use Land Cover (LULC) Data

The GIS analysis reveals that the habitation area in the villages covered around 2.1% (control villages) to 2.4% (treatment villages). The wetland, which can be defined as surface waterbodies and perennial/ water stream areas in the villages, is around 3.1% and 2.5% in treatment and control villages respectively. The forest is conspicuously marked only in the villages of Burhanpur, while the forest cover is mostly minimal in the rest of the villages. All the villages have significant agricultural land. However, some of the treatment villages of Barwani and control villages of Burhanpur have agricultural land much below the average.

Table 27: Classification of Land Use and Land Cover in MP

Districts	Village Types	Built Up (%)	Wet Land (%)	Forest Land (%)	Barren (%)	Agriculture (%)	Total Land
Alirajpur	Treatment	0.9	4.1	1.4	8.8	84.9	4,014.8
	Control	1.8	2.7	1.4	9.1	85.0	3,062.3
Barwani	Treatment	2.8	2.6	0.1	23.6	70.9	4,183.3
	Control	3.8	0.0	1.8	4.7	89.7	722.4
Burhanpur	Treatment	1.2	5.2	10.1	1.8	81.6	978.5

	Control	1.3	1.9	24.3	4.1	68.5	623.2
Khargone	Treatment	6.8	0.6	2.6	0.4	89.6	2,177.8
	Control	2.5	4.4	0.0	2.7	90.4	960.4
Jhabua 1	Treatment	2.9	1.4	1.3	7.1	87.2	1,342.1
	Control	1.8	2.5	0.0	2.9	92.7	1,011.1
Jhabua 2	Treatment	0.9	2.2	1.1	4.3	91.5	2,592.1
	Control	2.1	6.1	0.1	0.9	90.9	460.5
Ratlam	Treatment	2.8	4.7	10.6	5.8	76.0	1,143.7
	Control	1.0	2.3	0.2	19.5	77.1	717.3
Khandwa	Treatment	1.2	3.7	0.7	4.7	89.8	2,881.6
	Control	2.0	0.0	1.5	18.1	78.4	3298.0
Mean	Treatment	2.4	3.1	3.5	7.1	83.9	19,313.8
	Control	2.1	2.5	3.6	7.8	84.1	10,855.2

The study also attempts to understand the change in Land Use Land Cover (LULC) data to better analyse the surveyed geography. In confirmation with general understanding, the built-up area – the village habitation area has changed considerably- 659% in the first decadal period (2000-2010) and by 198% in the next decade (2010-2022). This change is a natural phenomenon based on the population expansion in the villages across the country. However, the data points towards a significant change in the treatment villages compared to the control villages.

The change in the wetland area is also in sync with the built-up area. Though the change in the recent decade (8.5%) has been more modest than the previous one (5519%), the wetland area has reduced in the last decade while those in the treatment villages witnessed an upward trend. Control villages in Alirajpur and Khargone have pulled the average down. The reasons for this may be many, but the most crucial issue reported by the community during both FGD and deep dive process has been the rainfall deficit in the recent past (at least 3-4 years).

Though the forest cover changed significantly (in terms of percentage change) during 2000-2010 and then reduced by 18.9% during 2010-2022, it is essential to note that the negative change is significant in Burhanpur, which has the maximum forest cover. The barren land has been continuously reducing, and field experience shows that this is mainly converted into agricultural land as well as for habitation built-up areas. The upsurge in the coverage area in agriculture only reinforces our field observations.

Table 28: Changes in Land Use and Land Cover (LULC)

Village Type	Built Up		Wet Land		Forest Land		Barren		Agriculture	
	2010-22	2000-10	2010-22	2000-10	2010-22	2000-10	2010-22	2000-10	2010-22	2000-10
Treatment	184.7	929.7	30.1	1250.5	-38.3	8845.4	-38.6	-52.4	5.8	13.9
Control	213	389.5	-13.2	9789	0.5	4847.3	-47.4	-27.7	24.9	28
All Villages	198.8	659.6	8.5	5519.7	-18.9	6846.4	-43	-40.1	15.4	21

3.3. Season Wise Agriculture Practices

Data analysis reveals that 98% of the surveyed farmers are growing kharif crops in 88% of the available agricultural land. This figure drops in the Rabi season when only 57% of the farmers are growing Rabi crops on 41% of the land. All three crops (Kharif, Rabi and Zaid) are only grown by 3.9% of the farmers in 1.6% of the land. This reduction is primarily because of the lack of irrigation in most villages.

As per the respondent data, the control villages of Alirajpur and Khargone have the lowest coverage in Kharif (56% and 59%, respectively) compared to the rest of the villages. For Rabi crops, the percentage is meagre in Burhanpur district (15% in the treatment area and 12% in the control area). In comparison, Khandwa tops the chart with 60% in the area under rabi in treatment villages and 71% in control villages.

The area under crop in all three seasons is almost negligible for most villages except for treatment villages in Khargone (4.8%), control towns of Alirajpur (2.3%).

Figure 4: Percentage of Households Taking Crops in Each Season

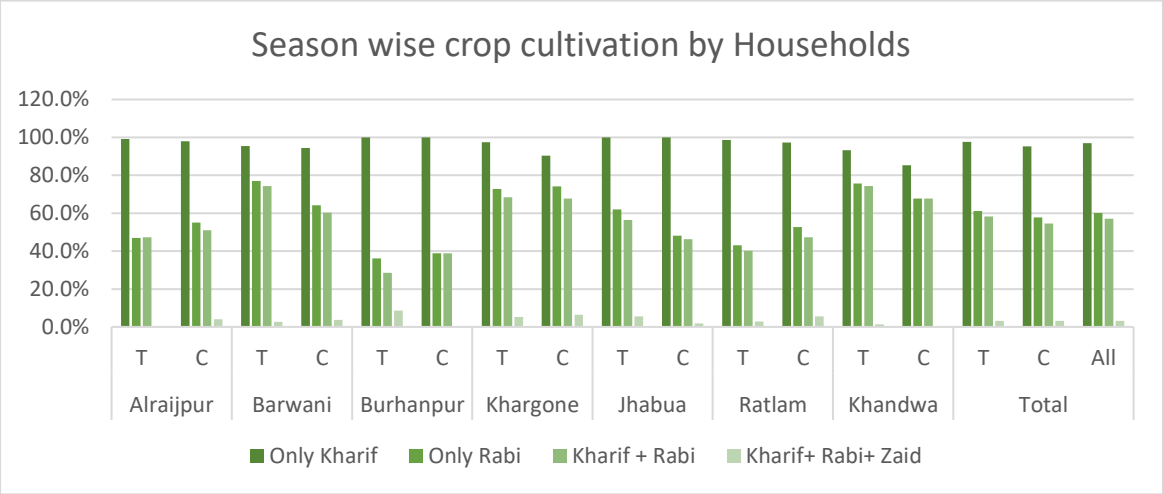
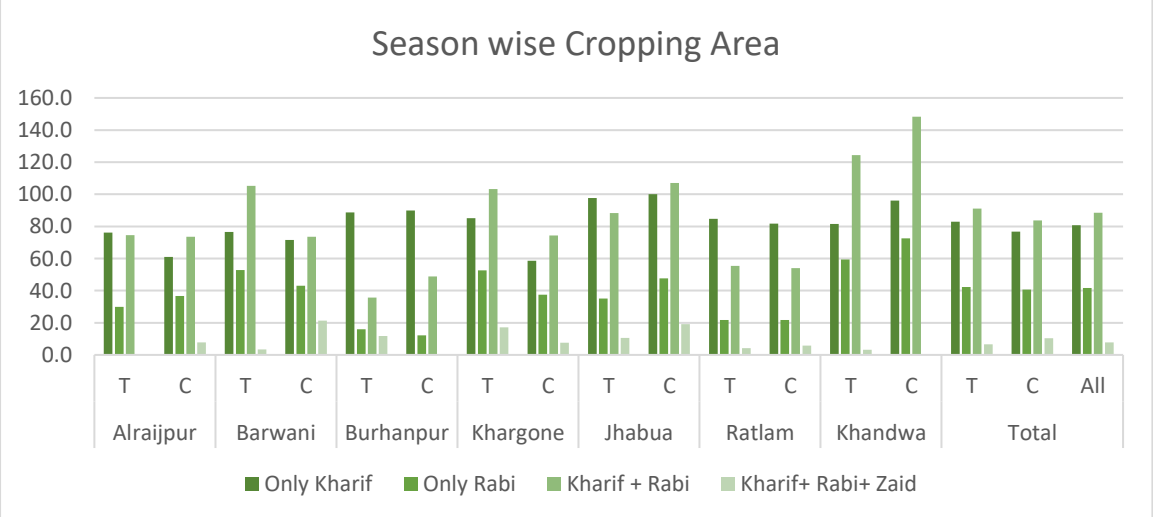


Figure 5: Season-wise Area under Crop (in Percentage)



Cotton is the most popular crop in the surveyed villages, followed by maize. Soybean is only prominent in one district of Khandwa (71%). In the Rabi season, wheat and gram are the most common crops; 76% of the surveyed HHs in the treatment villages and 64% of HHs in the control villages grow cotton. The average area under cotton in both the treatment and control villages is 1.2 acres and 1.6 acres, respectively. As discussed earlier, cotton is grown in all land types; however, it is primarily grown in upland and medium upland, both in treatment and control villages. Ratlam district has the highest percentage of farmers growing cotton (both in treatment and control villages). The data also reveals that in most of the districts, a larger share of farmers grow cotton in treatment villages compared to control villages. This may be primarily due to ASAs cotton value chain intervention. Khandwa is an exception where none of the surveyed farmers reported growing cotton.

Maize is also grown almost by the same percentage of farmers in treatment and control villages. The average area under maize is approximately the same in both treatment (1.2 acres) and control villages (1.3 acres). However, data shows that a larger area of upland and medium upland is covered with maize in both control and treatment villages. A smaller share of farmers grow maize in Barwani district (both treatment and control), Burhanpur (treatment area), Khandwa (control villages), and Khargone (control villages).

Though soybean is grown across all the districts, it is most pronounced in Khandwa and Khargone. Further, 72% of the respondents in Khandwa and 38% in Khargone are growing soybean. The acreage under soybean is almost equal in both treatment and control villages (2 acres). For growing soybean, medium upland is the most preferred choice for farmers.

Table 29: Average Crop Area and Land Type for Cultivation by Sample Households (N=864)[16]

Season	Crop	Village Type	# of HHs (N)	Average Area Under Crop/HH	% of Crop in Upland	% of Crop in Medium Upland	% of Crop in Medium Lowland
Kharif (HHs doing Kharif = 837, 96.9%)	Cotton	Treatment	342	1.3	50.8	59.5	24.6
		Control	157	1.6	52.7	52.1	26.3
	Maize	Treatment	428	1.2	55.3	55.8	28.7
		Control	164	1.3	56.1	44.6	26.1
	Soybean	Treatment	149	2.0	38.3	67.1	22.8
		Control	60	2.1	30.0	70.0	10.0
Rabi (HH doing Rabi = 519, 57.2%	Wheat	Treatment	326	1.7	30.1	71.8	20.9
		Control	145	2.0	27.6	73.8	20.7
	Gram	Treatment	73	1.2	31.5	67.1	30.1
		Control	28	1.3	35.7	64.3	32.1

More than 90% of the farmers grow wheat in both treatment and control areas, with an average acreage of 1.7 acres and 2 acres for treatment and control villages, respectively. Interestingly, 28% of upland and 70% of medium upland is used for growing wheat. A large share of the

[16] Total number of surveyed HHs taking seasonal crops is 864. Of these 864, 96.9 % (837) farmers are doing Kharif crop and 57.2% (519) are doing Rabi crop)

upland is under wheat cultivation (45%, 40% and 40%, respectively) in Alirajpur, Barwani and Jhabua districts. Khandwa, Khargone and Barwani are the districts where a large section of farmers grows wheat. The average area under wheat per HHs is high in the control villages of Barwani (4.3 acres) and control villages of Jhabua (4.6 acres), while lowest in the treatment villages of Burhanpur (1.5 acres).

Since wheat requires repeated irrigation, there is a considerable probability of production loss in wheat in the absence of a proper irrigation system to lift water to higher elevations (not counting the seepage loss). Consequently, growing wheat in the upland may not be the most efficient cropping format.

Figure 6: District-wise Percentage of Major Crops Grown in Kharif Season

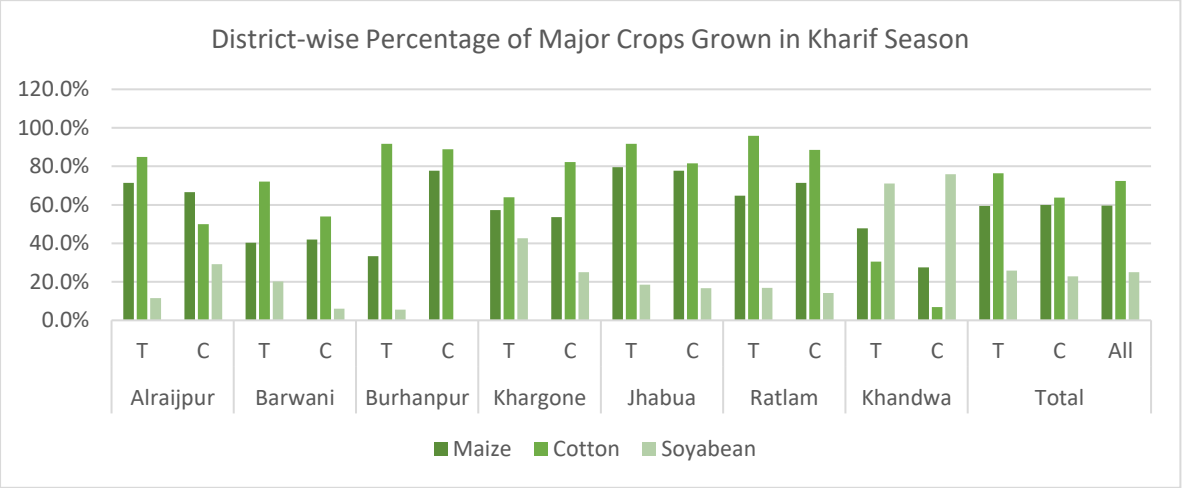
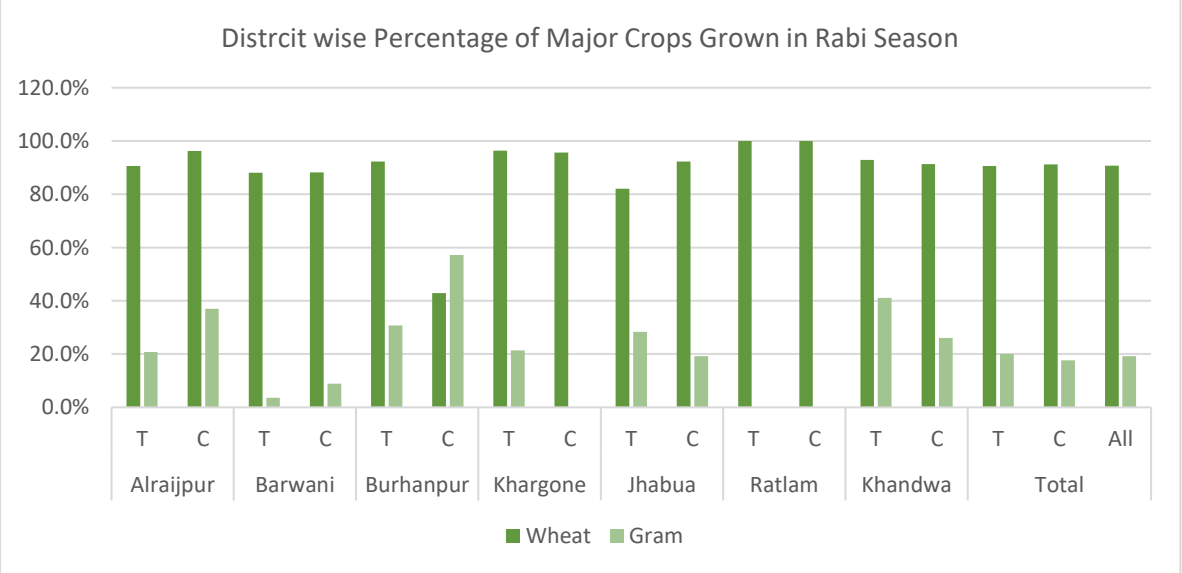


Figure 7: District-wise Percentage of Major Crops Grown in Rabi Season



Gram is the second most commonly grown crop in the Rabi season, but only 18% of the farmers in treatment areas and 21% of farmers in the control area grow it. The average area under the crop is 1.2 acres in treatment villages while 1.3 acres in control villages. Though most of the crop is grown in medium upland in treatment villages, farmers in control areas use all types of land for gram cultivation.

The data shows that farmers mostly use their own land to grow different crops, whereas 5% of farmers in treatment villages grow cotton crops on leased land. This may be because of the market pull of the ASA-promoted FPOs. A small percentage of farmers across treatment and control villages also grow other crops on leased land.

Table 30: Crop Cultivation by Land Ownership

	Crop	Village Type	Own Land only (HH%)	Lease Land only (HH%)	Both Own and Lease Land (HH%)
Kharif N – T= 575 C = 262	Cotton	Treatment	94.2	5.1	0.0
		Control	99.0	0.4	3.7
	Maize	Treatment	98.7	1.3	0.0
		Control	99.6	0.4	0.0
	Soybean	Treatment	98.0	2.0	0.0
		Control	100.0	0.0	0.0
Rabi N – T = 360 C= 159	Wheat	Treatment	99.2	0.8	0.0
		Control	97.9	2.1	0.0
	Gram	Treatment	98.9	1.1	0.0
		Control	100.0	0.0	0.0

3.4. Agronomic Practices

3.4.1. Land Preparation and Sowing Methodology

Across crops and districts, no notable change in the number of ploughings is observed among the treatment and control groups, pointing to a similar set of practices adopted by farmers in the survey areas.

Table 31: Ploughing Frequency Among Sample Households by District (in Numbers)

Districts	Cotton		Maize		Soybean		Wheat		Gram	
	T	C	T	C	T	C	T	C	T	C
Alirajpur	3.3	2.8	2.6	2.3	2	3	2.3	2.1	2.1	2.1
Barwani	3.2	3.6	2.7	2.9	3	3	2.5	2.5	-	-
Burhanpur	1.9	2.0	2.0	2.0	3	-	2.2	0.0	-	2.0
Jhabua	2.1	1.9	2.1	1.7	2	2	2.2	1.9	2.0	-
Khargone	3.0	3.1	2.9	2.1	2	2	2.5	2.1	2.7	-
Ratlam	2.5	2.4	2.6	2.6	3	2	2.3	2.5	-	-
Khandwa	0.0	0.0	2.2	0.0	2.3	2.5	2.2	2.5	2.1	-
Mean	2.7	2.6	2.4	2.3	2.3	2.5	2.3	2.3	2.2	2.1

Data from the household survey show that the community adopts varied sowing practices for different crops with no significant changes between treatment and control groups.

For kharif cotton, line sowing is the most preferred method adopted by 87.4% of the farmers in treatment villages and 84.7% of farmers in the control villages. However, a wide inter-district variation is observed where districts like Alirajpur and Barwani are more into line sowing (100% in the control villages of Alirajpur and treatment villages of Barwani) while some farmers in Jhabua and Ratlam prefer intercropping even though line sowing remain the dominant practice. The broadcasting method is the least adopted practice across farmers, though a few farmers in Khargone still prefer it.

In Maize, line sowing is more pronounced in control villages (91.7%), while farmers in treatment villages lag a little behind, with 89.6% adopting line sowing. Broadcasting methods in maize is practised by a limited set of farmers in some selected geographic pockets. Jhabua is the only exception where a large percentage of farmers (30.23%) practice intercropping with maize. This finding is in sync with the FGD as well as deep dive observations.

Soybean is produced mainly by the surveyed farmers in Khandwa and Khargone, and line sowing is the most preferred option (88% in control and 98% in treatment). Only 5% of farmers in control villages opted for broadcasting.

More than 75% of the farmers use line sowing methods in wheat, while the remaining do broadcast. The technique of wheat broadcasting is highest in Alirajpur, where 60% of the surveyed households in treatment villages and 69% in the control villages adopt broadcasting methods. On the other hand, the line-sowing method in wheat is most popular among the surveyed households in Khandwa district.

During Rabi season gram cultivation, 81% of the farmers use line sowing methods, while 18.5% broadcast the seeds.

Table 32: Seed Sowing Methodology for Different Crops

Crop	Village Type	Intercropping	Line Sowing	Broadcasting
Cotton	Treatment	10.9	87.4	1.7
	Control	12.5	84.7	2.8
Maize	Treatment	7.5	89.6	3
	Control	6.6	91.7	1.6
Soybean	Treatment	0	98	2
	Control	0	88	12
Wheat	Treatment	0	76.5	23.5
	Control	0	78.7	21.3
Gram	Treatment	1.1	81.9	17
	Control	0	80	20

3.4.2. Seed Application

Seeds play a crucial role in boosting the productivity of crops. Using hybrid and high-yielding variety seeds is one of the significant forms of enhancing production. These types of seeds are readily available in the market and are used by the majority of the farmers. Indigenous/ local varieties of seeds, on the other hand, perform exceptionally well in stress conditions. Farmers across the country, especially in tribal hinterland, use indigenous/ local varieties of seeds mainly for growing cereals and food crops.

In the surveyed households, a very similar pattern is observed. In the cotton crop, which is a cash crop for all the farmers, hybrid and high-yielding seed varieties are used by 97.5% of the farmers in the treatment area and 96.5% of the farmers in the control area. The notable exception is the farmers in the control villages of Burhanpur district, 12.5% of whom use indigenous (home-stored from earlier production) cotton seed.

Table 33: Seed Types Used by Sample Households for Major Crops in MP

Crop	Villages	High Yielding Variety (%)	Indigenous (%)
Maize	Treatment	76.7	23.29
	Control	73.95	26.05
Cotton	Treatment	97.45	2.54
	Control	96.4	3.60
Wheat	Treatment	54.8	45.11
	Control	46.76	53.16
Soybean	Treatment	59.18	40.82
	Control	45.45	54.55
Gram	Treatment	22.22	77.74
	Control	62.5	77.50

Maize, which is used both for home consumption as well as for sales, observes more than three-fourth of the seeds from a hybrid or high-yielding variety, with approximately 25% of indigenous or home-stored seed usage. The surveyed farmers of Alirajpur, Jhabua and Khargone have a higher propensity to use this indigenous (locally conserved) type of seeds, though the percentage of such usage never exceeded 47%.

Interestingly, for the soybean crop, which is a cash crop, the usage of local variety/home-stored seeds (48%) is very close to hybrid and high-yielding variety seed usage (52%). For wheat crops, 45% of the farmers in the treatment villages and 53% in control villages use locally stored/ indigenous variety of seeds.

The farmers in Ratlam (both treatment and control), Barwani (control) and Burhanpur (treatment) are the ones who are high up the ladder in terms of usage of hybrid and high-yielding varieties of wheat seeds.

Gram, grown in a few districts and mostly for household consumption, sees almost 77% of indigenous variety usage in treatment and control villages. It is worth noting that 88.5% of the farmers in Alirajpur district use indigenous/ locally stored variety of gram seeds.

According to the findings in Table 34, the seed replacement rate, which refers to the frequency of replacing seeds annually, is notably high for cotton in both the treatment and control villages. For maize, approximately 50% of the farmers in the treatment villages opt for seed replacement, while in the control villages, the percentage is higher at 77.8%. In the case of Rabi crops, specifically wheat and gram, the practice of seed replacement is followed by less than 50% of the farmers.

Table 34: Seed Replacement Rate and Seed Treatment Practices

Crop	Villages	# of HHs the cultivating crop (N)	HHs replacing seeds every year (% of N)	HH doing Seed Treatment (%)
Maize	Treatment	342	50.0	5.5
	Control	157	77.8	9.2
Cotton	Treatment	439	97.5	0.2
	Control	167	98.2	0.6
Wheat	Treatment	326	45.0	4.8
	Control	145	35.0	6.9
Soybean	Treatment	149	51.7	6.1
	Control	60	50.1	22.7
Gram	Treatment	73	49.3	7.5
	Control	28	46.4	0.0

The analysis of the survey data also reveals that seed treatment, i.e., an essential agronomic practice, is yet to get integrated into the farming ecosystem. Only 7.35% of the HHs reported treating maize seeds, and the farmers in the control villages are 2% points above the treatment villages. Only 0.43% of the farmers treated the cotton seeds. The farmers in the control villages of Khandwa for wheat crops (23.8%), control villages of Khargone for maize crop (33.3%) and control villages of Khandwa for soybean crop (22.7%) are the ones above the curve on seed treatment initiative.

3.4.3. Irrigation Usage and Sources

Irrigation is a critical factor in agriculture, and the number of irrigations to a particular crop is a function of the crop type, soil structure, and land type.

The survey findings in MP indicate that the percentage of potential irrigated land varies in different districts and across treatment and control villages. The data here presents the percentage of irrigated land area of the total household and the various sources of irrigation.

The data reveals that while 52% of the land has irrigation facilities available in both treatment and control villages, the irrigation sources are primarily ponds, open wells, and rivers. For instance, in Alirajpur district, treatment villages have 43.5 % potential irrigated area, compared to 23.7% in control villages. The major irrigation sources in treatment villages are open wells (30%), river streams (18.6%), and bore wells (10.6%), while in control villages, open wells (40%) and ponds (10%) are the major sources. The treatment villages of Burhanpur reported the lowest potential at 29%, while the HHs in the control villages of Khandwa reported 68%.

Table 35: District wise Potential Area under Irrigation and Sources in MP

Districts	Village Type	Potential Irrigated Area of the Total Area (%)	Potential Irrigated /HH (acre)	Irrigation Source (% of area)				
				Pond	Canal	Open wells	Bore wells	River/ Stream
Alirajpur	Treatment	47.0	2.0	0.9	0.0	30.1	10.6	18.6
	Control	38.0	2.3	10.2	0.0	40.8	2.0	4.1
Barwani	Treatment	57.1	1.9	3.7	8.3	52.3	1.8	20.2
	Control	53.5	2.8	0.0	11.3	32.1	28.3	3.8
Burhanpur	Treatment	43.5	3.5	0.0	2.8	16.7	11.1	19.4
	Control	23.7	2.4	0.0	0.0	22.2	5.6	16.7
Khargone	Treatment	63.4	2.8	10.4	0.0	40.3	22.1	9.1
	Control	68.0	3.9	25.8	6.5	54.8	22.6	3.2
Jhabua	Treatment	43.1	1.2	18.5	12.0	31.5	2.8	5.6
	Control	59.5	2.6	42.6	0.0	9.3	0.0	3.7
Ratlam	Treatment	29.8	1.4	4.2	0.0	20.8	2.8	26.4
	Control	35.9	1.2	5.6	0.0	8.3	0.0	50.0
Khandwa	Treatment	61.0	3.0	13.5	0.0	59.5	4.1	12.2
	Control	68.0	2.7	0.0	0.0	47.1	17.7	2.9
Mean	Treatment	51.9	1.7	7.8	3.9	37.5	7.3	15.5
	Control	51.9	2.0	13.8	2.9	29.8	10.9	10.6
	All villages	51.9	2.0	9.7	3.6	35.1	8.5	13.9

One must note that 24% of the potential irrigated land is from surface water sources like ponds (10%) and rivers/ nallahs (14%). Only 8.5% and 3.6 % of the land has the potential to be irrigated from borewells and canals, respectively. Over 35% of the land finds irrigation support from the open wells. However, most of these open sources of irrigation dry out post monsoon season and in deficit rainfall years; thus, farmers mainly depend on precipitation for irrigation. The study highlights the need to diversify irrigation sources and promote sustainable water management practices to improve the region's agricultural productivity and food security.



Irrigation through open wells. Households get water for irrigation distance increasing the cost of irrigation.

Cotton, i.e., the most popular crop in the region, is cultivated through two different techniques. On the one hand, some members of the community opt for short-duration cotton with early sowing. The households with access to irrigation during the Rabi season tend to adopt this practice. On the other hand, long-duration cotton is cultivated by others with limited or no irrigation access for their plots. However, during the post-monsoon period, when the cotton reaches a mature stage, a couple of irrigation cycles become necessary for its successful growth.

Maize is typically grown as a kharif crop in the surveyed region and only provided irrigation based on water stress and availability. Although Soybean usually doesn't require additional supplementary irrigation, the community irrigates the field based on water availability or in case of a prolonged drought spell. Wheat is a rabi crop, sown in November/ December and requires extensive irrigation support. Lack of irrigation adversely affects wheat crop production (and so does temperature variation). Gram, on the other hand, even being a rabi crop, is grown using the available soil moisture. Additional irrigation does boost production.

As per the HH survey, 16% of the farmers in treatment villages irrigate their cotton fields in comparison to 22% of the farmers in control villages. The average number of irrigations done by households at treatment villages is 2, one less than that of the frequency (3) in the control villages. Only a few farmers in the Alirajpur and Burhanpur districts irrigate their cotton fields; 39% of the farmers in the control villages of Khargone reported irrigating their fields 2.4 times. Regarding irrigation numbers, the villagers in the control villages of Barwani reported irrigating their land 5.1 times.

All the farmers in control villages and 98% of farmers in treatment villages irrigate their wheat fields 4.8 and 4.6 times, respectively. Interestingly in water-stressed areas like Alirajpur district, all farmers reported irrigating their wheat fields by at least 5.4 times. During deep dive (though not representative of the sample), it is observed that wheat is a ubiquitous crop in Alirajpur district, and even uplands are used for cultivation. However, crops in many fields were withering away due to irrigation shortage. Gram crops are also being irrigated by 83.5% of the farmers in treatment and 95% of the farmers in control villages by 2.4 times.

Table 36: Irrigation Coverage and Numbers per Crop by Sample Households

Crops	Villages	HHs cultivating the crop (N)	HHs providing Irrigation (% of N)	# of Irrigation
Cotton	Treatment	439	15.9	2.1
	Control	167	21.7	2.9
Wheat	Treatment	326	98.4	4.6
	Control	145	100.0	4.8
Gram	Treatment	73	83.5	2.4
	Control	28	95.0	2.4

3.4.4. Adoption of Agri-Technology

In rural India, the utilisation of farmyard manure (FYM) is a widespread practice. However, the decomposition process of this manure often lacks scientific methods, leading to a significant reduction in its potency. The nitrogen content in organic manures tends to escape and react with oxygen rapidly, further diminishing its effectiveness.

Based on the household survey, it is observed that the usage of FYM is more prevalent during Kharif crops, such as Cotton, Maize, and Soybean, compared to the Rabi crops. Notably, nearly 90% of households utilise FYM in all their plots for Cotton and Maize cultivation. However, the traditional composting method remains the most popular approach for FYM utilisation across all crops.

The survey aims to assess the level of adoption of various agricultural technologies and practices among farmers, focusing on regenerative agriculture as a foundational intervention. The questions seek to determine the community's uptake of specific practices, such as refraining from the conventional fertilisers and opting for organic fertilisers and bio inputs (including enzymes and pest control methods).

Additionally, the survey inquires about other practices, including intercropping and utilising climate-resilient indigenous seed varieties. It also seeks information on the adoption of advanced technologies like greenhouses, polyhouses, organic mulching, plastic sheet mulching, and the use of nurseries for seedling raising.

The gathered data indicates that only a small percentage, approximately 2.6% of the surveyed households, has adopted at least one of the mentioned practices. The overall adoption of agri-technological practices is minimal (Table 37). For example, only 3.2% of farmers reported practicing intercropping in cotton, and merely 2% reported doing so in maize. In the treatment village, 8.2% of households reported using only organic practices in gram cultivation, compared to 3.6% in the control village. Similarly, 4.1% of households in the treatment village are using indigenous seeds, while the figure is 3.6% in the control village.

Table 37: Crop-Wise Adoption of Agri-technology/ Improved Practices (percentage of HHs adopting the practices)

Crop	Village Type	Intercropping with Another Crop	HHs doing Only Organic	Used Indigenous Seeds	Did not use Fertiliser	Did not use Pesticide/ Weedicide
Cotton	Treatment	3.2	1.2	0.0	0.9	0.3
	Control	3.8	1.3	0.0	0.6	0.0
Maize	Treatment	2.1	0.9	0.2	0.7	0.7
	Control	2.4	0.0	0.0	0.0	0.0
Soybean	Treatment	0.0	1.3	0.7	0.7	0.0
	Control	0.0	1.7	0.0	0.0	0.0
Wheat	Treatment	0.0	1.5	0.3	0.6	0.0
	Control	0.0	1.4	0.0	0.0	0.0
Gram	Treatment	0.0	8.2	4.1	6.8	6.8
	Control	0.0	0.0	3.6	3.6	3.6

3.4.5 Soil Testing

Soil testing is more pronounced in districts like Barwani, Khargone and Jhabua and that too in the treatment villages. Overall, 12.1% of the surveyed households reported testing their agricultural soil ever. 5.9% of the households who have done the testing reported owning a soil health card and only 2.9% of the households reported applying nutrient to the soil as per the soil testing

Table 38: Percentage of Households doing Soil Testing

Village Type	HH ever tested soil		HH with a soil health card		HH applied nutrient as per soil test	
	(N)	% of HH	(N)	% of HH	(N)	% of HH
Treatment	87	10.3	4	4.6	2	2.3
Control	15	1.8	2	13.3	1	6.7
Total	102	12.1	6	5.9	3	2.9

3.4.6. Fertiliser and Pesticide Usage

Despite considerable variations across districts and crops, chemical pesticides are universally employed for all crops in both the treatment and control villages. Among these crops, cotton stands out as one with particularly high pesticide usage, except in the districts of Burhanpur and Jhabua. In these two districts, the utilisation of chemical pesticides in cotton is notably lower. Approximately 80% of farmers in treatment villages and 85% in control villages use pesticides for cotton cultivation.

In treatment areas, 8.8% of farmers reported using home-based pest control remedies like Bramhastra and Agniastra. In comparison, the corresponding figure for control villages is 5.5%. Notably, a significant proportion of farmers across all districts, especially in Jhabua (23%), produce these bio-pesticides for self-application in their own fields. The difference in

pesticide usage between treatment and control villages could be attributed to the presence of Farmer Producer Organisations (FPOs) in treatment villages, where training in organic practices has been provided.

Similarly, in soybean cultivation, a large percentage of farmers, both from treatment (84%) and control (96%), use chemical pesticides. Bio inputs for pest control is also used by 4% of the farmers. The use of chemical pesticides is less in maize and gram. In treatment villages, 59.5% and 60.5% of the farmers use chemical pesticides for maize and gram, respectively, while the corresponding figures in control villages are 55% and 57%. Burhanpur, Jhabua and Khargone are the districts which have lower usage of chemical pesticides and more bio inputs in maize. In gram cultivation, 82% of the farmers in treatment villages use chemical fertilisers, while 38% of farmers in treatment villages of Khargone use home-produced bio-pesticides.

The use of chemical pesticides in the wheat crop is notably lower than other crops. Approximately 57% in the treatment and 62% of farmers in the control groups, respectively, refrain from using pesticides on their wheat crops. These findings are consistent with the observations made during the Focus Group Discussions (FGD) and in-depth investigations.

Table 39: Usage of Pesticides and Homemade Bio-Pesticides in Various Crops across MP

Crop	Village Type	Chemical based pesticide	Bio-pesticide	Nothing used
Cotton	Treatment	79.8	8.8	14.0
	Control	84.7	5.5	10.5
Maize	Treatment	59.5	4.8	35.6
	Control	55.2	4.0	40.8
Soybean	Treatment	83.7	4.1	12.2
	Control	95.5	0.0	4.6
Gram	Treatment	60.5	12.9	27.6
	Control	57.5	0.0	42.5
Wheat	Treatment	35.9	5.7	57.3
	Control	35.6	2.8	62.2

Efforts are made to understand the HHs expenditure on fertilisers and pesticides. Broadly, the cost incurred by HHs in treatment villages is slightly less than the HHs in the control group. In cotton, an average HH in treatment villages is spending INR 3,011 on fertilisers and INR 1,973 on pesticides (compared to the control - 7% less in fertiliser and almost similar expenses on pesticides).

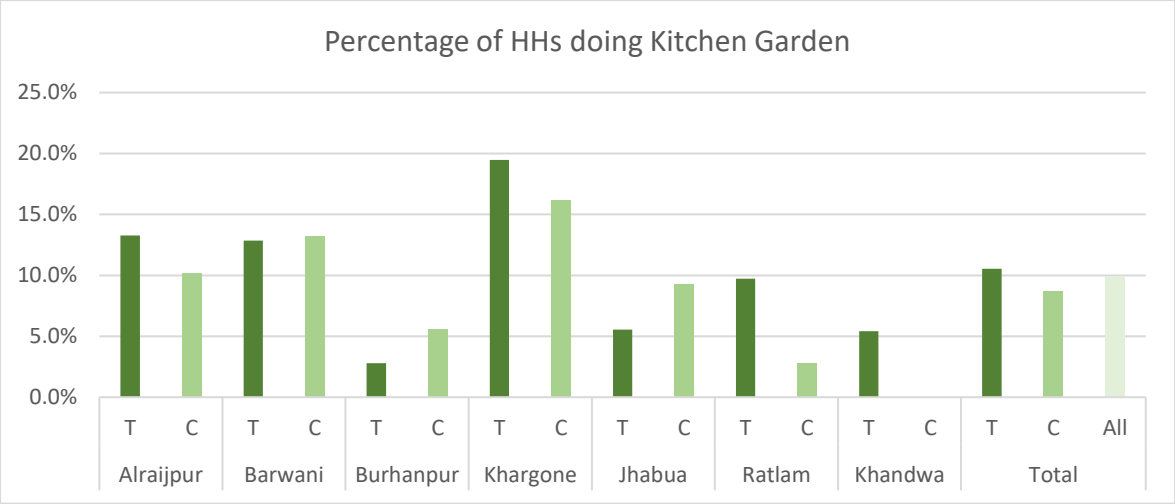
Table 40: Fertiliser and Pesticide Usage and Cost for Major Crops

Crops	Village Type	Amount of fertiliser used INR (Mean)	Amount of pesticide used INR (Mean)
Cotton	Treatment	3,011	1,973
	Control	3,234	2,053
Maize	Treatment	2,254	1,239
	Control	2,372	1,077
Soybean	Treatment	1,700	1,455
	Control	1,869	1,053
Gram	Treatment	1,512	851
	Control	1,214	1,057
Wheat	Treatment	2,242	720
	Control	2,496	728

3.5. Kitchen Garden Adoption

Adoption of kitchen gardens is low. Overall, only 10% of the households surveyed reported doing kitchen garden. District-wise, slight variations are visible; Khargone has the highest percentage of families reporting doing kitchen gardens (19.5% from the treatment village and 16.1% from control villages).

Figure 8: District-wise Percentage of Households Doing Kitchen Garden



3.6. Access to Agri Extension Services

We asked the surveyed groups questions regarding the departmental support received by the community as well as the frequency of visits by extension workers and village-level committee (VLC).

Although, overall, 10.8% of the HHs reported visits from the departmental staff in the village, only 4.7% reported getting any support from them, which includes technical inputs and crop advisory. It will be essential to note that the departmental visit is significantly more in treatment villages (17.6%)- though there are inter-district variations. HHs in the treatment villages of Burhanpur, Jhabua and Khandwa reported a higher incidence of departmental visits, including a higher degree of support gained. The frequency of visits of the extension workers is also high in the above-mentioned villages, where the community reported that 80% of such visits are monthly visits. In Ratlam and Alirajpur, 4.5% and 0.45% of the community respectively reported visits of the departmental staff, but only 2% support in Ratlam and no support in Alirajpur. In these villages, the frequency is almost annual.

Table 41: Agricultural Extension Support Received in Sample Households

Village Type	% HHs where VLC has visited	% HH received support from VLC	Freq of visits by Extension worker/VLC in villages (in %)			
			Monthly	Quarterly	Six monthly	Once a year
Treatment	17.6	8.6	53	12.9	5.5	28.6
Control	3.9	0.8	27.6	11.3	9.6	51.4
All villages	10.8	4.7	40.3	12.1	7.5	40

3.7. Crop Wise – Expenditure, Production, and Income Analysis

3.7.1. Input Cost Details

No specific pattern emerges while analysing data on input costs for different crops. The average per acre cost of cotton, maize, wheat, and gram is lesser in treatment villages than in the control villages. However, it is more for soybean and maize in treatment villages than in control villages. It is interesting to note that the fertiliser cost for cotton, maize, and wheat in the treatment area is slightly lower than in the control villages. In comparison, the cost of pesticides is slightly lower in treatment villages only in cotton and wheat.

It proclaims that the project's planned intervention has the potential to reduce the cost of cultivation substantially by usage of bio inputs.

Table 42: Crop Wise Input Cost in Sample Villages

Crop	Village Type	Leasing Land	Ploughing & Land treatment	Seeds	Pesticides	Fertilisers	Equipment Hiring	Irrigation	Labour	Transport	Total Cost
Cotton	T	10063	2303	2467	1973	3011	1709	2536	2478	758	10089
	C	8000	2168	2701	2053	3234	1415	2208	2268	700	10728
	All	9375	2265	2535	1995	3077	1665	2422	2423	743	10265
Maize	T	28670	2285	1869	1239	2254	1096	2315	1914	699	7510
	C	1000	2059	2015	1077	2372	1013	1436	1983	669	7557
	All	17600	2210	1917	1188	2293	1071	2361	1934	691	7525
Soy Bean	T	2222	1833	3646	1455	1700	1159	659	1422	615	7948
	C	0	1653	2899	1053	1869	1192	1667	1914	541	8342
	All	2222	1773	3418	1341	1752	1169	995	1590	595	8062
Wheat	T	4000	2117	2536	720	2242	1390	2647	2815	755	9268
	C	12500	2053	2514	728	2496	1433	2703	2392	628	9800
	All	8250	2098	2529	722	2324	1404	2666	2676	715	9432
Gram	T	11667	2167	2741	851	1512	1323	1586	1435	746	6629
	C	8750	2033	2633	1057	1214	959	1925	2730	573	7781
	All	10280	2133	2710	913	1411	1209	1712	1853	698	6948

3.7.2. Crop Productivity

Kharif: Productivity, Consumption, and Income Analysis

The cotton productivity per acre in the survey area has been 5.9 Q/acre. The treatment area performs comparatively better than the control area (6 Q/acre vs. 5.5 Q/acre). However, there is a significant district-wise variation in the productivity of cotton. It is lowest at 3Q/acre in the control villages of Jhabua and Khandwa while maximum in the treatment villages of Alirajpur (6 Q/acre). Cotton productivity is higher or the same in all the treatment villages except for the district of Barwani.

For maize, the mean productivity for the entire surveyed area is 8.8 Q/acre and once again the productivity in treatment villages is more than the control villages (8.8 Q/ acre vs 7.7 Q/ acre). Significantly high productivity is reported in the treatment villages of Barwani (10 Q/acre), treatment villages of Khargone (11 Q/acre) and control villages of Barwani (11 Q/acre).

Mean production of cotton per HH is 6.4 Q (which is a function of the sowed area) and there is no difference between treatment and control villages. Similarly mean production of Maize per HH is 11 Q – more in control (11.8 Q) than in control (10.6 Q). While all the cotton is used for sale, a portion of maize is used for home consumption. Out of the total maize production, almost 50% is used for consumption at the HH level.

Table 43: Kharif Crop Production and Usage

Villages	Kharif Crops	Production/ Acre (quintal)	Average Production/ HH (quintal)	Quantity for Consumption (quintal)/ HH	Quantity Sold /HH (quintal)
Treatment	Cotton	6	6.4	0	6.4
	Maize	8.8	9.9	5	4.9
	Soybean	5.8	10.6	2	8.6
Control	Cotton	5.5	7.2	0	7.2
	Maize	7.7	8.5	5	3.5
	Soybean	7.9	11.8	3.2	8.6
All Village	Cotton	5.9	6.6	0	6.4
	Maize	8.5	9.5	5	4
	Soybean	6.4	10.9	2.4	8.5

The mean income at a HH level are INR 50,000, INR 22,500 and INR 49,270 for cotton, maize and soybean respectively.

Table 44: Income from Kharif Crop for Year 2022-23

Villages	Kharif Crops	Mean Income from Sale of Crop/ HH (INR)	Max Income from Sale of Crop	Minimum Income from Sale of Crop
Treatment	Cotton	48,645	320,000	3,500
	Maize	23,973	120,000	1,800
	Soybean	48,867	400,000	3,000
Control	Cotton	53,413	720,000	7,000
	Maize	19,072	150,000	1,600
	Soybean	50,283	400,000	2,700
All Village	Cotton	49,959	720,000	7,000
	Maize	22,493	150,000	1,600
	Soybean	49,270	400,000	2,700

Rabi: Productivity, Consumption, and Income Analysis

The two major crops in the Rabi season are wheat and gram. The mean wheat productivity reported is 11 Q/acres, but the productivity is slightly higher in treatment (11.3 Q/acre) compared to the control (10.54 Q/acre). Within treatment villages, productivity is highest in Burhanpur at 13Q/acre while lowest in Alirajpur (8Q/acre). Control villages' highest and lowest productivity figures are 19 Q/acre (in Ratlam) and 7 Q/acre (in Burhanpur), respectively.

The average production per HH is 17.2 Q, which is significantly higher in control villages (18.5 Q/acre). The maximum available grains at the HH level are reported in the treatment villages of Khandwa and Khargone (both 26Q), while the lowest are in Alirajpur and Jhabua (both 11.1Q). In the control villages, the highest mean availability of wheat grains is reported at Khandwa (32 Q) and the lowest in Burhanpur (7.3 Q).

Approximately 43% of the wheat grain produced is consumed at HH level, and the rest is sold. No significant difference in consumption is recorded between treatment and control areas.

Table 45: Rabi Crop Production and Usage

Village Type	Rabi Crops	Production / Acre (quintal)	Mean Production/ HH (quintal)	Mean Quantity for Consumption (quintal)/ HH	Quantity Sold /HH (Mean) (quintal)
Treatment	Wheat	11.3	17.2	7.8	9.8
	Gram	4.6	6	1.4	4.6
Control	Wheat	10.5	18.5	7.7	10.8
	Gram	2.9	5.2	2.0	3.2
All Village	Wheat	11.0	17.6	7.8	9.8
	Gram	3.7	5.8	1.6	4.2

In the case of gram, the mean productivity for the entire surveyed region is 3.7Q/acre – 4.6Q/acre in the treatment area, while a relatively lower productivity of 2.9 Q/acre in the control areas. Regarding productivity variations in treatment areas, the maximum is reported in Burhanpur (8 Q/acre), and the minimum is in Alirajpur (3 Q/acre). The corresponding figures for maximum and minimum productivity are 5 Q/acre in Khandwa and Burhanpur and 3 Q/acre in Alirajpur.

The mean overall production of gram is 5.8 Q/HH. The total gram production per HH is slightly higher in the treatment areas (6 Q/HH) when compared to the control area (5.2 Q/HH). From an inter-district variation point of view, the treatment area of Khandwa (11 Q) reported the maximum at a HH level, while Alirajpur (2.8 Q) is the lowest. For the control region, Jhabua reported 6.7 Q/ HH as the maximum, with Alirajpur at 3 Q reported as the lowest.

Though the average consumption of gram is reported at 1.6 Q/ HH, around 20% of gram is reported to be consumed in the treatment areas, while the figure is significantly high at 40% in the control areas.

Table 46: Income from Kharif Crop for Last Year

Village Type	Rabi Crops	Mean Income from Sale of Crop/ HH (INR)	Max Income from Sale of Crop	Minimum Income from Sale of Crop
Treatment	Wheat	29,500	160,000	400
	Gram	30,288	100,000	1,600
Control	Wheat	32,591	140,000	1,800
	Gram	25,406	72,000	3,500
All Village	Wheat	30,473	160,000	400
	Gram	29,104	100,000	1,600

The mean sales revenue per HH from wheat is INR 29,104/- and not much difference is observed between the treatment and the control villages. The control villages of Khandwa reported the maximum mean income from wheat (INR 45,250/HH) and gram (INR 51,000/HH).

The maximum income from wheat is reported from the control villages of Khargone (INR 160,000/-), while the minimum income from wheat is reported INR 400/- from a farmer in the treatment villages of Jhabua. In gram, a farmer from the treatment village of Khandwa reported earning INR 100,000/- while the lowest income from gram is reported by some farmers from the treatment village of Jhabua (INR 1,600/-).



Irrigation of Gram Crop in Areas with Access to River/canal

3.8. Livestock Rearing

Livestock is widely available in the surveyed villages. Oxen are mainly reared for draught purposes (read ploughing), as most of the undulating lands in the surveyed areas deploy mechanical land-tilling methods. Cows are reared for the consumption of milk at the household level. Only a few HHs in the villages sell cow milk. Backyard poultry are all local breeds and reared for household consumption (mainly for catering to guests) and for sale in an emergency. Cow, followed by goats, is the most common livestock owned by the HHs in both the treatment and control villages; 81% of the HHs own cows, while 70% HHs own goats. Backyard poultry is owned by 54% of the HHs, while buffaloes are owned by 34% HHs. Only 6.7% of the HHs do not own any livestock. There is not much of a significant difference between treatment and control HHs in terms of livestock ownership at an aggregate level (except for backyard poultry (BYP) - more with control than treatment villages).

A stark difference in livestock ownership is revealed in Jhabua districts in ACZ Jhabua Hills cows are less with HHs from treatment groups than control - 60% and 78%, respectively, while in Jhabua- ACZ Malwa Plateau, cows are more with treatment HHs (75%) than control (61%). Also, a similar pattern emerges in the Khandwa district, where cows are more in the treatment group (82%) than the control (62%).

There is a wide variation in goad ownership within districts and village typology (treatment and control) as the percentage of HHs owning goats varied from 50-90%, except Burhanpur, which has the lowest ownership (33% in treatment villages). Even though 53% of the HHs own backyard poultry, the ownership is very low in the control villages of Khandwa (5.88%) and treatment villages of Burhanpur (11%). These two geographic areas have the highest percentage of HHs without any livestock (17% and 24%, respectively).

Table 47: Livestock Ownership among Sample Households in MP

Village type	% of HHs having Buffaloes	% of HHs having Cows	% of HHs having Goats	% of HHs having BYP	% of HHs with No Animals
Treatment	34.6	80	65.9	47.1	7.1
Control	33	79	66.4	52.8	6.6
All Villages	33.8	80.9	69.79	53.82	6.71

Table 48: Average Livestock per Sample Household

Village type	Buffalos	Cows	Goats	BYP
Treatment	1.8	3	3.6	5
Control	1.8	2.6	3.5	6
All Villages	1.8	2.8	3.6	5.5

The livestock per HHs figures are almost similar across treatment and control groups. The average number of buffalos and cows/HH in the surveyed area is 1.8 and 2.8, respectively. The average number of goats and poultry being owned by a household is 3.6 and 5.5. No major variation is observed at an inter-district level. The ownership for buffalos ranges between 1-2, while for cows, it is 2-4. The range is 2-5 for goats, while for backyard poultry, it is 3-9.

The data shows that the mean figure of animal kids (heifer, calves, goat kids and poultry chicks) per HH is one heifer, one calf, two goat kids and nine poultry chicks. No major variations are observed at the inter-district level or between the treatment and control groups. However, with the addition of these kids, it will be important to note that the average overall herd size of a certain category of animals per HHs increases substantially by 50% in the case of buffalo ownership, 35% for cows, 44% for goats and 145% for backyard poultry.

Table 49: Average Livestock (Kid) per Sample Household

Village type	Buffalos	Cows	Goats	BYP
Treatment	1.1	1	1.6	7.3
Control	1	0.9	1.5	8.8
All Villages	1.1	0.9	1.6	8

Animal health services, including animal health checks, deworming and vaccination, are critical areas that lead to lower mortality and morbidity of animals, thereby reducing risks and increasing income, nutrition sufficiency and access to quality draught animals. Data, however, reveals that the state of animal health service is poor in the surveyed areas. Only 8.9% of the large ruminants (buffalos and cows) were dewormed last year, while the numbers are 4.5% for goats and 1.2% for backyard poultry. At an aggregate level, though low, the status is better in treatment villages than in the control villages.

In terms of inter-district variations, the treatment villages of Alirajpur (11.3%), treatment villages of Khargone (18.4%) and Ratlam (13.4%) are doing better on deworming for large ruminants, while it is zero in Burhanpur district. The control villages across districts (with the only exception of Ratlam) are all in single-digit performance. On deworming of goats, the treatment villages of Khargone (11.8%) and Ratlam (10.5%) are performing better. The treatment villages of Jhabua, Khargone and Khandwa are the only villages where the community recorded deworming of their backyard poultry.

Table 50: Households (%) that Dewormed their Livestock in the Last Year

Village Type	Large ruminants (cow/ buffalo)	Small Ruminants (Goat and sheep)	BYP + Duck
Treatment	8.91	5.68	1.14
Control	6.7	2.3	0.55
All Villages	8.81	4.59	1.24

The data suggests that the first point of contact for deworming is the government department (41.5%), followed by the private vet practitioners (30.6%). The community takes support from the NGOs and SHG federations at 17.2% and 3.6%, respectively. It is interesting to note that even though the difference between treatment and control villages is only 1% point when it comes to reaching out to NGOs for livestock deworming, the villagers in the control group have higher access to government departments (47%) than the treatment group (35%). Even though 7% of the control group members informed that they get support from SHG federations, such support is absent in the treatment villages.

A more granular analysis reveals that support by SHG federation is only extended in the control villages of Alirajpur (25%), while NGO support is more pronounced in Khandwa (75%).

The community in the treatment villages of Ratlam depends on private players (77.8%) for deworming, while 80% of HHs in the control villages of Ratlam access the government veterinary hospitals.

Table 51: Households (%) Accessing Veterinary Services from Service Providers

Village Type	Private Veterinary Doctor / Agency	Govt Veterinary Doctor / Department	NGO	SHG/ VO/ Federation
Treatment	32.2	35.8	17.7	0
Control	29.1	47.1	16.7	7.1
All Villages	30.6	41.5	17.2	3.6

The average spending on deworming per HH is INR 346/- (ranging from INR 64/- to INR 1,071/-). The mean expenses per HHs in the control group (INR 404/-) is 40% more than that incurred by the HHs in the treatment group. There is an inter-district variation- the highest (INR 1,400/-) in the control villages of Alirajpur and the lowest being in the treatment villages of Khandwa (INR 43/-).

Table 52: Expenditure on Livestock Deworming in the Past Year (INR)

Village Type	Average	Minimum	Maximum
Treatment	287.86	14.29	1171.43
Control	404.29	114.29	971.43
All Villages	346.1	64.3	1071.4



Widespread mortality in small livestock due to inadequate rearing practices and limited veterinary support.

3.8.1. Livestock Vaccination

The status of animal vaccination is a noteworthy area because lack of vaccination and other support leads to large-scale mortality and morbidity. Moreover, the HHs considerably depend on livestock for nutrition and agricultural operations.

Only a minuscule 0.7% of the HHs reported that they have taken support from the government veterinary department. The percentage is slightly higher in treatment villages at 1% than the 0.5% of the control villages (Table 52).

Table 53: Institutional Health Services Received in Sample Districts

Districts	Village Type	Health Services from Panchayat/ Dept. for Livestock (% HHs)	Kind of Services Received
Alirajpur	Treatment	0.9	Vaccination
	Control	0	–
Barwani	Treatment	1	Vaccination
	Control	3.9	Deworming, Vaccination, Health check-ups and treatment
Burhanpur	Treatment	0	–
	Control	0	–
Jhabua 1	Treatment	1.4	Construction of animal shelter
	Control	0	–
Jhabua 2	Treatment	0	–
	Control	0	–
Khandwa	Treatment	1.5	Medicine and supplements, Training
	Control	0	–
Khargone	Treatment	0	–
	Control	0	–
Ratlam	Treatment	3	Vaccination, Health check-ups and treatment
	Control	0	–

3.8.3. Expenses on Livestock

The expense on livestock is substantial – for feed and fodder, livestock health and shelter, and insurance. While conducting the deep dive, the survey team came across examples of expenses of around INR 20,000/- for animal fodder, as fodder is a rare commodity in the region.

The mean expenses per HH on livestock feed and fodder, animal health and shelter, and insurance are INR 5,586/-, INR 886/- and INR 122/-, respectively (Table 53). When comparing the treatment and control villages, no substantial differences in these costs are observed, though there is a huge inter-district variation. The cost of feed/ fodder is the highest in the control villages of Jhabua - Malwa plateau (INR 9,000/HH) followed by the control villages of Khargone (INR 8,500/HH), while it is lowest in the control villages of Alirajpur (INR 2,500/HH) and Burhanpur (INR 2,666/HH).

Similarly, HHs in Jhabua and Ratlam districts are making remarkable expenses on animal health and shelter. The HH in the treatment villages of Alirajpur and the control villages of the

Khandwa are the only ones who are spending on the insurance of animals (INR 750/- and INR 1,200/- respectively).

Table 54: Livestock Expenditure in Sample Districts

Districts	Village Type	Expenditure on Feed/ Fodder (INR/ Year)	Expenditure on Health/ Shelter etc. (INR / Year)	Average Expenditure on Insurance (for all category) (INR/ Year)
Alirajpur	Treatment	7,166	687	750
	Control	2,500	475	-
Barwani	Treatment	8,333	362	-
	Control	7,111	779	-
Burhanpur	Treatment	4,812	233	-
	Control	2,666	-	-
Jhabua 1	Treatment	7,833	3,320	-
	Control	8,684	1,542	-
Jhabua 2	Treatment	5,133	1,079	-
	Control	9,000	882	-
Khandwa	Treatment	3,562	92	-
	Control	3,750	115	1,200
Khargone	Treatment	6,250	411	-
	Control	8,500	172	-
Ratlam	Treatment	3,209	2,541	-
	Control	5,833	1,457	-
Mean	Treatment	5,787	1,091	94
	Control	6,006	678	150
	All villages	5,896	884	884



Demonstration by Implementing Agency on Broiler Poultry Feeding Practices

3.9. Participation in different community organisations

The SHGs are present across all the different villages and blocks surveyed. This is mainly because of the work of state units of the DDU- National Rural Livelihood Mission. However, the quality of SHGs varies significantly across regions. In districts of Khargone, Burhanpur and Khandwa – the quality of SHGs are better than those in Alirajpur, Jhabua, Ratlam and Barwani.

As per the FGDs with the women groups, SHGs are present across all villages. However, all women are not in SHG fold. Many women are still left out from the SHG fold mainly because of migration or members unwillingness to attend regular meetings.

Women reported conducting monthly SHG meetings and save once in a month. SHGs are engaged in savings and credit though variations were reported in the interest rates (between (1% and 2% per month on every INR 100) charged by the SHGs across the FGDs. Members reported that they participated in SHGs mainly because of improving household level savings base, get access to credit during need and emergency as well as for their livelihood enhancement. In some of the FGDs women reported working on access to entitlements and government schemes.

As per the household survey, 70% of the households surveyed reported being member of a SHG, the percentage is significantly higher in the treatment villages. Similarly, 63% of the households are member of Producer Group (PG), Fisheries Interest Group (FIG) and Farmer Producer Organisations (FPO) promoted by NRLM and ASA. Once again, more percentage of households reported such membership in treatment villages. None of the households reported membership in Water User Groups or any Watershed Committees. Around 1.2% of the households claimed to be members of Joint Forest Management Groups. 4.8% of households reported membership in other form of community groups mainly Primary Agriculture Cooperatives (PACs)

The benefits received from SHGs are mostly in the form of credit and grant while benefits from PGs are agriculture inputs. Households also reported receiving loans and agri inputs from other organisations like PAC.

Table 55: Percentage of Households with membership in various groups

Village Type	SHG / VO / CLF	PG / FIG / FPO	Water users' group	Land/ forest users' groups	Watershed committee	Other groups
Treatment	84.7	58.2	0	2	0	3.9
Control	55.9	34.4	0	0.4	0	5.8
All villages	70.3	63.4	0	1.2	0	4.8

3.10. Access to Forest and Forest Produce Collection

Though the forest cover has been depleting over the years, the data reveals that forests continue to support 35% of the surveyed HHs with fuelwood, fodder, edible flowers, and some source of income by selling minor forest produce. The percentage of HHs having access to forests is highest in Barwani, followed by Ratlam and Alirajpur district, while lowest in the control villages of Jhabua (Jhabua Hills).

The major Forest Produce, as reported by the community, are fuelwood and fodder in all districts, while mahua flower/seeds, kendu/ tendu leaves, and bamboo are mostly found in Barwani, Khandwa and Khargone districts.

Table 56: Access to Forest and Forest Produce Collected across Sample Districts in MP

Districts	Village Type	# HH with Access to Forest	% of HH with Access to Forest	Produce Collected
Alirajpur	Treatment	42	37.2	Fuelwood, Fodder
	Control	16	32.7	Fuelwood, Mahua flower/seeds
Barwani	Treatment	53	48.6	Fuelwood, Fodder, Mahua flower/seeds, Kendu/Tendu leaves, Honey
	Control	25	47.2	Fuelwood, Fodder, Mahua flower/seeds, Kendu/Tendu leaves
Burhanpur	Treatment	15	41.7	Fuelwood, Fodder
	Control	5	27.8	Fuelwood, Fodder
Jhabua 1	Treatment	10	13.9	Fuelwood, Fodder
	Control	1	2.8	Fuelwood
Jhabua 2	Treatment	3	8.3	Fuelwood, Fodder
	Control	6	33.3	Fodder
Khandwa	Treatment	30	40.5	Fuelwood, Fodder, Mahua flower/seeds, Kendu/Tendu leaves, Bamboo
	Control	11	32.4	Fuelwood
Khargone	Treatment	29	37.7	Fuelwood, Fodder
	Control	14	45.2	Fuelwood, Fodder, Mahua flower/seeds, Kendu/Tendu leaves
Ratlam	Treatment	46	63.9	Fuelwood, Fodder
	Control	17	47.2	Fuelwood

As reported by 95% of the surveyed members, the collected produce is mainly used for consumption, while only 3.4% sell the produce. Around 1.2% of the HHs do both selling and consumption. In Khandwa, 27% of the HHs and 10% of the HHs in Khargone only reported selling forest produce.

Table 57: Usage of Collected Forest Produce in Sample Households in MP

Village Type	Household Consumption	For Selling	For Consumption + Selling
Treatment	93.2	4.5	2.4
Control	97.6	2.4	0
All villages	95.4	3.4	1.2

3.11. Status of Migration

Overall, 51.7% of the HHs in the surveyed area reported migration, 49.5% in the treatment area and 53.9% in the control area. Migrations are mostly done to neighbouring growth centres like Udaipur, Ahmedabad, Surat, and Indore for various work ranging from agriculture labour, work in factories, or house construction in cities. There is an inter-district variation where Jhabua 1 and Alirajpur reported maximum migration at 71% and 69.4%, respectively, while the lowest has been reported in Jhabua 2 and Burhanpur, both at 36%.

Data also suggests that 1.8 males/HH in control villages and 1.4 males/HH in treatment villages migrate; the corresponding percentage for women migration is 1 and 1.1, respectively.

Table 58: District-Wise Migration Status of the Sample Households in MP

Districts	Village Type	HH member migrated out for work / wage (%)	Adult males migrated per HH (Mean #)	Adult females migrated (Mean #)	Earning from migration (INR /annum)	Remittance amount (INR/annum)
Alirajpur	Treatment	59.3	2	2	98,628	61,378
	Control	79.6	2	1	73,342	46,842
Barwani	Treatment	45.9	1	1	55,125	34,187
	Control	56.6	2	1	73,500	47,392
Burhanpur	Treatment	38.9	1	1	41,357	23,214
	Control	33.3	2	1	56,500	19,000
Jhabua 1	Treatment	59.7	2	1	80,825	41,523
	Control	83.3	2	1	52,466	27,766
Jhabua 2	Treatment	33.3	2	1	57,500	30,166
	Control	38.9	1	1	59,714	39,142
Khandwa	Treatment	41.9	1	1	79,535	36,286
	Control	41.2	1	1	46,909	27,273
Khargone	Treatment	53.3	1	1	53,650	31,975
	Control	45.2	2	1	79,538	50,384
Ratlam	Treatment	63.9	1	1	48,288	23,433
	Control	52.8	2	1	39,263	24,868
Mean	Treatment	49.5	1.4	1.1	64,364	35,270
	Control	53.9	1.8	1	60,154	35,333
	All villages	51.7	1.6	1.1	62,259	35,302

The average gross income from migration is INR 62,258/- higher among HHs in treatment villages at INR 64,363/- compared to INR 60,152/- in control villages. The treatment villages of Alirajpur reported a mean income from migration of INR 98,628/- while the control villages of Ratlam reported INR 39,260/-. The mean from other villages is within this range.

HHs reported that 49-64% (depending on the district) of the gross migration income is sent back home as remittances. This observation is critical because it reflects that HH-level livelihood portfolio significantly depends on remittance income.

The remittance amount is highest in the treatment villages of Alirajpur (INR 61,378/-) and lowest in the treatment villages of Ratlam (INR 23,433/-). The gross income from migration is a function of the destination geography, migration period, number of migrating members and the type of work engagement. Similarly, the remittance amount is again a function of the geography (cost of living) and the number of members who have migrated from a HH.

3.12. Shocks and Coping Mechanisms

Only 2.4% of the surveyed HHs in Madhya Pradesh reported climate and related shocks in the last five years. Erratic rainfall (43%) and pest attack (52%) are the most common shocks articulated by the HHs followed by drought (19%) and flood (9.5%).

Table 59: Incidence of Climate Shocks in the Past Five Years (in percentage)

Village Type	Treatment	Control	Total
% of total HH reported shocks	3.4	0.4	2.4
% of HH who experienced shocks due to drought	20	0	19
% of HH who experienced shocks due to pest attacks	50	100	52.4
% of HH who experienced shocks due to erratic rainfall	45	0	42.9

Village Type	% of total HH reported shocks	% of HH who expereinced shocks due to drought	% of HH who expereinced shocks due to pest attacks	% of HH who expereinced shocks due to erratic rainfall	% of HH who expereinced shocks due to flooding	
Treatment	49.0%	60.0%	71.4%	1.4%	7.1%	
Control	58.9%	34.9%	55.8%	11.6%	7.0%	
Total	52.3%	50.4%	65.5%	5.3%	7.1%	

The HHs are distinctively impacted on account of these climate shocks. Loss of standing crops is the most common impact, followed by lack of adequate food during that time and destruction of property. A percentage of HHs also reported a loss of livestock.

Table 60: Impact of Climate Shocks on Households (in percentage)

Village Type	Loss of crop (harvested or standing)	Loss of Animal Death of Animals	Destruction of House Property	Lack of Food	No Crop Grown that Season
Treatment	85.0	5.0	5.0	5.0	10.0
Control	100.0	0.0	0.0	0.0	0.0
Total	85.7	4.8	4.8	4.8	9.5

The coping mechanism has also been different based on the HH condition. One-third of the affected HHs migrated, while almost 29% received support from friends, relatives, and neighbours. Approximately one-fourth of the HHs sprang back from the crisis and replanted the field. No HH reported selling of HH assets or going hungry.

Table 61: Coping Strategies Employed by Households to Address Climate Shocks (in percentage)

Coping Mechanism	Treatment	Control	Total
Received government support – food/ shelter/ financial support	0.0	0.0	0.0
Replanted the agriculture field	25.0	0.0	23.8
Sold HHs assets (which assets - land/ jewellery/ trees/ animals)	0.0	0.0	0.0
Migrated	35.0	0.0	33.3
Eat less food that season	0.0	0.0	0.0
Received support from friend – food/ shelter/ financial support	30.0	0.0	28.6
Other support	15.0	100.0	19.0

Similar to the climate shocks, 7.2% of the surveyed HHs reported personal shocks – mostly due to the death or illness of a family member. Only one HH reported shocks due to litigation issues. A substantial percentage (48%) of the affected HH reported that shocks that have a significant economic impact on them are mostly the loss of earnings followed by the transfer of legacy credit.

Table 62: Incidence of Personal Shocks in the Past Five Years (in percentage)

Personal Shocks	Treatment	Control	Total
Got affected	8.1	5.1	7.2
Due to illness of family member	41.7	42.9	41.9
Death of family member	60.4	57.1	59.7
Due to litigation	2.1	0.0	1.6
experienced economic impact	50.0	42.9	48.4
Loss of earning (earning member was ill/ died)	79.2	83.3	80.0
Legacy credit passed on to the HH	45.8	16.7	40.0
Huge financial loss due to court orders/ hospitalisation	4.2	16.7	6.7
Discontinuation of education	8.3	0.0	6.7

The coping mechanism ranged from selling HH assets, migrating outside, or negotiating with the creditor. Only 3% of the HHs received financial support from govt/ NGOs/ friends or relatives. Two HHs reported children dropping out of school; one HH reported early marriage of children; and six HHs reported that the children started working early.

Table 63: Coping Strategies Employed by Households to Address Climate Shocks (in percentage)

Personal Shocks	Treatment	Control	Total
Sold HH assets	25.0	0.0	20.0
Child School Drop out	4.2	16.7	6.7
Married children early	4.2	0.0	3.3
Negotiation with the creditor	33.3	0.0	26.7
Children started working	20.8	16.7	20.0
Migrated outside	29.2	66.7	36.7
Received financial support from NGO/ Govt/ Friends/ Family	4.2	0.0	3.3

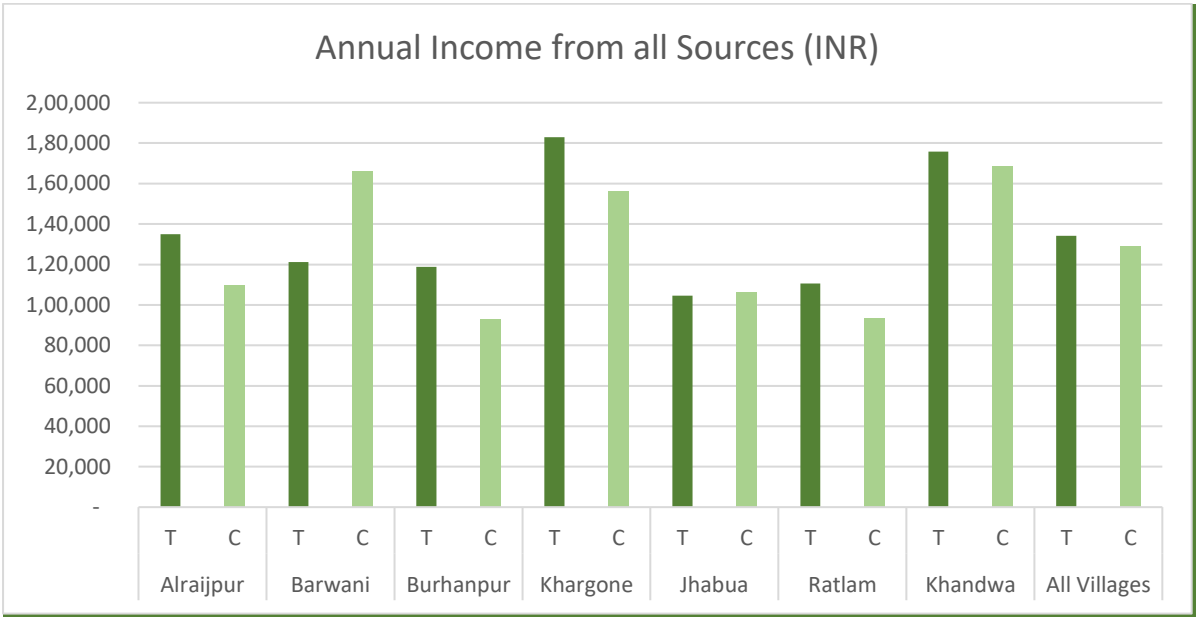
3.13. Household Income-Expenditure Analysis

3.13.1. Household Income

The income data set is highly critical, and we did cross-verification. Since there is a tendency to not report income data correctly among the respondents, the effort is made to understand income from various sources, both by asking directly and by analysing the different data sets shared by the respondents. In case a significant difference between the two data sets is observed during the analysis, it is overlooked and not considered. Income data is only taken from those HHs where the overall per-head income data broadly tallies with the calculations.

The mean income for all surveyed HHs is INR 132,601. The mean income for the treatment villages (INR 134,244) is slightly above the control villages (INR 129,083).

Figure 9: Household Income by District in MP



The different income sources are also defined – income from agriculture, forest produce, livestock and selling of trees are the most common ones, followed by the income from migration, wages/ salary or any business. The last three heads are clubbed together (Table 62) to facilitate an easy data reading.

Table 64: Source-wise Annual Income of the Sample Households in MP (in INR)

Districts	Village Type	Agriculture	Livestock	Sale - Trees	Forest produce	Remittance	Other sources
Alraijpur	Treatment	61,507	9,210	4,000	-	53,396	54,268
	Control	49,723	10,453	2,000	20,000	40,655	39,098
Barwani	Treatment	77,004	12,425	20,000	8,800	33,682	31,406
	Control	1,33,421	15,336	-	-	52,696	36,132
Burhanpur	Treatment	74,503	27,540	5,000	-	23,462	31,900
	Control	51,778	5,083	-	-	19,000	32,833
	Total	66,928	15,291	5,000	-	22,053	32,211
Khargone	Treatment	1,36,282	14,315	100	-	32,975	26,221

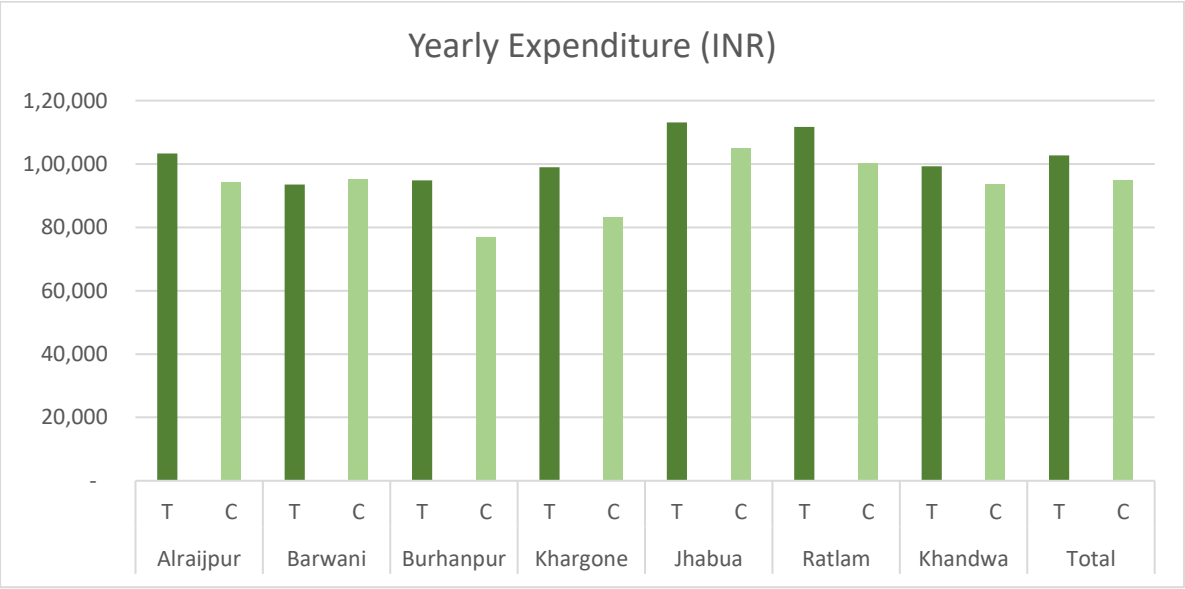
	Control	1,14,838	13,600	-	3,000	51,692	20,361
Jhabua	Treatment	36,205	9,997	-	-	40,142	46,728
	Control	44,555	11,084	-	-	31,382	43,570
Ratlam	Treatment	55,709	11,527	4,000	-	24,211	38,707
	Control	50,323	7,989	-	-	26,250	29,400
Khandwa	Treatment	1,21,441	10,679	-	3,231	36,783	46,841
	Control	1,09,307	9,545	-	-	26,923	58,835
All Villages	Treatment	77,309	11,905	6,183	4,778	36,586	40,785
	Control	77,824	11,580	2,000	11,500	37,254	38,053
	Total	77,465	11,792	5,586	5,450	36,812	39,916

3.13.2. Household Expenditure

In order to capture household expenditure in detail, we also posed questions to HHs regarding the frequent (monthly) and less frequent expenses that occur quarterly, bi-annually, or yearly. The monthly data, primarily concerning food and other household expenses, is then extrapolated to estimate the total annual expenditure.

The average annual household expenditure for all surveyed households is INR 100,217. In the treatment group, it amounts to INR 102,720, while in the control group, it is INR 94,857. Notably, the district of Jhabua shows the highest expenditure, with INR 113,097 in the treatment area and INR 104,816 in the control area. Conversely, the lowest household expenditure is reported in Burhanpur, with INR 94,807 in the treatment area and INR 76,900 in the control villages.

Figure 10: District wise Household Expenditure

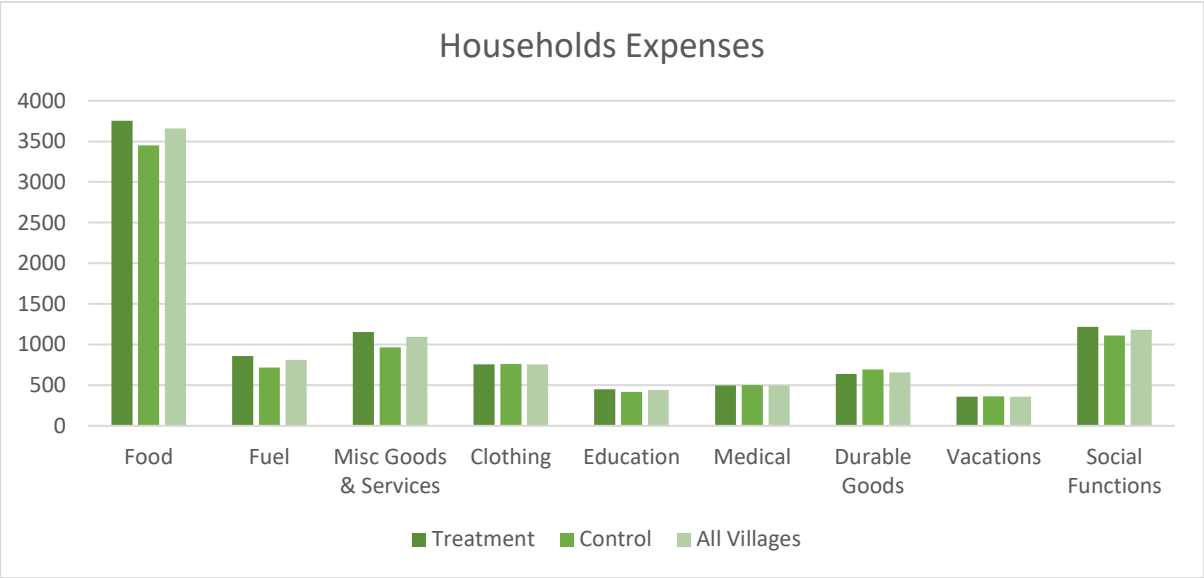


Detailed data analysis demonstrates that the bulk of the expenditure is on food and HH goods-related heads – 43.6% and 12%, respectively. These two heads have no significant variation across the treatment and control groups. The community in Burhanpur reported the maximum expenditure on food, which is 50%. The mean expenditure on fuel/electricity, clothing and education is around 6.8%, 9.1% and 3.2% respectively. The expenses on HH durables and

vacation are 4.5% and 1%. Both the control and treatment groups reported almost similar expenses on these five heads.

The mean expense on health is 5.6% (no difference between the treatment and control group), which may be attributed to low concerns for health among the community. Social events constitute a substantial expenditure head at 14% of the total HH level expenditure. Marriages, dowry, and death ceremonies are the primary reasons. Deep dive and FGD data also corroborated this, as many HHs are indebted to moneylenders for this reason. There is an intense social pressure to spend lavishly during all these ceremonies. The district of Jhabua reported a maximum of 21% of HH expenditure for social events.

Figure 11: Categorisation of Household Expenses in MP



3.14. Soil Analysis

We have carried out a detailed soil analysis in treatment and control villages in selected seven districts of Madhya Pradesh. Six parameters - including pH, electrical conductivity (EC), organic carbon content, and available Nitrogen, Phosphorus and Potassium of the samples - are measured. In the sections below, we present average values for each parameter in treatment and control areas across the districts to present an overview of the current situation in these areas. Further, detailed results in the different villages in each district provide a more in-depth understanding of the baseline soil parameters in these areas. The data presented for each village (treatment and control) is an average of two or three soil samples collected from different areas in the village. The number of soil samples collected and analysed from each village is given in Table 64. It is ensured that these samples are not collected from only one type of area in the village and are spread across regions such as uplands, medium uplands, and lowlands.

Table 65: Number of Soil Samples Collected Across Control and Treatment Villages

District	Control			Treatment			Grand Total
	No of Villages	No of Samples per Village	Total Samples	No of Villages	No of Samples per Village	Total Samples	
Alirajpur	3	2	6	6	2	12	18
Ratlam	2	2	4	4	2	8	12
Jhabua	3	2	6	6	2	12	18
Burhanpur	1	2	2	2	2	4	6
Khargone	2	2	4	3	2	6	10
Khandwa	2	2 + 1	3	3	(2*2) + 1	5	8
Barwani	2	2	4	6	2	12	16
Total	15	-	29	30	-	59	88

For the Jhabua district, in the overall district-level analysis, two values are presented to account for the two agro-climatic zones in which the treatment and control villages fall. For each of the other districts, only one value is given for treatment and control, as in these districts, all villages fall in the same agro-climatic zone.

Findings and Discussions

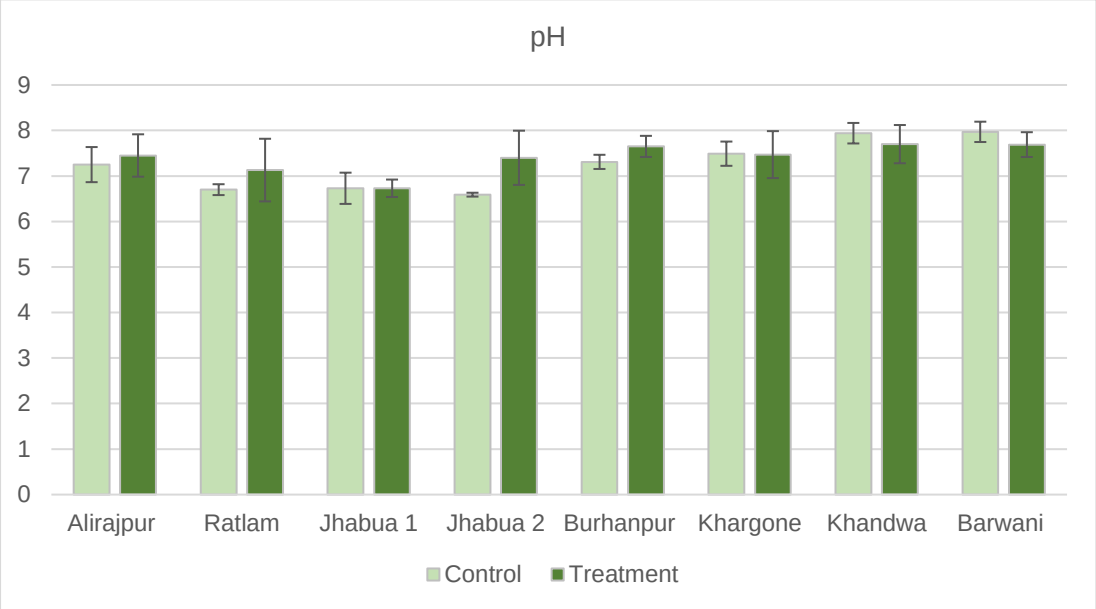
3.14.1. Soil pH

Soil pH[17] is a measure of the soil's acidity or alkalinity, where a pH of 7 shows a neutral soil profile, pH below 7 indicates acidic soils, and basic soils have pH above 7. In general, a range between 5.5 to 7.5 is considered optimal for growth of most plants[18], however soil pH can range anywhere from 3 to 10. The pH of the soil has impacts on nutrient availability and uptake, thus having a significant role in the growth of plants, which is also impacted by management practices such as irrigation and fertiliser use. Overall, the average pH levels ranged between 6.70 and 7.97 across treatment and control areas (Figure 17). While the pH in all the districts

[17]IOWA State University, Digital Library: https://iastate.pressbooks.pub/introsoilscience/chapter/ph-base-saturation/
[18] Soil Management and Filed Preparation by National Council of Education, Research and Training: https://ncert.nic.in/vocational/pdf/kegr105.pdf

in the state is within the neutral range, some variations are seen when looking at data across the villages in each district. However, these variations are modest and pH across most of the villages (both treatment and control) is within acceptable limits, indicating that the soil in the region is neither acidic nor alkaline (Figure 17). There are some samples where the pH is close to 8, showing these farms to have slightly alkaline soils. Soil acidity is not seen in the soil samples across both states.

Figure 12: Average Soil pH of Treatment and Control Areas in Districts



Error bars denote Standard Deviation.

3.14.2. Electrical Conductivity of Soil

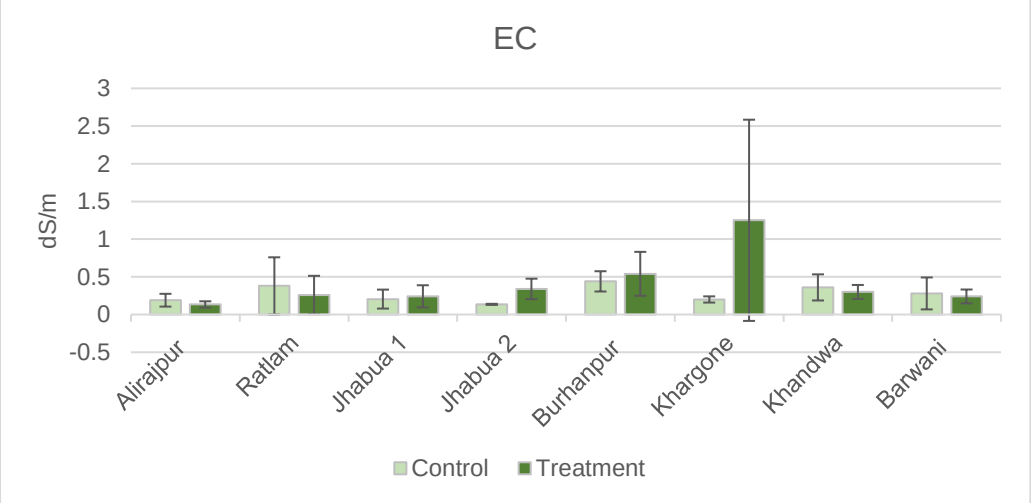
Agricultural soil's electrical conductivity (EC) is a measure of the soil water to carry electrical current and is an indirect indicator of the soil's several physical and chemical properties. The EC of soil-water mixtures indicates the number of salts present in the soil. While it is primarily used as a measure of salinity in non-saline soils, it can also be used as an indicator of soil moisture levels. The Final Corrected Manual on Soil Testing by the Ministry of Agriculture classifies soils as salt-free when EC ranges between 0-2 deci siemens per metre (dS/m) (Table 65).

Table 66: Critical Limits for EC of Soil[19]

Parameter	Unit	Range	Interpretation	Crop Growth
EC	dS/m	0-2	Salt free	No effects on crop growth except on some sensitive plants such as *beans and carrots*
		2-4	Slightly saline	Yields of some crops such as *onions, bell peppers* impacted
		4-8	Weakly saline	Yields of many crops such as *cotton and cereals* impacted
		8-15	Moderately saline	Tolerant crops are able to main productivity – *potato and broccoli*
		>15	Highly saline	Only very tolerant plants are able to grow – salt tolerant grasses, herbaceous plants, certain shrubs and trees

The average EC values in MP ranged between 0.19 to 0.64 dS/m across control and treatment villages. However, significant variations are seen in the samples in different villages. As seen in Figure 18, the control area data from Ratlam and treatment area data from Khargone show a wide range. In Ratlam, one control sample from Naharpura (upland) has EC of 0.95 dS/m. In Khargone, three treatment samples show high EC content – Bedhanya Bujurga (medium) 2.6 dS/m, Bedhanya Bujurga (medium upland) 1.09 dS/m, and Ted (upland) 3.2 dS/m. In Alirajpur, one treatment sample, Devlai (middle), has an EC value of 6.19 dS/m. Given that this data point is an outlier, it is not included in the analysis in the graphs below. On average, it is observed that both treatment and control areas had salt-free soils, with some samples showing slight salinity. However, only one sample in some villages (treatment and control) showed salinity, with the rest having low ES values, indicating that the soils of these areas are salt-free.

Figure 13: Average EC (dS/m) of Treatment and Control Areas in Districts



Error bars denote Standard Deviation.

[19] Final Corrected Manual on Soil Testing, Ministry of Agriculture: https://agriculture.uk.gov.in/files/Soil_Testing_Method_by_Govt_of_India.pdf

3.14.3. Soil Organic Carbon

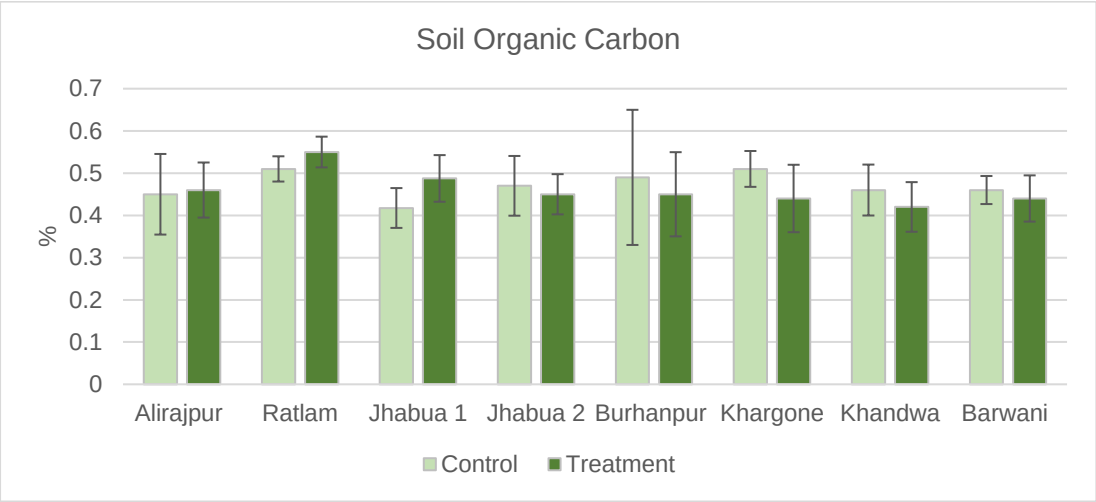
Soil organic carbon (SOC), the largest carbon pool in the terrestrial biosphere, is an important component of the global carbon cycle. It is estimated that SOC pools store 1500 PgC (Petagrams of carbon) in the top one metre of soil, which is more than carbon stored in the atmosphere (800 PgC) or vegetation (500 PgC).[20] This is not a static reservoir but is constantly cycling between different pools. SOC is the major constituent of soil organic matter, playing a critical role in soil productivity and a wide array of ecosystem processes. Soil organic matter contains about 55-60% carbon by mass, and the majority of soils is the carbon stock, with small amounts of inorganic carbon also present. Though organic matter makes up just 2-10% of most soil's mass, it has a vital role in agricultural soil's physical, chemical, and biological functions, including their water retention capacity and structural stability. Organic matter also contributes to nutrient retention and turnover, degradation of pollutants, carbon sequestration and soil resilience.

The amount of SOC present in the soil is dependent on the balance between the amount of carbon entering the soil and the amount leaving it through carbon-based respiration gasses released by microbial mineralisation. Carbon is also lost from soil due to erosion and gained through re-deposition, and thus, its levels can be controlled and increased by managing the amount and type of organic residues being added to the soil. While the agricultural sector can impact the carbon cycle on a large scale, often through unsustainable management practices that release carbon, farmers have a vested interest in retaining and increasing SOC as both soil quality and yield tend to improve when SOC levels rise. Higher SOC results in improved soil aeration and water drainage and retention stabilise pH levels, and reduces the risk of erosion and nutrient leaching. If the soil has lower than 0.5% of organic carbon, it is considered poor-quality soil; between 0.5 to 0.75%, it is considered medium quality, and if it is above 0.75%, the soil is considered high-quality soil.[21] It is estimated that in India, on average, SOC content has gone down from 1 to 0.3% in the past 70 years.[22]

The average soil organic carbon percentage when looking at the district level in MP (treatment and control) is between 0.42 and 0.55% (Figure 19), and only moderate variation is seen within the districts. These overall levels indicate that SOC in these regions is not very high, and the soil quality is medium. When looking at the SOC in different villages across districts, large variations are not seen in the state. The highest value of 0.6% SOC is seen in one sample in Ratlam district – Sundrel (treatment, upland) and one sample in Burhanpur district – Pandhri (control).

[20] FAO, Soil Organic Carbon: the hidden potential. Food and Agriculture Organisation of the United Nations Rome, Italy: https://www.fao.org/3/i6937e/i6937e.pdf
[21] Tamil Nadu Agriculture University Soil Rating Chart: https://agritech.tnau.ac.in/agriculture/agri_soil_soilratingchart.html
[22] Soil organic carbon content fell from 1% to 0.3% in 70 years in India: NRAA: https://www.business-standard.com/article/current-affairs/soil-organic-carbon-content-fell-from-1-to-0-3-in-70-years-in-india-nraa-122032600305_1.html

Figure 14: Average SOC (%) of Treatment and Control Areas in Districts in MP



Error bars denote Standard Deviation.

3.14.4. Available Nitrogen, Phosphate and Potassium

Nitrogen, Phosphorus and Potassium are considered primary macronutrients that are essential for plant growth, whereas, in cultivated systems, these can also be limiting factors for growth. While the three work together, they each have specific roles for a plant and must be readily available. Nitrogen is a key component of amino acids, which form the building blocks of plant proteins and enzymes, and it constitutes 2-4% of plant dry matter. It plays a critical role within the plant to ensure energy is available when and where the plant needs it. Nitrogen is also a component of the chlorophyll molecule, which enables the plant to capture energy through photosynthesis, driving plant growth and yield. This crucial nutrient is even present in the roots where proteins and enzymes help regulate water and nutrient uptake.[23] Phosphorus is also one of the major plant nutrients present in soil. It is a constituent of plant cells, required for cell division and development of the growing tip of the plant, playing an essential role in seedling vigour and growth of young plants. Potassium is essential in nearly all processes needed to sustain plant growth and reproduction. Plants deficient in potassium are less resistant to drought, excess water, and high and low temperatures. They are also less resistant to pest and disease attacks. Potassium affects quality factors such as size, shape, colour and vigour of the seed and grain and improves the fibre quality of cotton. The amount of available potassium also impacts the nitrogen uptake by plants, and a plant's response to applied nitrogen decreases if the amount of potassium in the soil is below a critical level. The table below shows the amounts of Nitrogen, Potash and Phosphorus in soil that determine its fertility (Table 66).

Table 67: Fertility of Soil Based on Nutrient Availability[19]

Nutrients	Low	Medium	High
Available N as per alkaline permanganate method (kg/ha)	<280	280-560	>560
Available P by Olsen's method (kg/ha)	<10	10-24.6	>24.6
Available K by Neutral N, ammonia acetate method (kg/ha)	<108	108-280	>280

[23] Final Corrected Manual on Soil Testing, Ministry of Agriculture: https://agriculture.uk.gov.in/files/Soil_Testing_Method_by_Govt_of_India.pdf

According to the 29th Report on the Impact of Chemical Fertilisers and Pesticides on Agriculture and Allied Sectors in the Country[24], usage of NPK has shown an increasing trend across most of the country. Table 67 shows that while in MP consumption, has increased from 2011 to 2014.

Table 68: NPK Consumption ('000 tonnes) Trends in MP[24]

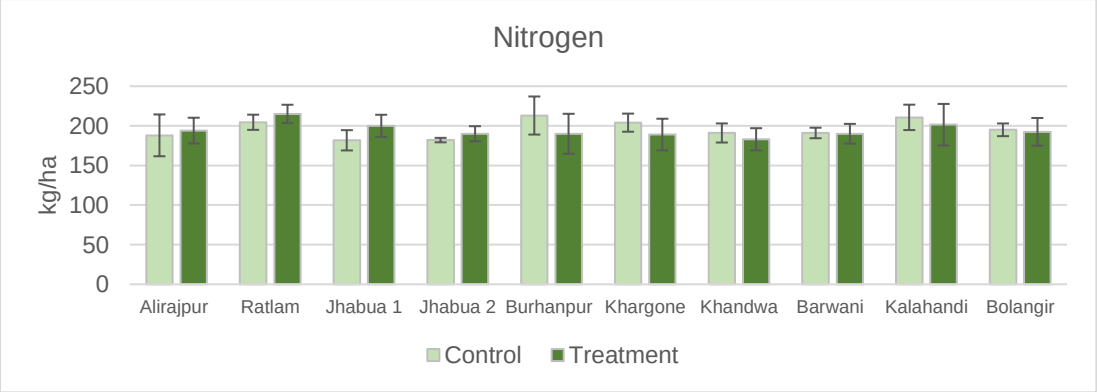
States	2011-2012	2012-2013	2013-2014
Madhya Pradesh	1,892	1,869	1,901

An NPK ratio of 4:2:1 is generally considered ideal and accepted for macro-level monitoring of consumption of plant nutrients.[25] Imbalance of NPK in soil impacts plant growth as well as results in greenhouse gas (GHG) emissions due to the overuse of nitrogenous fertilisers and leads to increased pollution in water bodies due to run off. Studies show that the NPK ratio in 2014-15 in MP is 15.5:8.4:1, which is imbalanced and requires intervention.

Nitrogen

For control and treatment areas, average Nitrogen content in soil samples ranged from 182 to 215 kg/ha (Figure 20). The nitrogen values are consistent in the samples taken from the villages, and substantial variations are not seen in any of the locations. Overall, it is seen that across treatment and control areas in MP the current levels of available nitrogen in the soil are on the lower side (Table 66), with the majority of values being less than 220 kg/ha.

Figure 15: Average Available Nitrogen of Treatment and Control Areas in Districts in MP



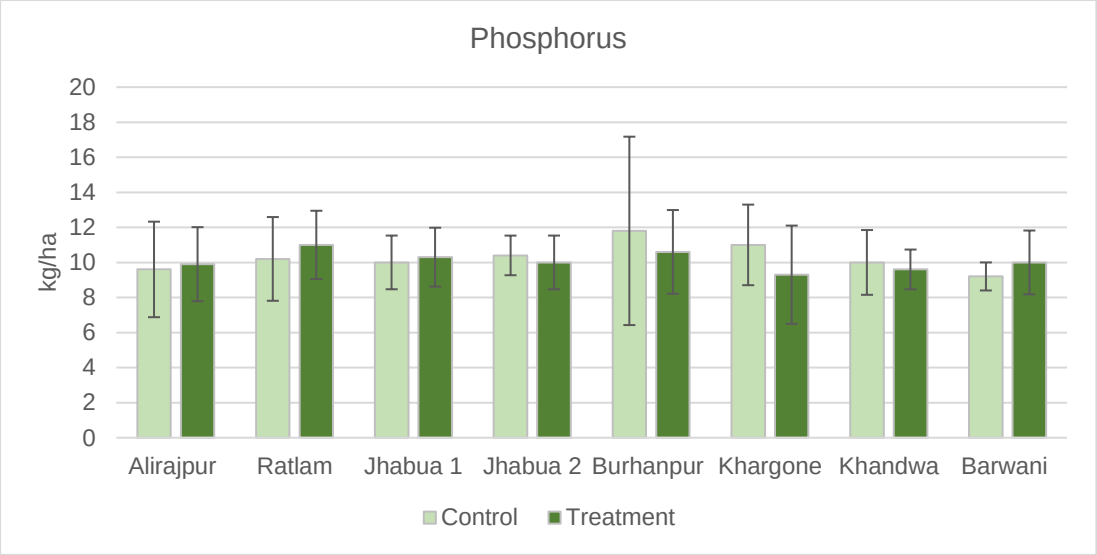
Error bars denote Standard Deviation.

[24] 29th Report on Impact of Chemical Fertilisers and Pesticides on Agriculture and Allied Sectors in the Country: https://eparlib.nic.in/bitstream/123456789/64994/1/16_Agriculture_29.pdf
[25] National Academy of Agricultural Sciences: https://naas.org.in/Policy%20Papers/policy%2042.pdf.

Phosphorus

The average Phosphorus content in the soil samples from MP ranges from 9.3 to 11.8 kg/ha in controlled and treatment areas. While some variations are seen in the phosphorus content amongst the different samples, the majority of the areas tested showed phosphorus content lower than 15 kg/ha, with a large proportion of these having values lower than 10 kg/ha (Figure 20). Only one sample in MP in Burahanpur district had a value higher than this – 15.6 kg/ha in Pandhri (control). These results show that the phosphorus content of soils in treatment and control areas of both states is on the lower side, with some areas showing it very marginally in the medium range (Table 66).

Figure 16: Average Available Phosphorus of Treatment and Control Areas in Districts in MP



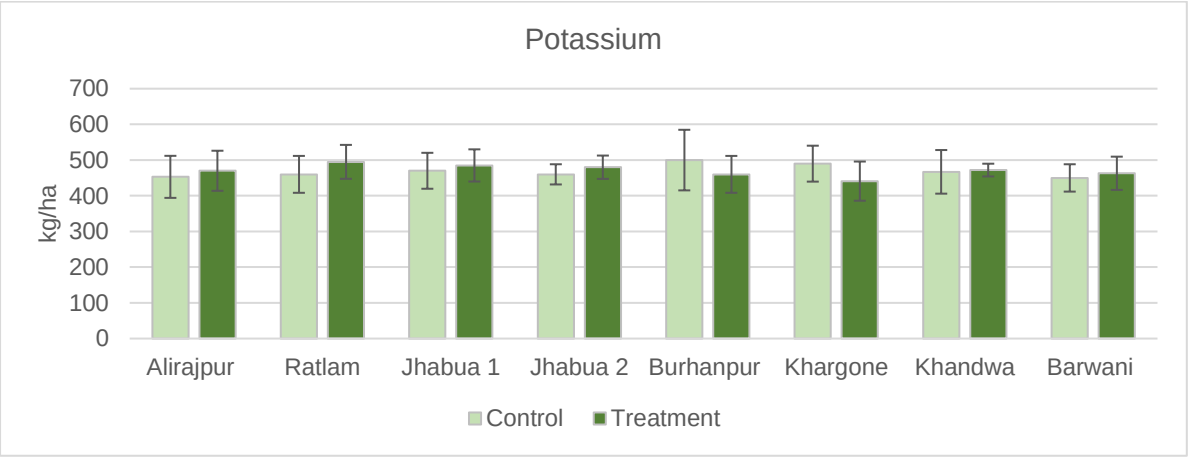
Error bars denote Standard Deviation

Potassium

Average Potassium content in soil samples from MP ranged from 450 to 500 kg/ha in control and treatment areas (Figure 22). Significant variations in the potassium content are not seen in the majority of samples in different villages in treatment or control areas in the state. Only one sample in Burahanpur district has a higher-than-average value at 560 kg/ha – Pandhri (control) – this is the same sample that also shows higher than average phosphorus levels, along with slightly higher nitrogen level (230 kg/ha) compared to other samples in the district.

Overall, the potassium levels in all soil samples across control and treatment areas are in the higher range. This is the only macronutrient tested that is present in high quantities. As mentioned above, a critical level of available potassium is necessary for the uptake of nitrogen by plants. The presence of these high levels of potassium indicates that the application of natural or bio-fertilisers that increase nitrogen in soils will help improve plant growth, as the high potassium level aids nitrogen uptake.

Figure 17: Average Soil Potassium of Treatment and Control Areas in Districts in MP



Error bars denote Standard Deviation.

While the soils in treatment and control areas show balanced pH levels, not being either acidic or alkaline, and have a normal range of EC, indicating they are not saline, other parameters assessed indicate that the soils are not of high quality. The soil's organic carbon content and nitrogen and phosphorus levels are all on the lower side. However, phosphorus levels are all in the high range. Interventions such as using bio-fertilisers, low tillage cultivation, mulching and green manuring, amongst others, would help improve soil quality and promote carbon sequestration. Table 68 presents strategies to improve the overall soil health of the area.

Table 69: Practices to Increase Soil Organic Carbon[26]

Management category	Management practices to increase soil carbon
Crop management	Soil fertility enhancement Better rotation Erosion control Irrigation
Conservation tillage	Stubble retention Reduced tillage No-tillage
Pasture management	Fertiliser management Grazing management Earthworm introduction Irrigation Improved grass species Introduction of legumes Sown pasture Introduction of perennial pastures
Organic amendments	Animal manure Green manure Recycled organics

[26] Soil Management and Filed Preparation by National Council of Education, Research and Training. https://ncert.nic.in/vocational/pdf/kegr105.pdf

3.15. GIS-Remote Sensing Analysis

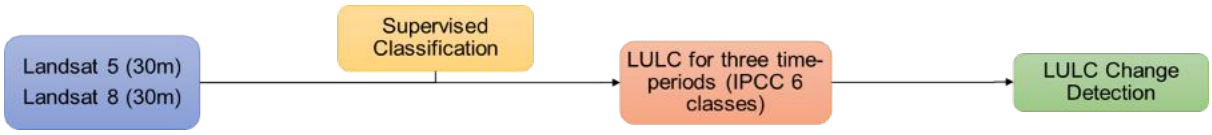
3.15.1. Land Use Land Cover

LULC analysis is carried out to observe changes over the two decades; therefore, three years are chosen – 2001, 2010 and 2022. For 2022, Landsat 8 (30m resolution) data are taken, and for 2001 and 2010, Landsat 5 (30m resolution) data are used. 5 LULC classes viz. Wetland, forest land, agriculture (cropland and fallow land), barren land and built-up are identified using the "Supervised Image Classification" technique. The area statistics are calculated for each class along with the change detection. District-wise GIS and Remote sensing data is provided in Annexure. This report specifically utilises imagery from Karadwad, a treatment village in Jhabua district, for reference.

Table 70: IPCC LULC Classes and their Description

LULC class	Description
Built-up land	This refers to the area with settlements and it is put to non-agricultural use. It has a cover of buildings and infrastructure.
Agricultural land	This refers to the land which is put to use for farming for the production of food, fiber, as well as commercial and horticultural crops. It includes land under crops (irrigated and unirrigated), fallow land
Forest	This refers to the area which lies within the limits of reserve andprotected forests (RF and PF), and has a thick cover of trees and Shrubs
Barren land/Waste land	This refers to the land which is degraded
Wetland	This refers to areas/structures where water is impounded/stored during monsoon. For example, reservoirs/lakes/tanks/canals, besides natural lakes, rivers/streams.

Figure 18: Methodology Flowchart for LULC Change Detection



A general trend observes a decrease in the barren and forest land areas and an increase in agriculture and built-up areas.The study area has also witnessed remarkable expansion and growth in urban built-up areas, roads and other infrastructure development during the past few decades due to population growth, leading to land conversion and LULC change. It has also led to deforestation, mainly for agriculture expansion.

Interventions to improve LULC include forest conservation and restoration, promoting sustainable agriculture practices, implementing effective land use planning, managing water resources, incorporating green infrastructure in urban planning, raising public awareness, and fostering collaboration amongst stakeholders. These interventions aim to balance economic

development with environmental conservation, protect natural resources, mitigate land degradation, and promote sustainable practices for long-term benefits.

Figure 19: LULC Change Map of Karadwad Village, Jhabua District

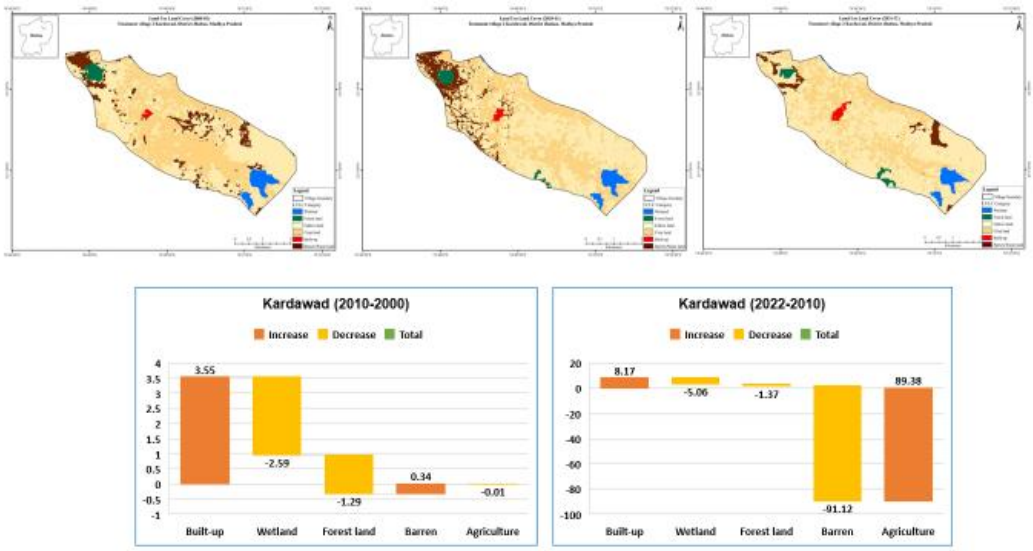


Table 71: LULC Change Detection from 2000-2010

District	2010/2000	Built Up	Wet Land	Forest Land	Barren	Agriculture
Alirajpur	Treatment	12.5	30.5	-44.8	-823.5	825.2
	Control	8.9	21.1	30.9	-758.8	697.9
Barwani	Treatment	35.8	42.7	8.4	-151	164
	Control	13.7	-0.1	5.4	-63.3	52.7
Buhranpur	Treatment	8.3	4.8	51.7	-61.8	-3
	Control	2	11.3	119.3	-36.1	-96.7
Khargone	Treatment	18	9.5	137.4	-460.7	295.6
	Control	8.2	61.1	0	-422.5	353.1
Jhabua 1	Treatment	4	8.4	47	-379.1	319.6
	Control	4.7	11.6	0	-357	340.7
Jhabua 2	Treatment	4.6	2.1	9.4	-24.5	8.4
	Control	-0.8	14.3	0	33.5	-46.9
Ratlam	Treatment	1.2	31.2	95.5	-152	24
	Control	0.7	11.8	0.8	-45.7	32.5
Khandwa	Treatment	1.5	6.8	53.1	-266.6	205.2
	Control	17.5	-0.3	33.1	-874.2	823.9

Among all the LULC categories, agricultural land exhibits (during 2000-2010) the most significant increase over the course of ten years, with the highest growth observed in Alirajpur and Khandwa districts. The built-up category followed closely, showing maximum expansion in Barwani and Alirajpur districts (Table 70).

Table 72: LULC Change Detection from 2010-2022

Districts	2022/2010	Built Up	Wet Land	Forest Land	Barren	Agriculture
Alirajpur	Treatment	24.72	14.8	-0.05	-155.86	116.38
	Control	45.12	-7.46	-25.29	-50.82	38.35
Barwani	Treatment	45.34	-6.12	-6.16	-450.57	417.62
	Control	6.75	0	-3.57	-205.64	207.95
Buhranpur	Treatment	-0.58	0.58	-26.49	5.29	21.19
	Control	5.82	0.31	-98.44	4.72	87.65
Khargone	Treatment	86.7	3.34	-81.4	-90.87	82.34
	Control	14.65	-19.02	0	-17.9	22.3
Jhabua 1	Treatment	32.42	-0.2	-29.29	-63.15	60.28
	Control	11.71	-4.29	0	-136.99	129.59
Jhabua 2	Treatment	11.6	-4.89	-12.04	-183.6	189
	Control	7.49	2.45	0.24	-50.82	40.55
Ratlam	Treatment	25.04	11.95	9.12	-65.25	19.08
	Control	4.82	4.39	0.38	-273.92	264.31
Khandwa	Treatment	18.11	68.84	-45.24	-121.07	79.37
	Control	32.59	0	15.74	-138.45	90.2

Among all the LULC categories, agricultural land exhibits (during 2010-2022) the most significant increase over the course of 10 years, with the highest growth observed in Barwani and Ratlam districts. The built-up category followed closely, showing its maximum expansion in Barwani and Khargone districts (Table 71).

3.15.2. Slope, Aspect and Elevation

The Slope, aspect and elevation classes are calculated using the SRTM Digital elevation model (DEM) data 30 m resolution.

Figure 20: Methodology Flow Chart for Slope and Aspect Mapping



The Slope tool (in ArcGIS software) identifies the steepness at each cell of a raster surface and describes the steepness of the ground's surface. The results are presented in degrees, and the range varies from 0 to 62. The slope of the land affects water drainage and soil erosion. Steep slopes can lead to rapid water runoff, causing erosion and nutrient loss. Implementing appropriate measures such as contour ploughing, terracing, or constructing bunds is pertinent to reduce soil erosion, retain water, and prevent nutrient runoff. Additionally, slopes influence the distribution of irrigation water, as it tends to accumulate in lower-lying areas. Managing slopes effectively helps optimise water use, prevent erosion, and promote sustainable agricultural practices.

The aspect is the compass direction or azimuth that a terrain surface faces and determines the amount and intensity of sunlight the land receives. The aspect tool (in ArcGIS software) identifies the direction the downhill slope faces. It is measured clockwise in degrees from 0 (due north) to 360 (again due north), coming full circle. This influences microclimatic conditions and affects crop growth and productivity. Different crops have varying sunlight requirements, and selecting suitable crops based on aspect can maximise sunlight exposure and optimise yield.

Based on these findings, an effort has been made to understand the distribution of land types across different districts.

Figure 21: Slope and Aspect Map of Karadwad Village, Jhabua District

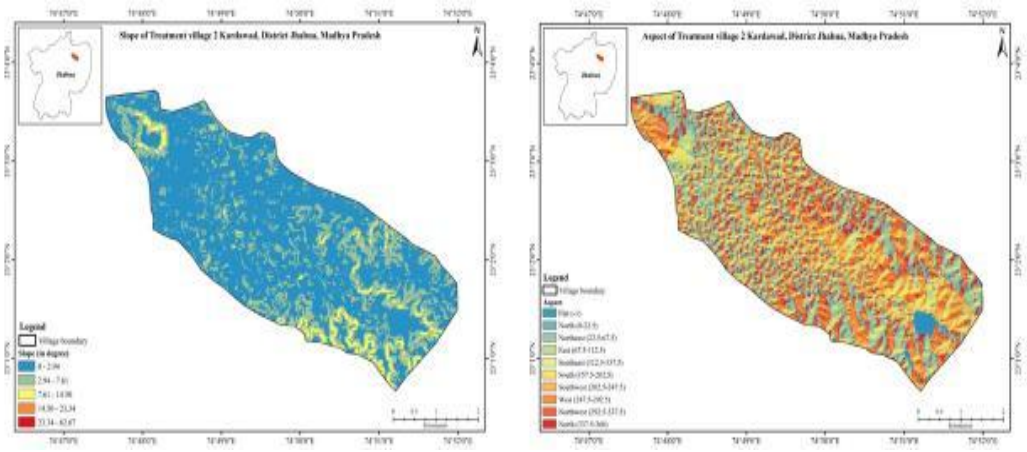
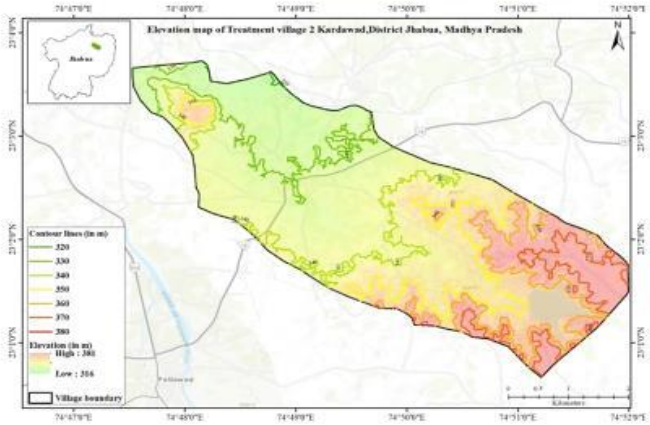


Figure 22: Elevation Map of Karadwad Village, Jhabua District



Findings –

- The land is mostly undulating in the survey area with presence of **upland, medium land and low land.**
- **Majority** of land in both treatment and control villages is **medium upland** (58% and 66% respectively), followed by **upland** (27% and 26%).
- The **treatment villages** have a **higher share of medium lowland** (14%) than the **control villages** (8%).

Table 73: Land Type Classes and the % Area in Our Study Area

Districts	Village Type	Upland %	Medium Upland %	Medium Lowland %
Alirajpur	Treatment	40	43	17
	Control	26.9	63.4	9.7
Barwani	Treatment	43.9	48.3	7.8
	Control	32.8	57	10.2
Buhranpur	Treatment	17.8	39.3	42.9
	Control	59	17.3	23.7
Khargone	Treatment	12.3	84.9	2.8
	Control	16.6	80.3	2.6
Jhabua	Treatment	40.5	31.4	28
	Control	57.2	14.2	27.6
Ratlam	Treatment	19.1	74.5	6.4
	Control	28.8	65.5	5.8
Khandwa	Treatment	22.1	59.4	18.5
	Control	5.2	94.8	0
Mean – All Villages	Treatment	27.5	58.1	14.3
	Control	26	65.9	8.1
	All Villages	27	61.1	11.9

The data analysis exhibits that the land is mostly undulating in the surveyed area with the presence of upland, medium land and low land. The majority of land in both treatment and control villages is medium upland (58% and 66%, respectively), followed by upland (27% and 26%). The treatment villages have a higher share of medium lowland (14%) than the control villages (8%).

3.15.3. Soil Type

The soil type data is digitised; overall, nine classes are observed in the study area, i.e., Chromic Haplusterts, Entic Haplusterts, Fluventic Haplustepts, Lithic Haplustepts, Lithic Ustorthents, Typic Haplustalfs, Typic Haplustepts, Typic Torripsamments and Vertic Haplustepts. U.S. Geological Survey (USGS) is used to analyse the soil type in the area.

Table 74: USGS System of Classification and their Soil Name

S. No.	USGS System of Classification	Soil Name
1	Chromic Haplusterts	Red and yellow soil
2	Lithic Haplustepts	Rocky soil
3	Fluventic Haplustepts	Alluvial soil
4	Lithic Ustorthents	Laterite soil
5	Typic Haplustepts	Clayey soil
6	Vertic Haplustepts	Black soil
7	Entic Haplusterts	Mixed soil
8	Typic Haplustalfs	Clayey soil
9	Typic Torripsamments	Sandy soil

Table 75: Percentage of Different Soil Types Found in Our Study Area

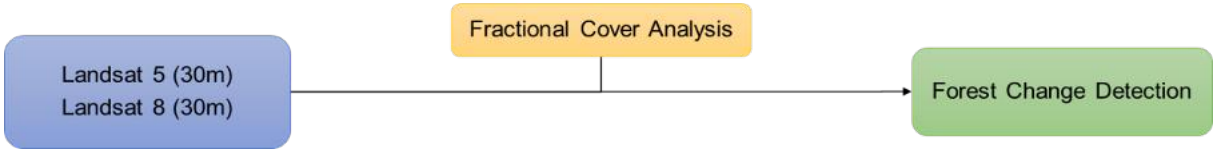
Village Type	Red & Yellow Soil	Mixed Soil	Alluvial Soil	Rocky Soil	Laterite Soil	Clayey Soil	Clay Soil	Sandy Soil	Black Soil
Treatment	15%	2%	8%	7%	23%	1%	11%	0%	34%
Control	25%	0%	9%	16%	16%	0%	17%	0%	16%
All Villages	19%	1%	9%	10%	20%	1%	13%	0%	27%

- The most common soil type in the surveyed villages is Black soil (27%), followed by Laterite soil (20%) and red and yellow soil (19%).
- Alirajpur has a predominance of Rocky soil followed by Alluvial soil.
- Barwani is mostly lateritic and black soil, followed by red and yellow soil.
- The treatment villages of Buhranpur are primarily red and yellow soil followed by mixed soil, while the control villages have a higher share of black soil.
- The treatment villages of Khargone are mostly black soil, while the control villages have clayey soil.
- The treatment villages of Khandwa have a good mix of black and clayey soil, while the control villages have both clayey and red and yellow soil.
- The villages in Jhabua have black and laterite soil, while Ratlam has black, red and yellow soil.

3.15.4. Forest Cover Density

The forest cover change analysis is carried out to study the changes in forest cover density classes over a decade (2010-2022).

Figure 23: Methodology Flowchart for Forest Cover Change Detection



For the year 2022, Landsat-8 imagery is taken, and for the year 2010, Landsat-5 imagery is taken. The forest cover density classes are obtained using the “Two Component Linear Mixture Model”. The obtained forest cover is then classified into four categories (adopted from the Forest Survey of India classification system).

Table 76: Forest Cover Density Class and their Description (adopted from FSI)

Class	Description
Scrub	canopy density less than 10 percent
Open forest	canopy density between 10% and 40%
Moderately Dense Forest	canopy density between 40% and 70% above
Very dense Forest	canopy density of 70% and above

The analysis of forest cover using remote sensing shows that overall, there has been a decrease in forest density over the decade.

Figure 24: Forest Cover Change Map of Kardwad Village, Jhabua District

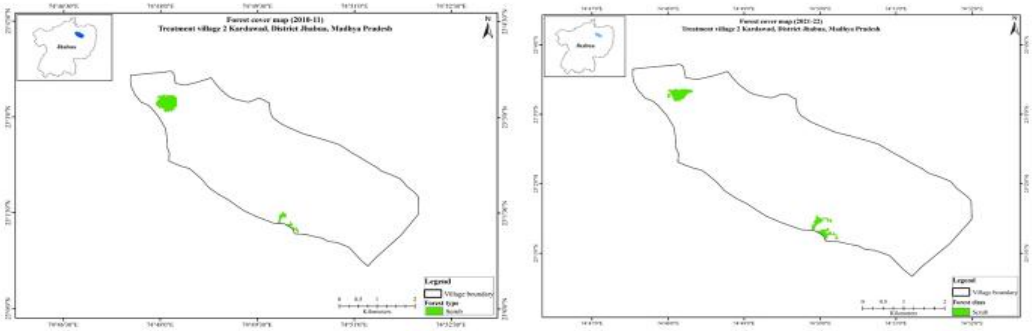


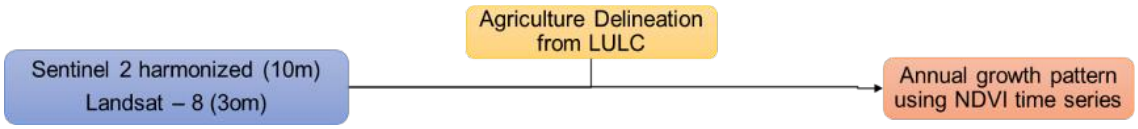
Table 77: Forest Cover Change (2010-2020) in Hectare

District	Village Type	Scrub	Open forest	Moderately Dense Forest
Alrajpur	Treatment	-0.17	-1.43	0
	Control	-17.14	0	0
Barwani	Treatment	0	-5.03	0
	Control	-2.72	-0.68	0
Burhanpur	Treatment	-32.55	6.24	-0.97
	Control	-10.13	-34.12	-23.05
Khargone	Treatment	-28.72	-43.99	-7.94
	Control	0	-1.77	-0.08
Jhabua	Treatment	-22.95	0.73	0
	Control	3.08	2.29	0
Ratlam	Treatment	-0.93	0.75	0
	Control	1.29	0	0
Khandwa	Treatment	-61.79	-6.01	-3.43
	Control	-0.99	3.11	-0.12

3.15.5. Crop Health

The rainfall data is analysed for the last ten years, and it is observed that the total rainfall was maximum in 2020 and minimum in 2015. Therefore, these two years and the current year (2022) are chosen for our study.

Figure 25: Methodology Flow Chart for Mapping Crop Health



Depending on the availability of the satellite imagery for different time periods, Sentinel-2 harmonised (10m resolution) and Landsat-8 (30m resolution) data is taken. NDVI, or Normalised Difference Vegetation Index, is used to monitor crop health and growth. NDVI is a measure of the greenness of a surface and provides an automated way to monitor the progress of the crop and its health throughout the growing season. The red colour region on the maps indicates low health, whereas green indicates good health.

Three cropping seasons are defined for our study area - Kharif, Rabi, and Zaid. The duration of each cropping season from sowing to harvesting period is identified, and the peak growing time of the crop is determined based on the general phenology of the crop.

Figure 26: Season-wise Surface Water Availability, Year 2022

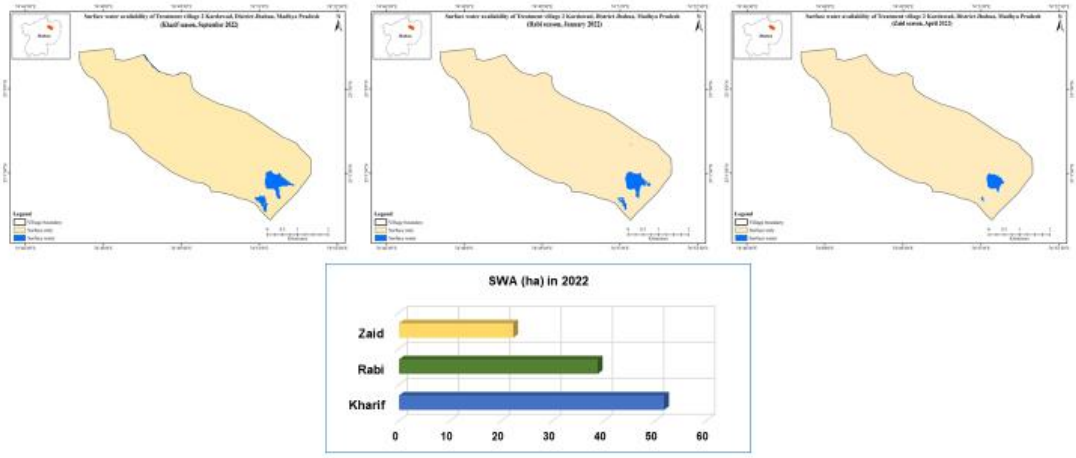


Table 78: Cropping Seasons and their Time Period Used for Our Study

Cropping Season	Time Period
Kharif season	01-Sep – 31-sep
Rabi season	01-Jan – 31-Jan
Zaid season	20-April – 20-May

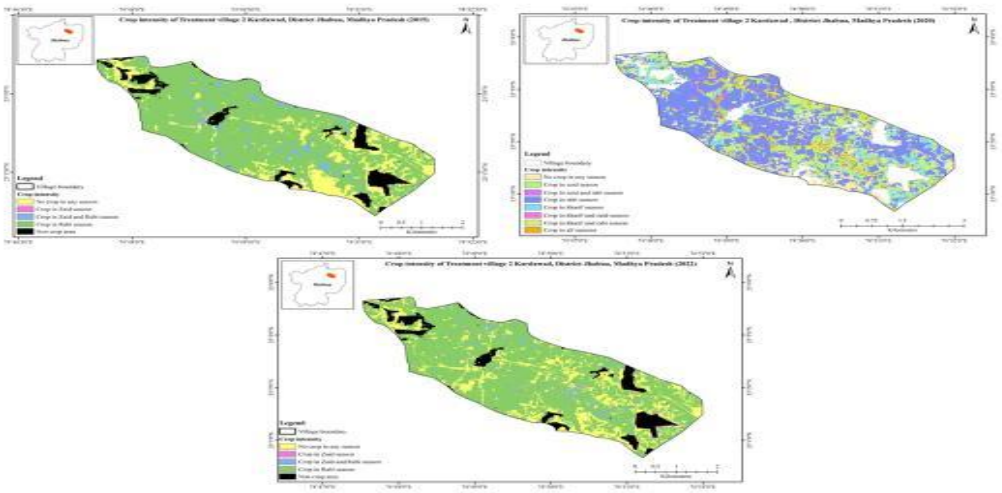
The crop health depends on adequate rainfall, avoiding waterlogging and soil erosion, managing pests like cotton bollworms and pod borers, timely sowing, irrigation, disease management, heat stress protection, and employing practices like crop rotation.

Table 79: Crop Health Status - Rabi

District		Rabi 2015 (% land)			Rabi 2020 (% land)			Rabi 2022 (% land)		
	Village	High	Low	Medium	High	Low	Medium	High	Low	Medium
Alirajpur	Treatment	13.17	48.96	37.88	22.69	42.67	34.63	28.55	35.28	36.16
	Control	12.42	53.83	33.74	25.13	43.69	31.18	33.51	34.76	31.73
Barwani	Treatment	21.93	36.57	41.5	42.62	27.75	29.63	45.18	25.21	29.6
	Control	12.66	50.73	36.61	30.23	42.13	27.65	27.86	44.97	27.18
Buhranpur	Treatment	10.52	38.54	50.93	16.51	24.88	58.62	29.32	27.22	43.45
	Control	1.82	80.48	17.69	5.38	65.87	28.75	6.58	69.66	23.76
Khargone	Treatment	34.82	30.14	35.04	54.16	22.57	23.27	52.99	24.08	22.93
	Control	19.85	48.17	31.97	31.25	36.47	32.28	35.97	37.12	26.91
Jhabua	Treatment	31.91	37.04	31.05	43.64	29.95	26.41	44.33	26.13	29.54
	Control	10.39	43.69	45.91	24.18	31.9	43.91	25.77	27.03	47.2
Ratlam	Treatment	9.57	65.11	25.31	24.69	51.88	23.43	27.14	47.05	25.81
	Control	3.38	77.32	19.3	11.24	65.18	23.58	17.89	55.05	27.07
Khandwa	Treatment	18.55	57.42	24.03	31.63	42.59	25.78	36.73	42.12	21.15
	Control	40.29	30.91	28.79	54.06	23.28	22.66	49.41	27.21	23.38

The data shows that in better rainfall years, the quality of crops in Rabi season is slightly better than the other years.

Figure 27: Crop intensity maps of Karadwad village for the year 2015,2020,2022



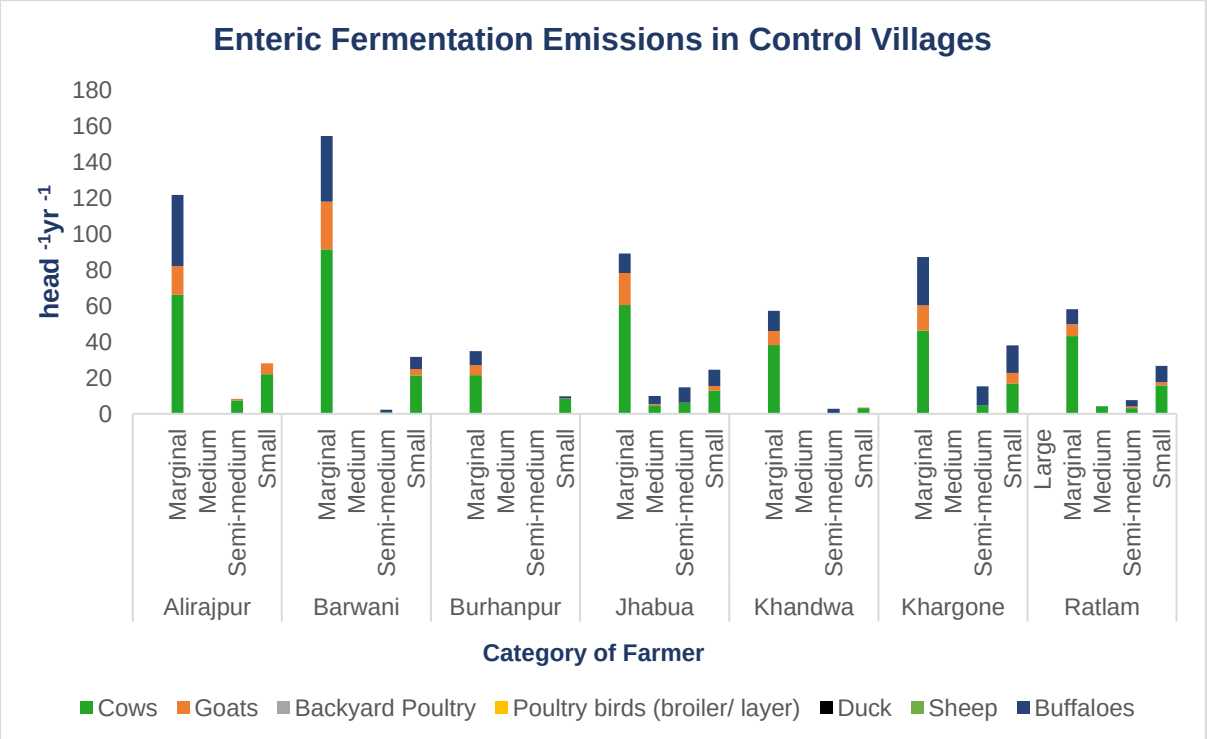
3.16. Green House Gas Emissions

In the present study, the farmers of all the seven districts are primarily marginal, small and semi-medium farmers. There is only one farm that falls under the large category. Therefore, the emissions from the large farmer are comparatively lower than the others and hence excluded in this section. All the information on the large farmer is included in the Annexure.

3.16.1. Emissions from Enteric Fermentation

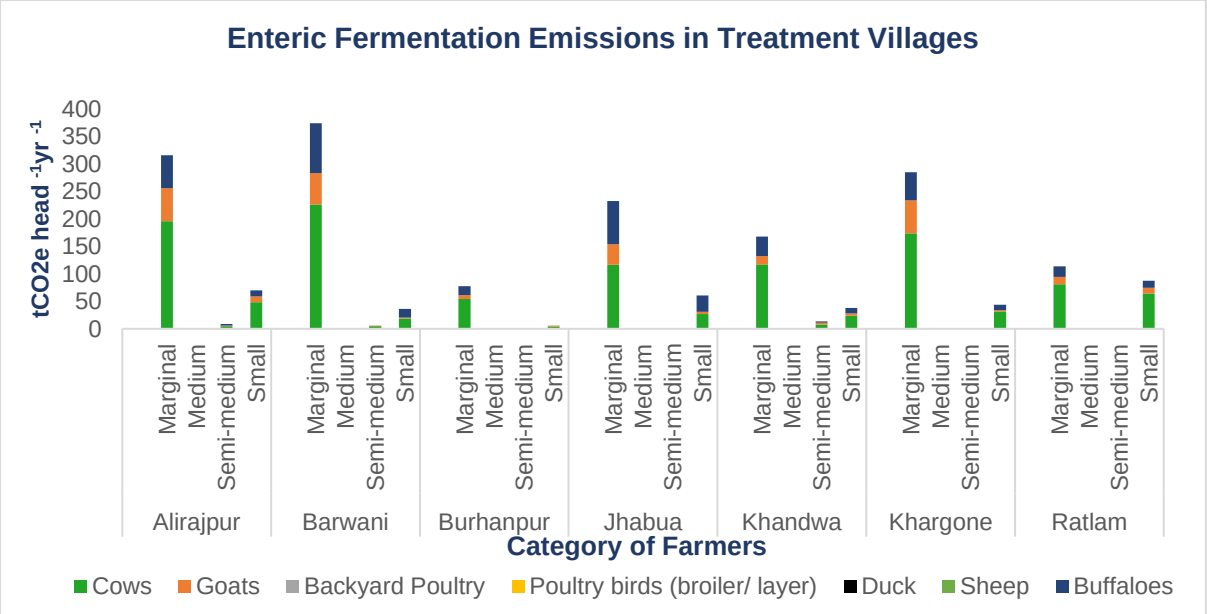
The emission from enteric fermentation comprises emissions from cows, goats, buffaloes, sheep, ducks, backyard poultry and poultry birds (broiler/layer). In both the control and treatment villages of all the seven districts, emissions from cows are more than any other livestock. In addition to that, enteric fermentation emissions in the control villages are more by livestock owned by marginal farmers. The highest emissions in both control and treatment villages are seen in Barwani and Alirajpur districts in the marginal farmer category. In the control villages of Alirajpur district, livestock emissions from marginal farmers is 121.73 tCO2e head -1yr -1 followed by 154.63 tCO2e head -1yr -1 in Barwani, 34.95 tCO2e head -1yr -1 in Burhanpur, 89.13 head -1yr -1 in Jhabua, 57.25 head -1yr -1 in Khandwa, 87.28 head -1yr -1 in Khargone and 58.18 tCO2e head -1yr -1 in Ratlam (Figure 33).

Figure 28: Cattle-wise Emissions from Enteric Fermentation in Control Villages



In the treatment villages of Alirajpur district, livestock emission from marginal farmers is 316.33 tCO2e head $^{-1}$yr $^{-1}$ followed by 374.65 tCO2e head $^{-1}$yr $^{-1}$ in Barwani, 77.80 tCO2e head $^{-1}$yr $^{-1}$ in Burhanpur, 232.55 head $^{-1}$yr $^{-1}$ in Jhabua, 168.05 head $^{-1}$yr $^{-1}$ in Khandwa, 285.30 head $^{-1}$yr $^{-1}$ in Khargone and 113.73 tCO2e head $^{-1}$yr $^{-1}$ in Ratlam (Figure 34).

Figure 29: Cattle-wise Emissions from Enteric Fermentation in Treatment Villages

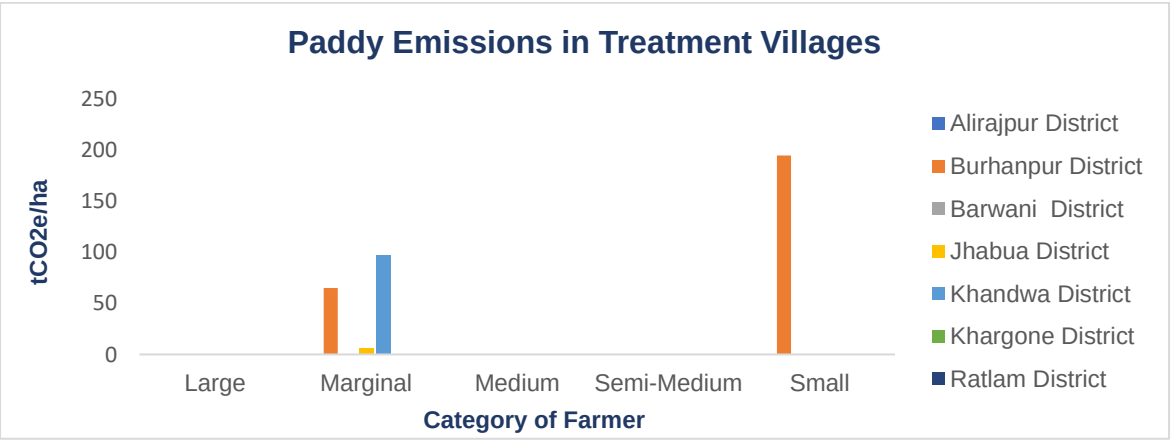


One of the reasons for higher emissions from marginal farmers of all seven districts is either the possession of a significant portion of livestock or more than one type of livestock. Also, the study has considered primarily marginal and small farmers; only one farm falls under the large category.

3.16.2. Emissions From Paddy Cultivation

In the control villages of the seven districts in Madhya Pradesh, Paddy cultivation is only seen among the marginal farmers of Burhanpur district. Here, the emissions amount to 32.5 tCO2e/ha (Annexure 2). While in the treatment villages, paddy emissions are seen among the small and marginal farmers of the Burhanpur district along with marginal farmers of Khandwa and Jhabua district. The emissions are seen higher in the small farmers of Burhanpur district, amounting to 195 tCO2e/ha. The marginal farmers of the Khandwa district emit 97.5 tCO2e/ha followed by 65 tCO2e/ha in the Burhanpur district and 6.5 tCO2e/ha in the district of Jhabua (Figure 35).

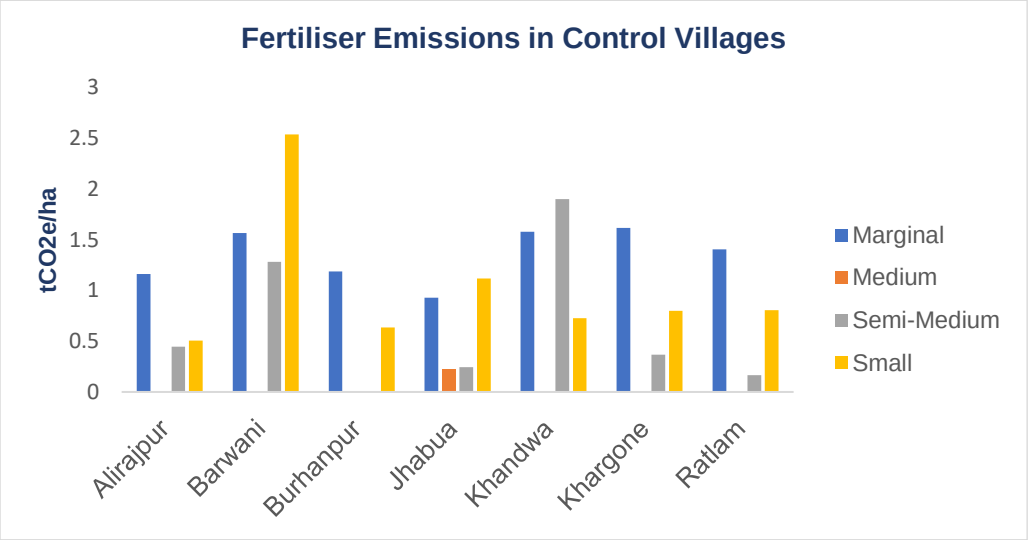
Figure 30: Paddy Emissions in Treatment Villages



3.16.3. Emissions from Agricultural Soils (Fertiliser Use)

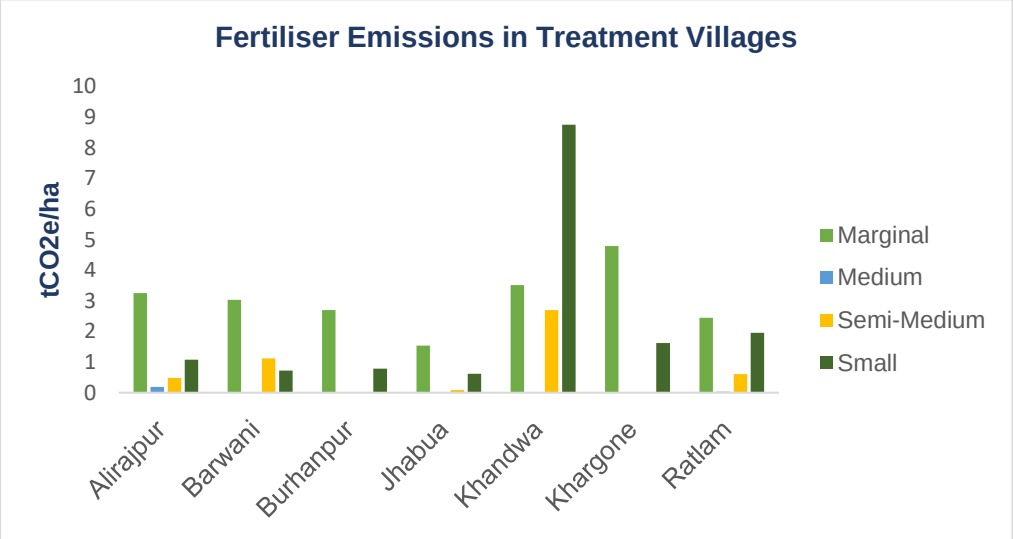
The emissions from agricultural soils (fertiliser use) are seen mostly by the small farmers in the control villages of the Barwani district; however, it is lower than the highest values in treatment villages across the majority of the districts. The emissions from the Barwani district amount to 2.53 tCO2e/ha, followed by 1.89 tCO2e/ha from the semi-medium farmers of Khandwa district, 1.61 tCO2e/ha from the marginal farmers of Khandwa district, 1.61 tCO2e/ha from the marginal farmers of Khargone district, and 1.56 tCO2e/ha from the marginal farmers of Barwani district (Figure 36).

Figure 31: Agricultural Soils (fertiliser use) Emissions in Control Villages



In the treatment villages, emissions for this category are seen higher in the small farmers of the Khandwa district, amounting to 8.75 tCO2e/ha followed by 4.79 tCO2e/ha from marginal farmers of Khargone district, 3.5 tCO2e/ha from the marginal farmers of Khandwa district, 3.24 tCO2e/ha from the marginal farmers of Alirajpur district and 3.02 tCO2e/ha from the marginal farmers of Barwani district (Figure 37).

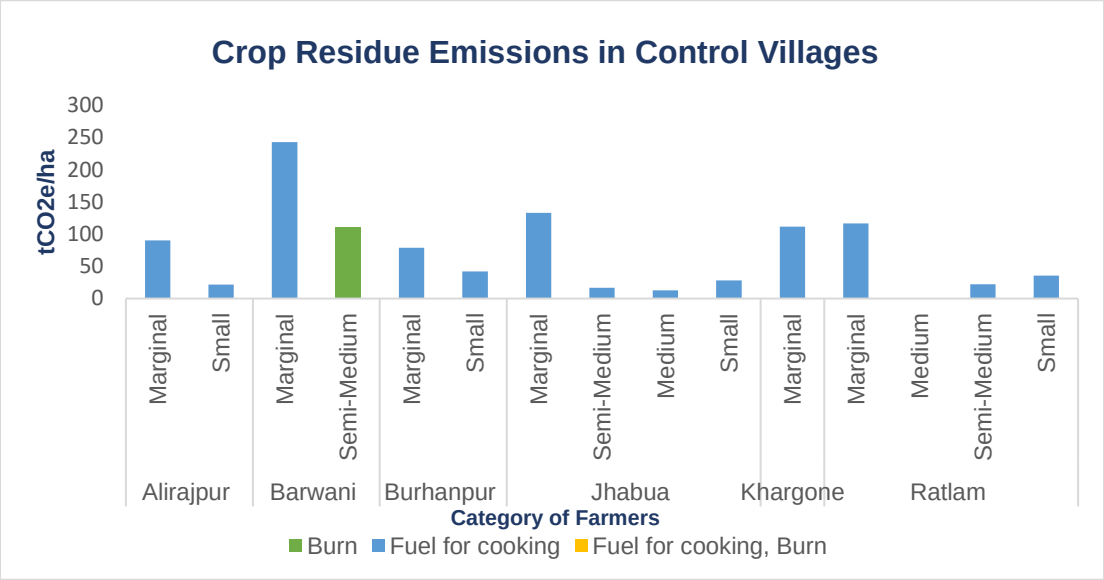
Figure 32: Agriculture Soils (Fertiliser Use) Emissions in Treatment Villages



3.16.4. Emissions from Crop Residue Burning

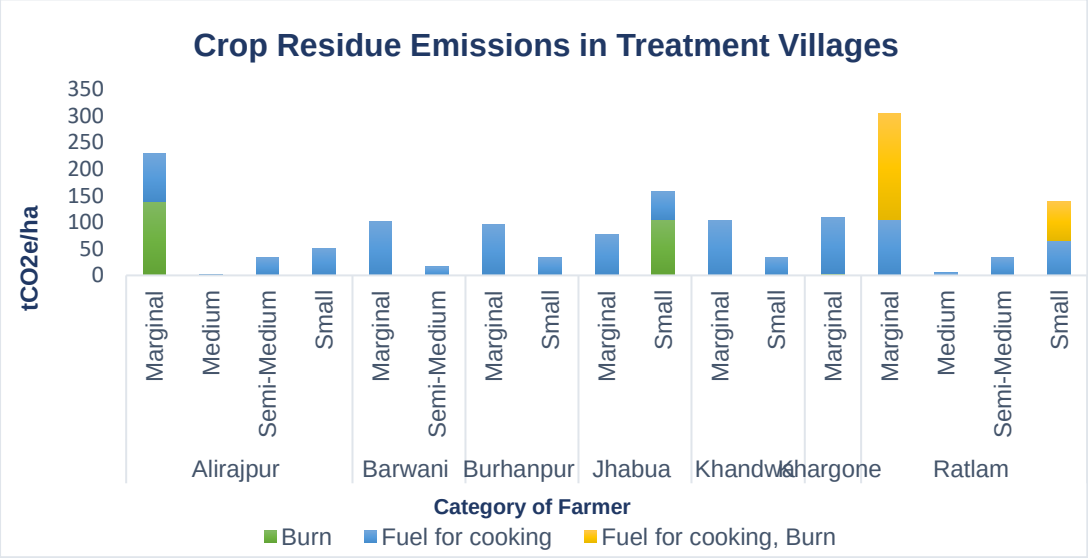
For this category, it is observed that the residue of the crops is mostly used as fuel for cooking in both the control and treatment villages across the seven districts of Madhya Pradesh. The amount of residue used as fuel for cooking is comparable across control and treatment villages, with no major outliers. In the control villages, most emissions are seen in the marginal farmers of the Barwani district, amounting to 242 tCO2e/ha followed by 133 tCO2e/ha from the marginal farmers of the Jhabua district, 116 tCO2e/ha from the marginal farmers of Ratlam district and 111 tCO2e/ha from Khargone and Barwani district (Figure 38).

Figure 33: Activity wise Crop residue emissions in control villages



In the treatment villages, most emissions are seen in the small farmers of Ratlam district, amounting to 303 tCO2e/ha followed by 228 tCO2e/ha from marginal farmers of Alirajpur district, 157 tCO2e/ha from the small farmers of Jhabua district, 138 tCO2e/ha from the small farmers of Ratlam district, 107 tCO2e/ha from the marginal farmers of Khargone and 100 tCO2e/ha from marginal farmers of Barwani district (Figure 39).

Figure 34: Activity-wise Crop Residue Emissions in Treatment Villages

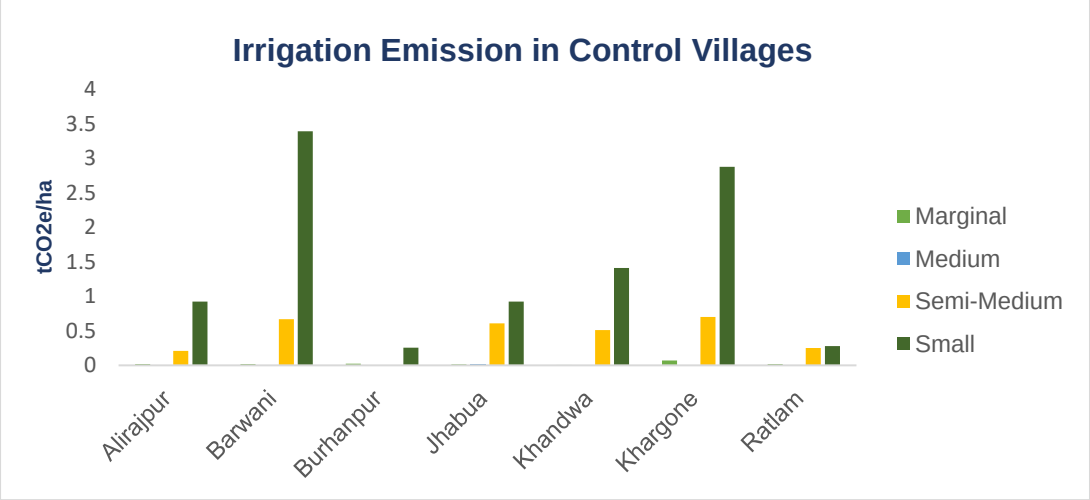


One of the reasons for higher emissions from marginal and small farmers of all seven districts is the burning of residues of two or more crops or the residue for both burning and using as fuel for cooking.

3.16.5. Emissions from Irrigation

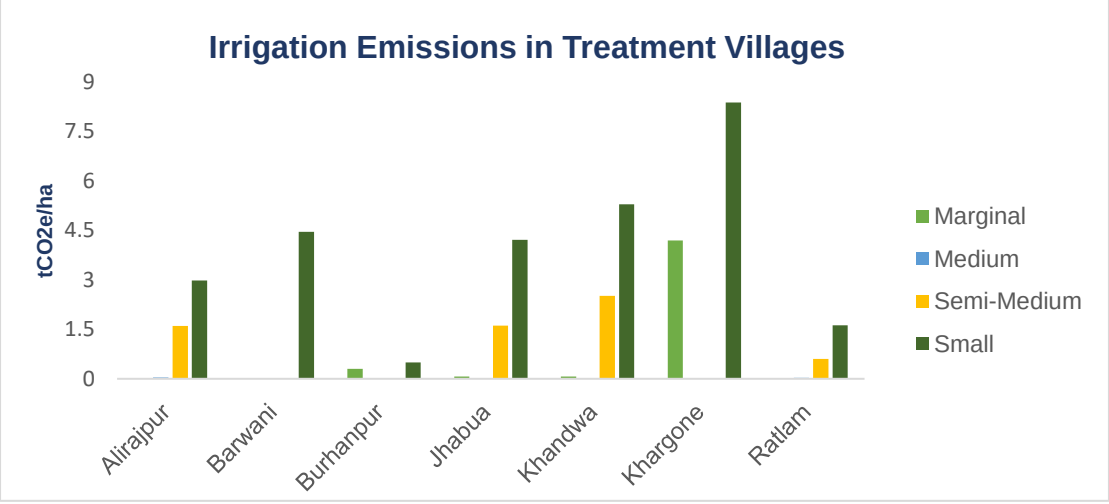
In the present study, the crops are primarily rainfed. Nevertheless, if water is used through pumps for irrigation, the farmers use either diesel or electric pumps. In the control villages, the emissions from irrigation of agricultural land are more from small farmers of Barwani district, amounting to 3.39 tCO2e/ha followed by 2.87 tCO2e/ha from Khargone district, 1.41 tCO2e/ha from Khandwa district and 0.92 tCO2e/ha from both Jhabua and Alirajpur district (Figure 40).

Figure 35: Emissions from Irrigation in Control Villages



In treatment villages, most emissions are seen from small farmers of the Khargone district, amounting to 8.37 tCO2e/ha followed by 5.29 tCO2e/ha emissions from the Khandwa district and 4.46 tCO2e/ha from the district of Barwani. In the district of Khargone, marginal farmers emit 4.19 tCO2e/ha followed by 2.98 tCO2e/ha from marginal farmers of Alirajpur district (Figure 41).

Figure 36: Emission from Irrigation in Treatment Villages



While estimating irrigation emissions from different crops, it is found that in the control villages, most of the emissions are from wheat, i.e., around 77%, followed by 18% from cotton, 4% from maize, and 1% from gram (Figure 42). Emissions are seen higher in the Khargone district as they cultivate wheat, cotton and maize, which have higher emissions than soybean and gram.

Figure 37: Crop-wise Emissions from Irrigation in Control Villages

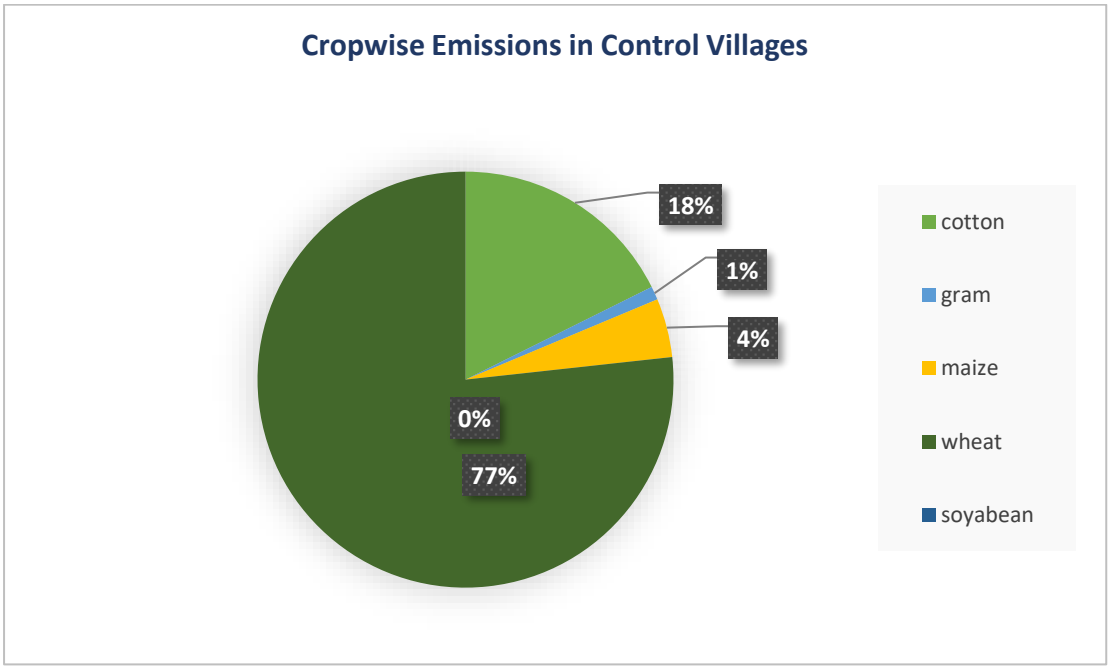
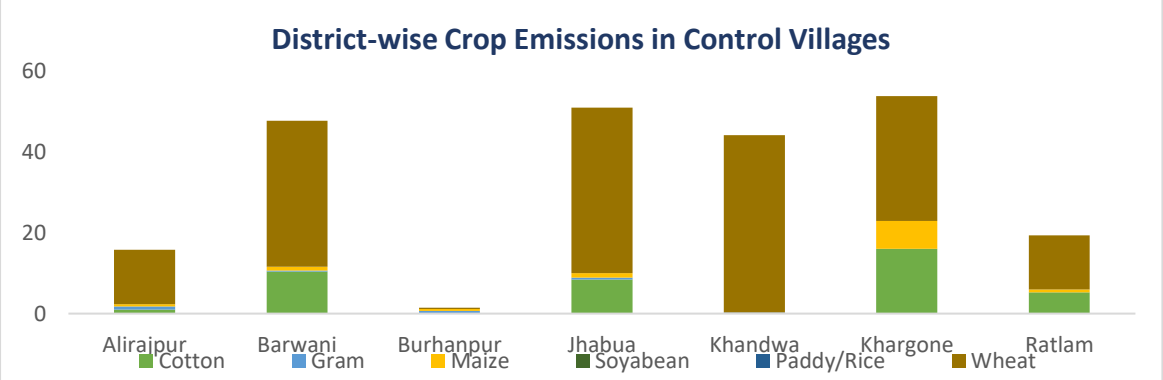


Figure 38: District-wise Crop Emissions from Irrigation in Control Villages



The emissions in treatment villages are comparable to those in the control villages. Most of the emissions are from wheat, i.e., around 82%, followed by 11% from cotton, 4% from maize and 3% from gram (Figure 44). Emissions are seen higher in the treatment villages of Barwani district as they are cultivating wheat, cotton and maize, which has higher emissions than soybean and gram (Figure 45).

Figure 39: Crop-wise Emissions from Irrigation in Treatment Villages

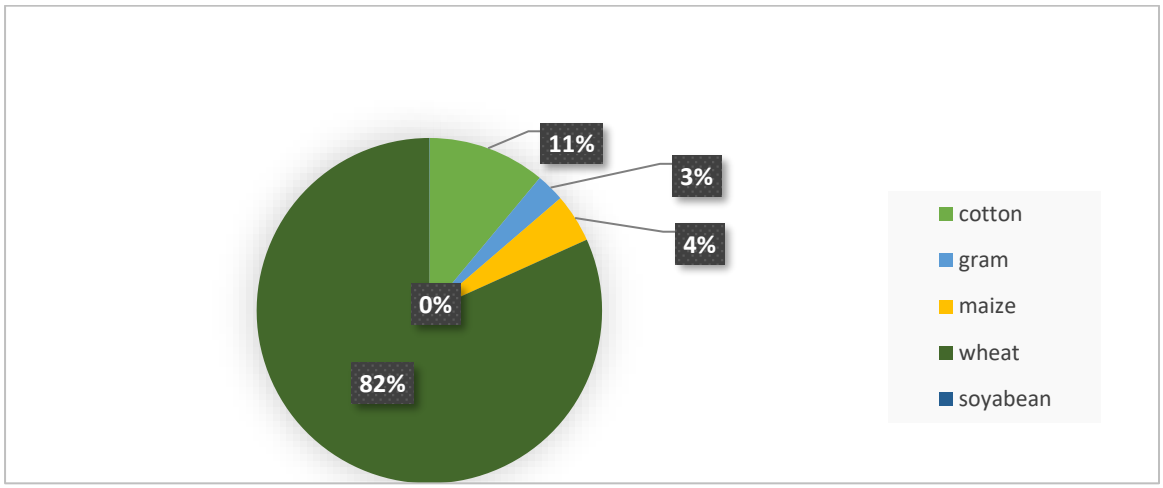
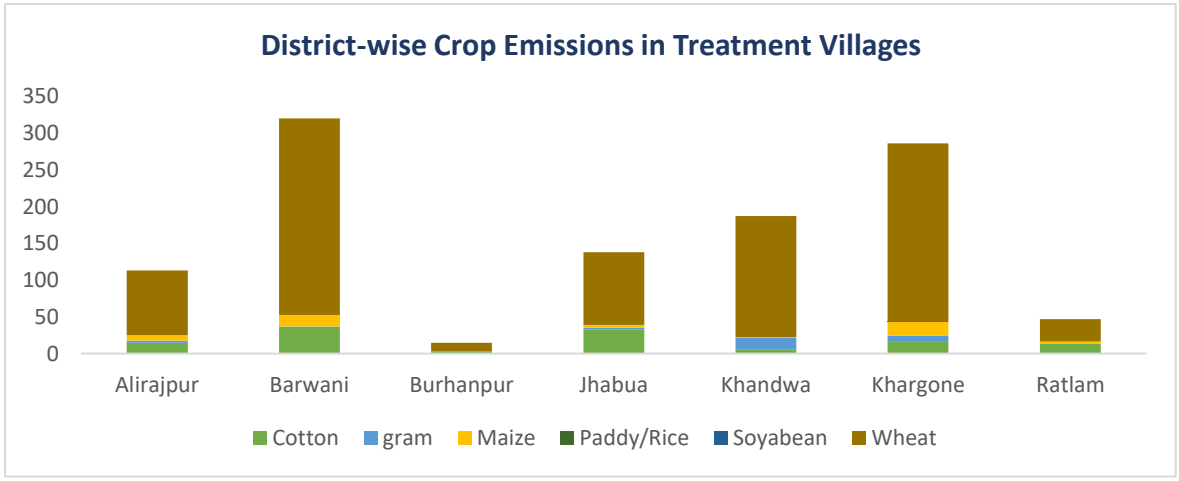


Figure 40: District-wise Crop Emissions from Irrigation in Treatment Villages.



3.16.6. Crop wise Emissions Detail

An effort has been made to understand the GHG emissions per acre for different major crops using the main variables like crop residue usage, amount of application of synthetic fertilizers and pesticides, emissions from irrigation and ploughing. Since adequate and correct data for transportation could not be captured properly during the survey, the specific variable has been left out. The FAO developed Cool-Farm tool has been used to determine the crop specific GHG emissions per acre. Table 80 details the GHG emissions per crop per acre of land.

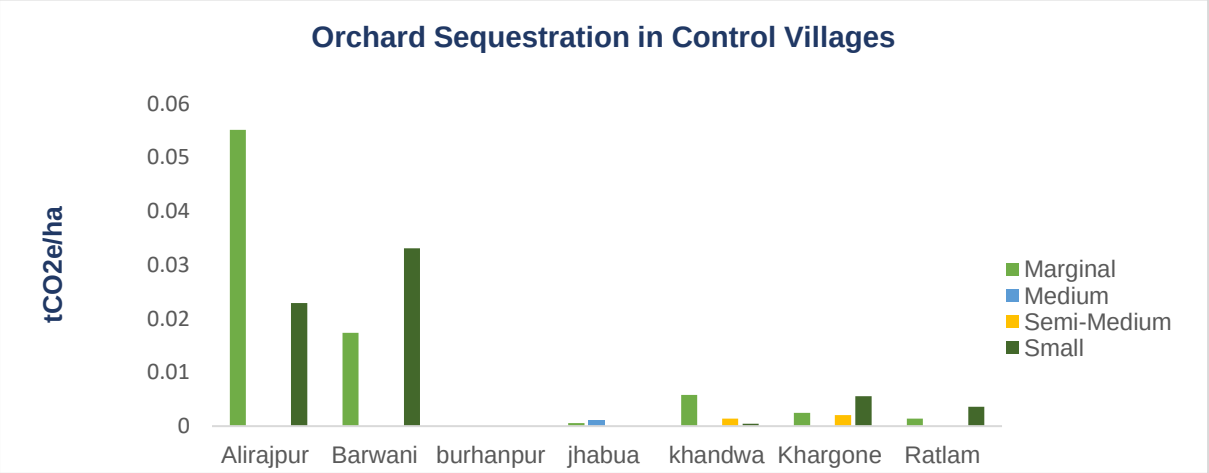
Table 80: GHG Emission for each crop per acre land (in percentage)

Crop	Crop residue usage for fuel/ burning	Synthetic Fertilizer usage (kg/acre)	Synthetic Crop protection usage (ml/acre)	% HH irrigating crop	% HH using diesel pump set (*rest electric pump)	Av no of irrigation	Av no of ploughing	GHG emissions (kg CO2e)
Cotton	94	443	810	18.7	1.2	2	3	1209
Maize	3.4	519	740	5	5.9	4	2	890
Soybean	4.7	230	513	2	0	1	2	548
Wheat	0	362	438	98.5	3.4	5	2	575
Bengal Gram	0	297	505	86.3	11.1	2	2	1016

3.16.7. Orchard Sequestration

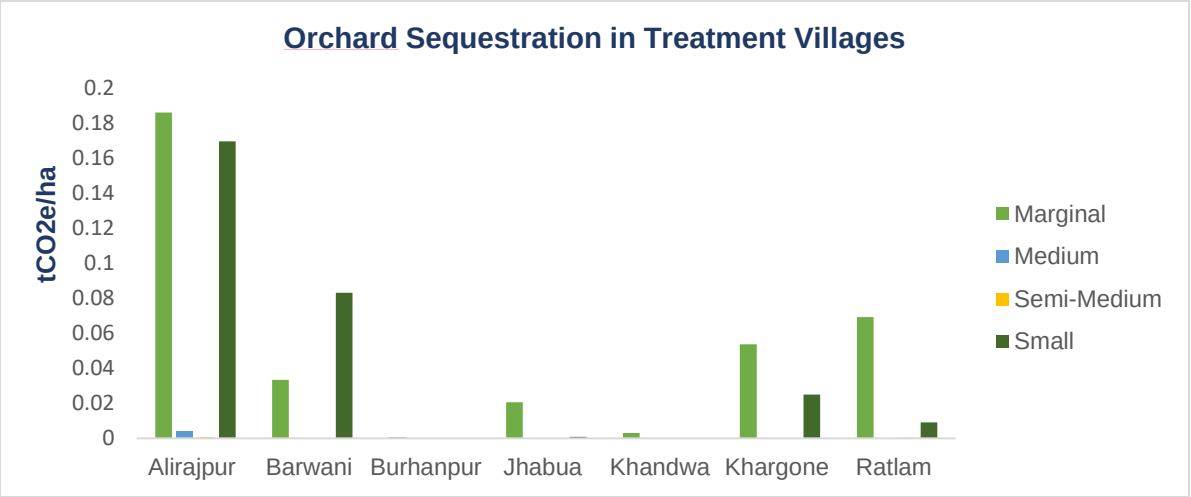
The amount of sequestration currently is meagre across control and treatment villages. In the control villages, orchard sequestration is primarily seen in marginal farmers of the Alirajpur district, amounting to 0.0551 tCO2e/ha followed by 0.033 tCO2e/ha from the small farmers of Barwani district, 0.0228 tCO2e/ha from small farmers of Alirajpur district and 0.0173 tCO2e/ha from marginal farmers of Barwani district (Figure 46).

Figure 41: Orchard Sequestration in Control Villages



In the treatment villages, orchard sequestration is largely seen in marginal farmers of the Alirajpur district, amounting to 0.1859 tCO2e/ha followed by 0.1695 tCO2e/ha from the small farmers of Alirajpur district, 0.0831 tCO2e/ha from the small farmers of Barwani district, 0.0691 tCO2e/ha from the marginal farmers of Ratlam district and 0.0535 tCO2e/ha from the marginal farmers of the Khargone district (Figure 47).

Figure 42: Orchard Sequestration in Treatment Villages



3.16.8. Emission Recommendations

Emissions Reduction from Enteric Fermentation

- **Improved Feed Management**: Providing livestock with nutritionally balanced diets and high-quality forage can enhance digestion efficiency by reducing feed fermentation in the gut and, consequently, methane emissions. Research has shown that certain feed additives and supplements, such as herbal oil extracts and tannins, can inhibit methanogens in the rumen (Króliczewska et al., 2023).

- **Grazing Management**: Implementing rotational grazing systems and managing pasture can optimise the animals' diet, reducing the time spent on high-fibre, low-digestibility forage leading to increased methane production.

- **Breeding and Genetics**: Selective breeding for livestock with lower methane production potential can be a practical and effective long-term approach to reducing enteric fermentation emissions. Genetic research is ongoing to identify and breed animals with a lower propensity to produce methane.

- **Methane-Capturing Feed Additives**: Innovative research explores the use of feed additives that can capture and convert methane into less harmful byproducts in the digestive tract before it is released into the atmosphere.

- **Dietary Supplementation**: Certain feed additives, such as seaweed-based supplements, and using probiotics and yeast/algae in dietary supplements, have shown promise in reducing methane emissions significantly when added to livestock diets (Palangi et al., 2022).

Emissions Reduction from Paddy Cultivation and Agricultural Soils (fertiliser use)

- **Adoption of Sustainable and Innovative Agricultural Practices**: An innovative method for growing rice called System of Rice Intensification encourages nutrient- and water-efficient techniques, which reduces GHG emissions. SRI encourages the adoption of younger, healthier seedlings with well-developed root systems and involves transplanting young rice seedlings, which reduces methane emissions. In the field, younger plants emit less methane as they grow. By promoting an aerobic soil condition, SRI encourages intermittent irrigation or Alternate Wetting and Drying (AWD), reducing the duration of flooded conditions and lowering methane emissions. Regular soil aeration, which reduces rice paddy methane emissions and aids in suppressing methane-producing microbes, is one of the key components of SRI (Thakur et al., 2023).

- **Improved Water Management**: Institute devised an irrigation method that alternates between wetting and drying to conserve water and reduce the emission of CH4 and N2O in rice fields. Without affecting productivity, Alternate Wetting and Drying (AWD) lowered irrigation water use by 15–35% and CH4 and N2O emissions by 45–90% when compared to CF. If irrigation water percolates less in AWD,

leaching losses of soil N (nitrogen) may also be reduced. By increasing the amount of aerobic microorganisms and organic matter through earthworm activity, AWD may improve the soil's phosphorous content. This might result in more robust root anchoring, improved nutrient absorption, more effective tillers and increased grain yield (Hossain et al., 2022; Cheng et al., 2022).

- **Conservation Agriculture**: Adopting conservation agriculture practices like direct seeding or minimum tillage can help decrease soil disturbance, which in turn reduces the release of nitrous oxide—a potent greenhouse gas—by minimising soil nitrogen availability (Meena et al., 2016).

- **Controlled-Release Fertilisers**: Using Controlled-Release Fertilisers (CRF) or urea super granules can reduce nitrogen losses and nitrous oxide emissions. CRFs release nutrients gradually, matching the crop's nutrient requirements, which enhances nitrogen use efficiency and reduces emissions (Lawrencia et al., 2021).

- **Nutrient Management**: Practicing site-specific nutrient management can optimise fertiliser use by applying the right type and amount of nutrients according to soil conditions and crop needs. This approach can decrease nitrogen leaching, runoff, and subsequent nitrous oxide emissions (Bana et al., 2020).

- **Integrated Crop-Livestock Systems**: Integrating rice production with livestock systems can help reduce GHG emissions. For instance, incorporating ducks into the rice field can control weeds without the need for herbicides, thus reducing emissions associated with herbicide production and application (Xu et al., 2017).

Emissions Reduction from Crop Residues

- **Conservation Tillage**: Adopting conservation tillage practices, such as no-till or minimum tillage, can help retain crop residues on the field surface. By disturbing the soil minimally, these practices reduce the decomposition of crop residues and decrease the release of CO2 into the atmosphere. Conserved crop residues act as a protective cover, enhancing soil moisture retention and organic matter content (Powlson et al., 2014; Busari et al., 2015).

- **Mulching**: Using crop residues as mulch is an eco-friendly way to manage them while preventing GHG emissions. Mulching involves spreading crop residues on the soil surface around the plants. It helps regulate soil temperature, conserve moisture, suppress weed growth, and enhance soil fertility by gradually releasing nutrients during decomposition. Mulching also reduces CO2 emissions by shielding the soil from direct sunlight and limiting microbial activity that leads to CO2 release (El-Beltagi et al., 2022).

- **Incorporating Crop Residues into Soil**: Incorporating crop residues into the soil as green manure or organic matter is beneficial. This approach facilitates the slow decomposition of crop residues under controlled conditions, minimising GHG

emissions. As crop residues break down, they contribute to soil carbon sequestration, promoting soil health and fertility (Lal, 2004).

- **Bioenergy Production**: Crop residues can be used as feedstock for bioenergy production through processes like anaerobic digestion or bioethanol production. By converting crop residues into biogas or biofuels, we can harness their energy potential while avoiding GHG emissions that would otherwise occur during uncontrolled decomposition (Wang, 2010; Khan et al., 2021).

- **Livestock Feed and Bedding**: Incorporating crop residues into livestock feed or using them as bedding material can effectively manage residues sustainably. When appropriately managed, crop residues provide additional value to the farm, reducing the need for synthetic inputs and decreasing the carbon footprint of animal husbandry. Residues can also be used for commercial purposes such as packaging materials and mushroom production.

Reduce Emissions from Irrigation

- **Drip Irrigation and Precision Irrigation**: Drip irrigation minimises water waste and lowers GHG emissions associated with waterlogging and runoff by delivering water directly to the root zone of plants in a controlled and effective manner. To further decrease water use and related GHG emissions, precision irrigation technologies, such as soil moisture sensors and automated irrigation systems, have the potential to optimise water application based on real-time data (Balafoutis et al., 2017; Reyes-Cabrera et al., 2016).

- **Alternate Wetting and Drying (AWD)**: AWD is a water-saving technique used in paddy fields. Instead of keeping the fields continuously flooded, AWD allows the water level to fluctuate, periodically drying the field to create aerobic conditions. This practice reduces methane emissions from the field by promoting aerobic soil conditions, which inhibit methane-producing bacteria (Sander et al., 2014).

- **Modernising and Repairing Irrigation Infrastructure**: Upgrading and maintaining irrigation infrastructure can significantly reduce water losses, reducing the need for excessive pumping and associated energy consumption. Well-maintained infrastructure ensures that water reaches crops efficiently, minimising GHG emissions related to energy use in irrigation (Levidow et al., 2014). Installing solar-powered irrigation systems, such as solar pumps and solar-powered drip irrigation, reduces reliance on fossil fuels for pumping water. By utilising clean and renewable solar energy, these systems significantly lower GHG emissions associated with conventional energy sources used in irrigation (Mekhilef et al., 2011).

- **Improved Water Management and Scheduling**: Efficient water management practices, such as scheduling irrigation based on crop needs and weather conditions, can reduce water wastage and consequently lower GHG emissions. Avoiding over-irrigation can prevent waterlogging and reduce methane emissions from waterlogged soils (Yang et al., 2012).

- **Sustainable Land Management**: Implementing sustainable land management practices, such as contour farming and agroforestry, can improve soil structure and water-holding capacity. This reduces irrigation requirements and associated GHG emissions while enhancing overall soil health and resilience (Fahad et al., 2022).

Increasing Carbon Sequestration

- **Cover Cropping**: Planting cover crops, such as legumes or grasses, during fallow periods can enhance carbon sequestration. Cover crops add organic matter to the soil, which increases soil carbon content and fosters beneficial microbial activity (Moukanni et al., 2022).

- **Agroforestry**: Incorporating trees into agricultural landscapes through agroforestry practices can significantly boost carbon sequestration. Trees capture atmospheric carbon dioxide and store it in their biomass and in the soil. Agroforestry systems also improve soil structure and nutrient cycling, further enhancing carbon sequestration.

- **Crop Rotation and Diversification**: Practicing crop rotation and diversification helps maintain continuous plant cover on the soil, leading to increased organic matter inputs and improved carbon sequestration potential. Different crops contribute different types and amounts of organic matter, enriching the soil's carbon pool (Meena et al., 2020).

- **Organic Farming**: Transitioning to organic farming practices encourages the use of organic inputs such as compost and manure, which helps enhance soil carbon. Organic farming fosters healthier and more biologically active soils, increasing carbon sequestration.

- **Soil Amendments**: Applying soil amendments like biochar or compost can improve soil structure and enhance carbon sequestration. Biochar, for example, is a stable form of carbon that can remain in the soil for centuries, thus providing long-term carbon storage (Woolf et al., 2010)

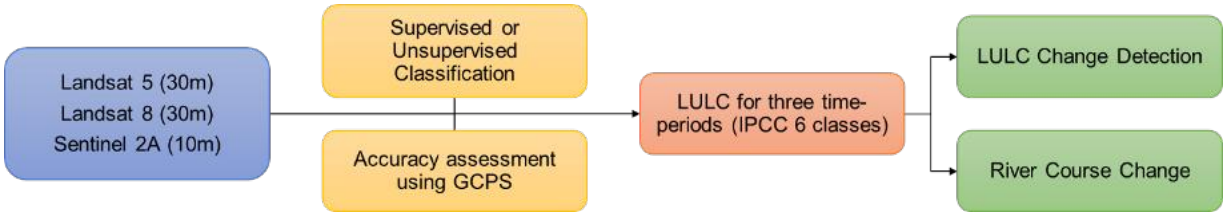
Annexure 1

Methodology: Data Gathering and Analysis through GIS and Remote Sensing

Land Use Land Cover Mapping

For this study, we have mapped land use land cover (LULC) for three time periods for the selected districts, using moderate and high-resolution images viz. Landsat 5 and/or Landsat 8 (30m resolution) as well as Sentinel 2A and 2B (10m resolution). Moderate-resolution data has been used for LULC mapping for years, where high-resolution Sentinel 2A and 2B images are unavailable. We utilised supervised classification methods for mapping LULC for the target districts; six LULC classes (Forest land, Cropland, Grassland, Wetland, Settlements, and other land) are mapped based on the IPCC Good Practice Guidance guideline for LULC classification. Training sites are chosen across the six land covers for training the classification algorithm; maximum likelihood and/or random forest classification methods are used for creating the final LULC image. These classified images are then subjected to visual adjustment, following which accuracy of the mapping of the individual LULC classes is done using ground control points (GCPs) collected in situ during field visits and/or Google Earth. User's and producer's accuracy, along with overall accuracy, is estimated for individual classes as well as the entire district. If the accuracy levels are unsatisfactory, we have refined the training sites for classification, along with further visual adjustment of the classified image, followed by re-estimation of the accuracy values. The process is reiterated until the desired level of accuracy is achieved. The following methodology is used for land use land cover and change detection.

Figure 1: Methodology for the Land Use, Land Change and Change Detection



Slope and Aspect Mapping

We have generated slope layers using Carto DEM. The resolution of this DEM is 30 m, and height (Z) values of the DEM are used for spatial averaging using an appropriate spatial filter. The output slope layer thus generated is represented in degrees. Similarly, the aspect layer is also generated from the raw DEM image.

Figure 2: Flow Diagram for Slope and Aspect Mapping



NDVI & NDWI Analysis

Normalised Difference Vegetation Index and Normalised Difference Water Index are generated for multiple time periods to indicate vegetation growth and water-related information. The following algorithm is used for generating NDVI and NDWI:

NDVI = $\frac{R_{NIR}-R_{Red}}{R_{NIR}+R_{Red}}$	**NDWI =** $\frac{R_{NIR}-R_{SWIR}}{R_{NIR}+R_{SWIR}}$

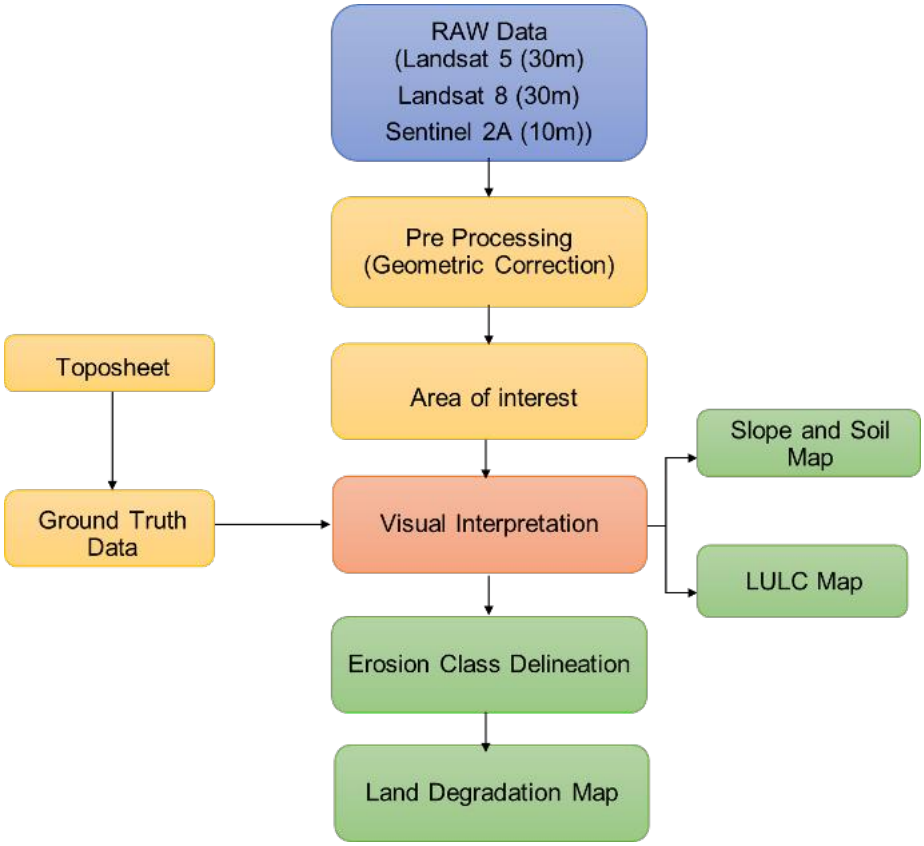
Where $R_{Red,}R_{NIR}$, and R_{SWIR} are spectral responses at the Red, Near Infrared and Shortwave Infrared wavelengths.

Normalised Difference Vegetation Index (NDVI) quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). NDVI always ranges from -1 to +1; values near 1 will reflect healthy vegetation, and as the values decrease from 1, the possibility of the pixel being of healthy vegetation will decrease. When having negative values, most likely it's water, but when NDVI is close to zero, there are likely no green leaves, and it could even be an urbanised area. NDVI is the most common index analysts use in remote sensing, especially for vegetation growth.

Land Degradation Mapping

Delineation of degraded areas is done using the Land Degradation datasets from National Remote Sensing Centre (NRSC). The degradation dataset is already available for 2015-16. Landsat (FCC) images of October-November, January and April are used. The data, therefore, represents Rabi, Kharif and Zaid seasons. The standard false colour composite (FCC) images of the study area are prepared using bands 5 (NIR), 4 (Red), and 3 (Green), and discrimination of features is made by visual interpretation (on-screen) using these images. The interpretation of key areas, based on the relationships between ground features and image elements, like texture, tone, shape, location and pattern, is done. A flowchart indicating the general procedure for Land Degradation Mapping (LDM) is shown in Figure 3. Landsat Satellite data is used for the qualitative assessment of areas subject to soil erosion. Based on the length and degree of slope from SRTM, land use / land cover and soil characteristics as revealed by Rabi, Kharif, and Zaid seasons satellite data and other related ancillary data, three soil erosion classes, namely Sheet Erosion, Gullied, and Stony Waste are mapped. Representative sample sites are selected for ground truth data collection. During field visits, features of topography and soil profiles are studied; site characteristics and soil samples are also collected for laboratory analysis. The preliminary interpreted maps are modified using field data and soil chemical analytical data; final maps are prepared with appropriate legend.

Figure 3: Flow Diagram for Generation of Land Degradation Map



Forest Cover Change Mapping

The fractional cover is estimated for the three time points using Sentinel 2A/2b and Landsat 5/8; once fractional cover images have been estimated, they are compared to detect forest cover changes across the three time periods. Fractional cover can be estimated as follows:

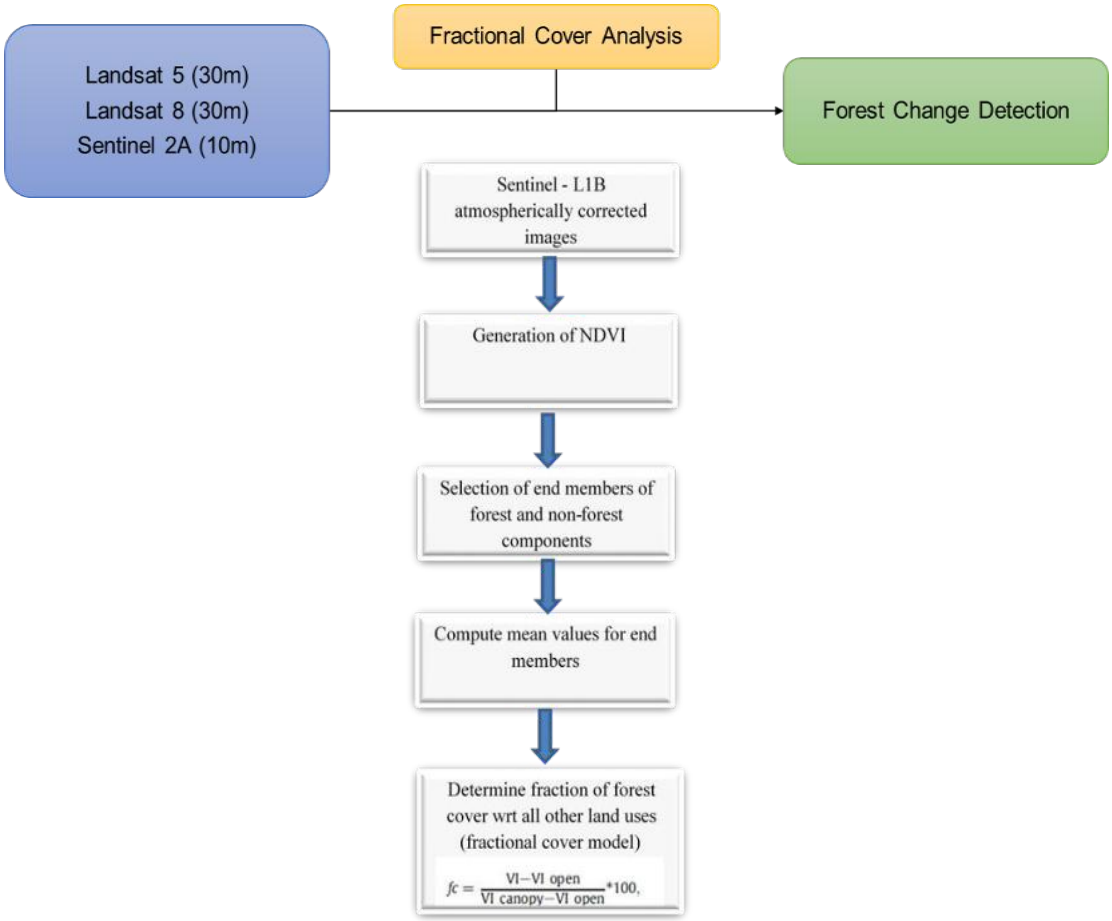
- It is mapping forest cover into different canopy density classes to quantify the changes over different time points to map the degradation in forests.
- Fractional cover refers to estimating the proportion of an area each member of a predefined set of vegetation or land cover types covers.
- It is based on Vegetation Indices (VI), which require selecting two end members, one representing close canopy forest and soil/bare ground pixels, respectively.

The two end-member linear mixture model equation is-

$$fc = \frac{\text{VI} - \text{VI open}}{\text{VI canopy} - \text{VI open}} * 100,$$

where,
fc=green fractional percentage,
VI=vegetation index value,
VI canopy=vegetation index value of the tree green canopy, and
VI open=vegetation index value of soil\open areas.

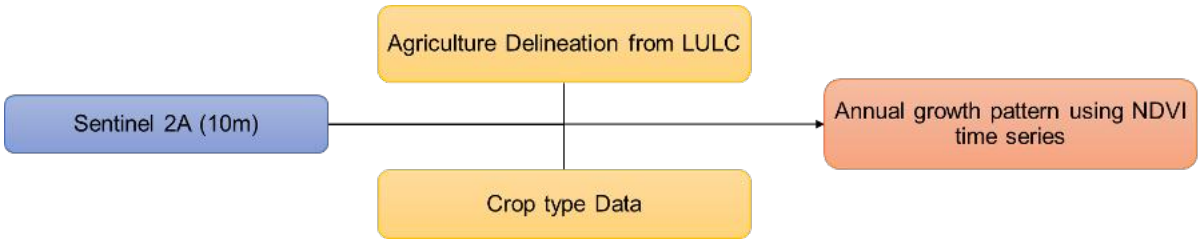
Figure 4: Methodology for Forest Change Detection Mapping



Mapping Cropping Pattern, Intensity and Growth over Seasonality

High-resolution Sentinel 2A and 2B is acquired for the current year to create a comprehensive annual time-series. The time-series Sentinel data is utilised for mapping cropping patterns for three cropping seasons (Zaid, Kharif and Rabi; images are acquired during the peak of these seasons). The mapping is conducted by combining Sentinel images with in-situ data on crop types collected during field data collection. The intensity and seasonal growth are estimated using NDVI time series generated from the Sentinel time series data.

Figure 5: Methodology for Mapping Cropping Patterns



Change in Course of Water Bodies and Enhancement of Water Table

Change in the course of water bodies is estimated by comparing LULC across three time points already generated. Water table or groundwater level information is acquired as a geospatial layer from the Central Ground Water Board (CGWB).

Annexure 2

Methodology: GHG Emissions

The GHG inventory is prepared using the internationally accepted IPCC methodology in conjunction with the IPCC Good Practice Guidance 2000 and 2003. The sectors and sub-categories considered in this study leading to GHG emissions and sequestration, along with their level of methodological tier and type of emission factors, are briefly explained in Table 1. The IPCC 2019 guidelines and other secondary literature, such as published research articles, have also been cross-referenced and used for any updates or assumptions.

Table 1: Type of Emission Factor and Level of Methodological Tier Employed for GHG Estimation

Gas / Category	CO2		CH4		N2O	
	Method used	**Emission Factor**	**Method used**	**Emission Factor**	**Method used**	**Emission Factor**
A. Enteric Fermentation	NO		T2	D, CS	NO	
B. Paddy Emissions	NO		T2	D, CS		
C. Agricultural Soils	NO		NO		T2	D, CS
D. Crop Residue Burning	NO		T2	D	T2	D
E. Irrigation	T2	SL	NO		NO	
F. Orchard Sequestration	T2	NA*	NO		NO	

T1- Tier 1; T2- Tier 2; T3- Tier 3; CS- Country Specific; D- IPCC Default; SL- Secondary Literature; NO-Not Occurring; NA- Not Applicable.

*Sequestration potential has been considered here using secondary literature.

Box 1: Tiers of Estimation

Tier-1 approach employs activity data that is relatively coarse, such as nationally or globally available estimates of deforestation rates, agricultural production statistics, and global land cover maps.

Tier-2 uses the same methodological approach as Tier 1 but applies emission factors and activity data that are defined by the country.

Tier-3 approach uses higher order methods, including models and inventory measurement systems tailored to address national circumstances, repeated over time and driven by disaggregated levels.

The type of farmers are categorised into marginal, small, semi-medium, medium and large, based on their size of landholdings (Table 2).[27]

[27] Ministry of Agriculture & Farmers Welfare, Government of India https://pib.gov.in/Pressreleaseshare.aspx?PRID=1562687

Table 2: Categorisation of Framers Based on Size of Landholding

Sl. No.	Category of Farmers	Landholding size (hectares)
1.	Marginal	Below 1
2.	Small	1-2
3.	Semi- Medium	2-4
4.	Medium	4-10
5.	Large	10 and above

Enteric Fermentation

To calculate the Emissions from a livestock category, the IPCC default equation is used (V4_chapter10: Equation 10.19):

Emissions=$EF_{(T)}.(N_T/10^6)$

Where,

Emissions = methane emissions from Enteric Fermentation, $KgCH_4\ yr^{-1}$

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of head of livestock species / category T in the country,

T = species/category of livestock,

To calculate the total emission from livestock, the IPCC default equation is used (V4_chapter10:equation 10.20):

Total emissions= $_{n=i}\sum E_i$

Where,

Total CH4 = total methane emissions from Enteric Fermentation, $tCO2e\ yr^{-1}$

E_i = is the emissions for the i^{th} livestock categories and subcategories.

Table 3: The Parameters, Data and Units Considered for Calculating Emissions from Enteric Fermentation

Parameter	Data			Units	Source
$EF_{(t)}$	**Crossbred Cattle**			kg CH_4 $head^{-1}$ yr^{-1}	NATCOM (India Second National Communication to the United Nations Framework Convention on Climate Change)
	Dairy		43		
	Non-Dairy	0–1 year	11		
		1–3 years	26		

Parameter	Data			Units	Source
		Adult	33		
	Indigenous Cattle				
	Dairy		28		
	Non-Dairy	0–1 year	9		
		1–3 years	23		
		Adult	32		
	Buffalo				
	Dairy		50		
	Non-Dairy	0–1 year	8		
		1–3 years	22		
		Adult	44		
	Sheep	Non-Dairy	5		
	Goat	Non-Dairy	5		
	Horses and Ponies	Non-Dairy	18		
	Donkeys	Non-Dairy	10		
	Camels	Non-Dairy	46		
	Pigs	Non-Dairy	1		
	Poultry	Non-Dairy	0		
$N_{(T)}$				See Annexures	Data from the field

Rice Cultivation

The area under rice cultivation collected from the field is recorded in acres. The area is then converted to hectares to have a standard unit for calculation. The total methane (CH4) emissions for paddy cultivation is calculated using the following equation.

Total Emissions (tCO_2e/ha)= A_i*EC*GWP

Where,

A_i = Area under paddy cultivation

EC= Average emissions per A_i

GWP= Global Warming Potential

The value for GWP considered for this calculation is derived from the Second Assessment Report (SAR) of IPCC, 2006.

Agricultural Soils

The total emissions associated with fertiliser use are calculated using the following equation derived from A/R methodology tool for GHG emissions calculations.

$$N_2O_{direct\text{-}N} = (F_{SN} + F_{ON}) * EF_1 * MW_{N2O} * GWP_{N2O}$$

$$F_{SN} = \sum_{I} M_{SFi} * NC_{SFi} * (1 - Frac_{SY})$$

$$F_{ON} = \sum_{J} M_{OFj,} * NC_{OFj} * (1 - Frac_{OR})$$

Where,

$N_2O_{direct-N}$ = Direct N_2O emission as a result of nitrogen application within the project boundary (t-CO2-e in year t)

I= Number of synthetic fertiliser types and J= Number of organic fertiliser types. The other parameters used to calculate emissions from fertilisers are discussed in detail (Table 4).

The percentage nitrogen content in urea, DAP, MAP and TSP is taken out from secondary literature.[28,29,30]

Table 4: Parameters, Values and Units Considered for Calculating Emissions from Fertilisers

Parameters	Values	Unit	Description	Source
M_{sy}	1	Ton/ha	Mass of synthetic fertiliser applied, tonne in year t	Given
M_{or}	0	Ton/ha	Mass of Organic fertiliser applied, tonne in year t	Given
EF	0.01	tonne-N_2O-N (t-N input)$^{-1}$	Emission Factor for emissions from N inputs	A/R Meth tool
MW_{N20}	1.571428571	tonne-N_2O (t-N)$^{-1}$	Ratio of molecular weights of N2O and N (44/28)	A/R Meth tool
GWP_{N20}	310	tCO_{2e} / tN_2O	Global warming potential of Nitrous Oxide	IPCC Default Value
$Frac_{Sy}$	0.1	fraction	Fraction that volatilises as NH3 and NOX for synthetic fertilisers (dimensionless)	A/R Meth tool

[28] https://extension.umn.edu/nitrogen/fertilizer-urea
[29] https://www.iffco.in/en/urea-fertilizer
[30] https://www.hindalco.com/our-businesses/fertilisers

Parameters	Values	Unit	Description	Source
$Frac_{Or}$	0.2	fraction	Fraction that volatilises as NH3 and NOX for organic fertilisers (dimensionless)	A/R Meth tool
F_{sn}	0.46	t-N in year t	Mass of synthetic fertiliser nitrogen applied adjusted for volatilisation as NH3 and NOX	A/R Meth tool
F_{on}	0	t-N in year t	Mass of organic fertiliser nitrogen applied adjusted for volatilisation as NH3 and NOX	A/R Meth tool
MSFi		tonne in year t	Mass of synthetic fertiliser type i applied	A/R Meth tool
MOFj		tonne in year t	Mass of organic fertiliser type j applied	A/R Meth tool
NCSFi		g-N (100 g fertiliser)$^{-1}$	Nitrogen content of synthetic fertiliser type i applied	A/R Meth tool
NCOFj		g-N (100 g fertiliser)$^{-1}$	Nitrogen content of organic fertiliser type j applied,	A/R Meth tool

Crop Residue Burning

The total residue for various agricultural crops (CR) used are collected in kilograms. The net emissions for CO2, CH4 and N2O are calculated using Global Warming Potential (GWP) provided by the IPCC, 2006 in the equations below (Table 5).

Net emissions (CH4) = ∑CR*EF*GWP

Net emissions (N2O) = ∑CR*EF*GWP

Net emissions (CO2) = ∑CR*EF*GWP

Table 5: Emissions Factor (EF) and Global Warming Potential (GWP) for Different GHGs

Gas	Emission Factor (EF)	Unit	GWP	Source
CH4	2.70	g kg^{-1}	21	IPCC-2006, Vol. 4 (AFOLU), Chapter 2
N2O	0.07	g kg^{-1}	310	
CO2	1515		1	

The total emissions (tCO2e) are calculated using the equation mentioned below.

Total Emissions (tCO2e) = [Net Emissions (CH4) + Net Emissions (N2O) + Net emissions (CO2)]/10^6

Irrigation

The calculations for this category are based on assumptions derived from secondary literature (Table 6).

Table 6: Assumptions and its Sources for Emissions Calculations for Pump Irrigation Used for Agricultural Crops

Activity	Assumptions	Sources
Irrigation	Calculation of emission are based on the data available from field, with a cumulative efficiency of 70%; assuming the pump efficiency to be 75% and motor efficiency to be 65%. Average irrigation days are calculated per crop cycle. Emissions factor for diesel pump: 2.68 kgCO2 Emissions factor for electric pump: 0.815 tCO2/MWh Emissions factor for kerosene pump: 2.5 kgCO2	Jat et al., 2006 Gautam et al., 2021 https://barringtondieselclub.co.za/technical/fuel/diesel-fuel-consumption-nat-aspirated.pdf https://irade.org/Discussion%20Paper%20Irrigation%20Sector%20-%20Assam.pdf https://cea.nic.in/wp-content/uploads/baseline/2023/01/Approved_report_emission__2021_22.pdf https://www.eib.org/attachments/lucalli/eib_project_carbon_footprint_methodologies_2023_en.pdf

To calculate total hours of pump irrigation, the data is summed up and segregated into-irrigation hours by electric pumps and irrigation hours by diesel pumps. The following equation is used to calculate per hour consumption by electric pumps.

Consumption per hour (electric pumps) = AP*T*CE

Where,

AP= Average horsepower (hp)

T= Total Count of horsepower (hp)

CE= Cumulative Efficiency of 70% at capacity

The equation used to further calculate the total emissions (tCO2e) is mentioned below.

Total Emissions (tCO2e)= (Consumption per hour* N_{ep}*EF)/1000

Where,

N_{ep}= Total of pump hours (electric pumps)

EF= Emissions factor

Similarly, for kerosene pumps the following equation is used to calculate per hour fuel consumption by kerosene pumps.

Consumption per hour (diesel pumps)= AP*T*CE

Where,

AP= Average horsepower (hp)

T= Total Count of horsepower (hp)

CE= Cumulative Efficiency of 70% at capacity

The equation used to further calculate the total emissions (tCO2e) is mentioned below.

Total Emissions (tCO2e)= (Consumption per hour* N_{dp}*EF)/1000

Where,

N_{dp}= Total pump hours (diesel pumps)

EF= Emissions factor

Orchard Sequestration

Orchard plantation leads to carbon sequestration, making it a carbon sink. In order to quantify the carbon sequestered, the Carbon Sequestration Potential (CSP) of a mixed species orchard plantation is considered from secondary literature. The value is converted to tonnes of carbon equivalent per hectare per year (tCO2e ha-1 yr-1). The data for counting the number and age of the trees are collected from the ground (Table 7). Since wood density is already taken into account in the secondary literature calculation, the same is not considered again for further calculations. The carbon sequestration potential in the referred literature is calculated for 667 trees, using which the carbon sequestration potential for one tree is also calculated. The equation used for calculation of total orchard sequestration is mentioned below.

Total Orchard Sequestration = CSP*C*A (tonnes per hectare)

Table 7: Parameters, Data, Units and Sources for Orchard Sequestration Potential Calculations

Parameter	Data	Units	Source
Carbon Sequestration Potential (CSP)	1.6	Mg C/ha/yr	Dhyani et al. (2016)
Count of trees (C)	Given	Dimensionless	Data from field
Age of Trees (A)	Given	Years	Data from field

Annexure 3

District Wise Soil Analysis

Soil Analysis is carried out in treatment and control villages in seven districts of Madhya Pradesh. Six parameters, including pH, electrical conductivity (EC), organic carbon content, and available Nitrogen, Phosphorus and Potassium of the samples, are measured. In the sections below, we present average values for each parameter in treatment and control areas across the districts to present an overview of the current situation in these areas. Further, we present detailed results in the different villages in each district to provide a more in-depth understanding of the baseline soil parameters in these areas. The data presented for each village (treatment and control) is an average of two or three soil samples collected from different areas in the village. The numbers of soil samples collected and analysed from each village are given in Table 1. When collecting samples, it is ensured that these are not collected from only one type of area in the village and are spread across regions such as uplands, medium uplands, lowlands, etc.

Table1: Number of Soil Samples Collected Across Control and Treatment Villages in MP

District	Control			Treatment			Grand Total
	No of Villages	No of Samples per Village	Total Samples	No of Villages	No of samples per Village	Total Samples	
Alirajpur	3	2	6	6	2	12	18
Ratlam	2	2	4	4	2	8	12
Jhabua	3	2	6	6	2	12	18
Burhanpur	1	2	2	2	2	4	6
Khargone	2	2	4	3	2	6	10
Khandwa	2	2 + 1	3	3	(2*2) + 1	5	8
Barwani	2	2	4	6	2	12	16
Total	15	-	29	30	-	59	88

For the Jhabua district, in the overall district-level analysis, two values account for the two agro-climatic zones in which the treatment and control villages fall (Table 2). For each of the other districts, only one value is given for treatment and control, as in these districts, all villages fall in the same agro-climatic zone.

Table 2: Agro-climatic Zones of Jhabua District and the Names Assigned in Analysis

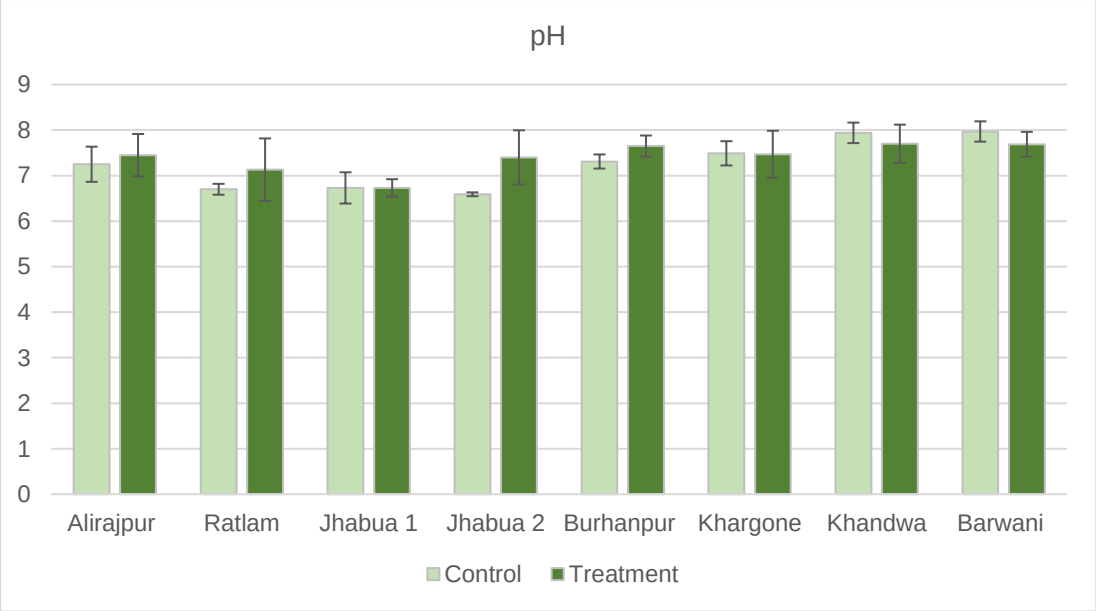
Name	Village		Agro-Climatic Zone
	Treatment	Control	
Jhabua 1	Dhamanichimna, Dhamni Nana, Amli and Sagwani	Panch Kheriya and Matasula	Jhabua Hills
Jhabua 2	Khoria and Kardawad	Unnai	Malwa Plateau

Findings and Discussions

Soil pH

Soil pH[31] is a measure of the acidity or alkalinity in soil, where a pH of 7 shows a neutral soil profile, a pH below 7 indicates acidic soil, and basic soils have pH above 7. In general, a range between 5.5 to 7.5 is considered optimal for the growth of most plants[32]. Soil pH can range anywhere from 3 to 10. The pH of soil impacts the nutrient availability and uptake, thus having a significant impact on the growth of plants while also being impacted by management practices such as irrigation and fertiliser use. Overall, the average pH levels ranged between 6.70 to 7.97 across treatment and control areas (Figure 1). While the pH in all districts in the state is within the neutral range, some variations are seen when looking at data across the villages in each district. However, these variations are slight and pH across most of the villages; both treatment and control are within acceptable limits, indicating that the soil in the region is neither acidic nor alkaline (Figure 2). There are individual samples with a pH close to 8, showing these farms to have slightly alkaline soils. Soil acidity is not seen in the soil samples across the state.

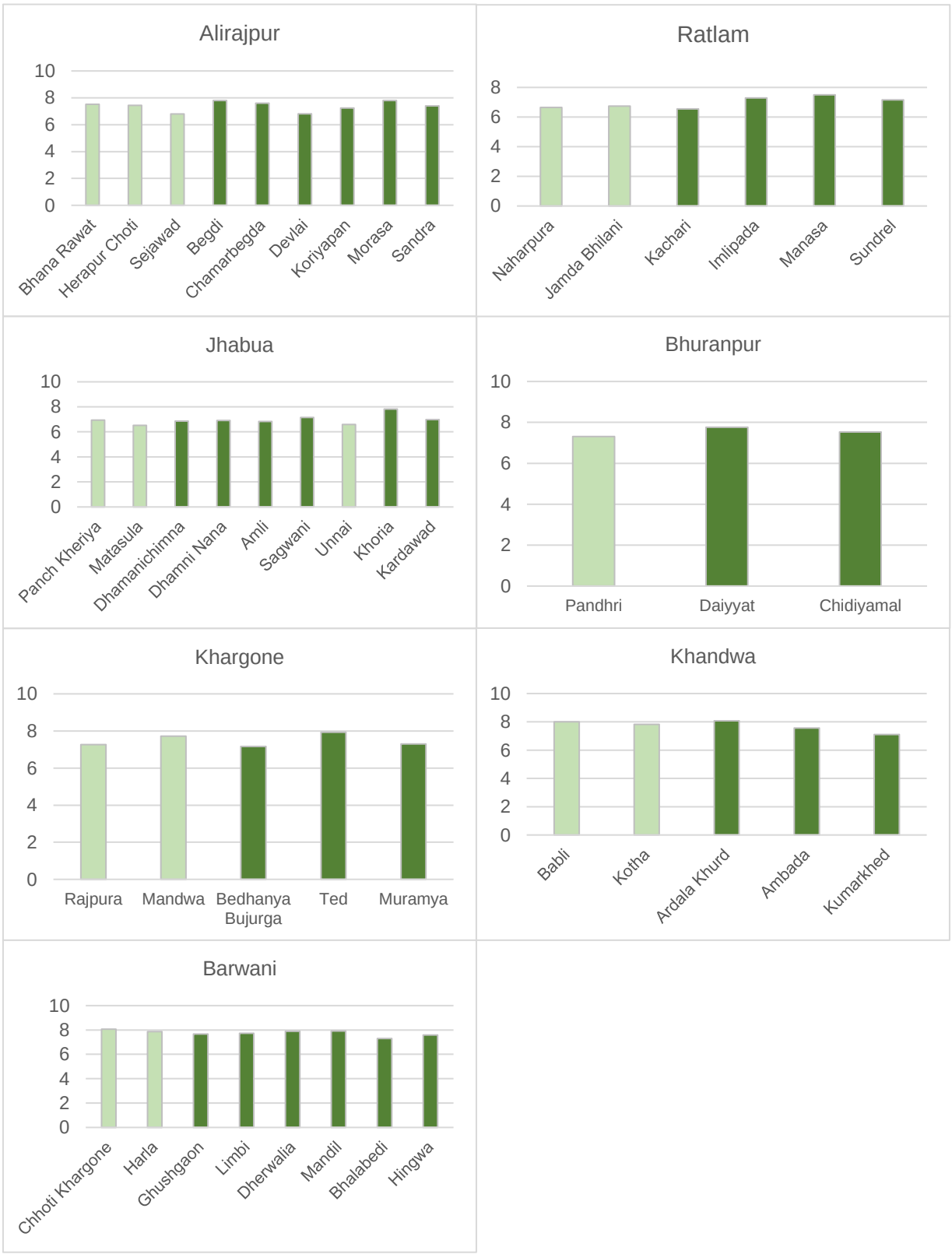
Figure 1: Average Soil pH of Treatment and Control Areas in Districts in MP



Error bars denote Standard Deviation.

[31]IOWA State University, Digital Library: https://iastate.pressbooks.pub/introsoilscience/chapter/ph-base-saturation/
[32] Soil Management and Filed Preparation by National Council of Education, Research and Training: https://ncert.nic.in/vocational/pdf/kegr105.pdf

Figure 2: Average Soil pH of Treatment and Control Areas in Districts in MP



Electrical Conductivity of Soil

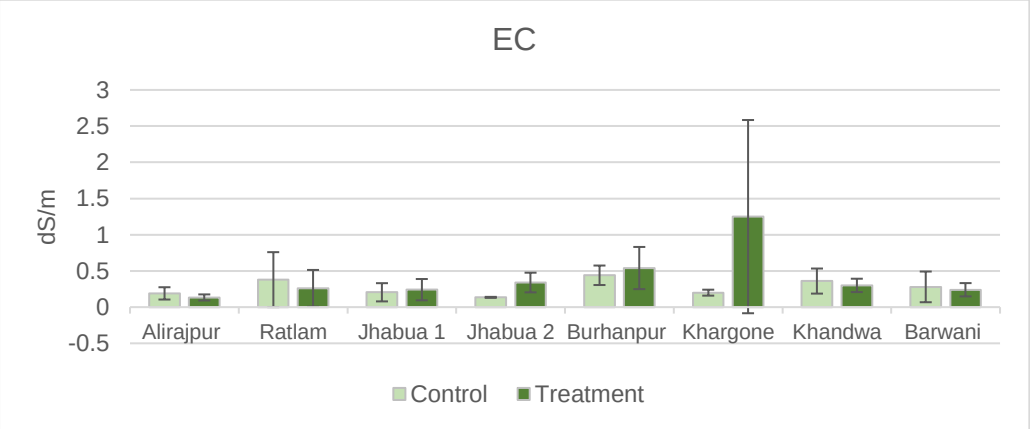
Agricultural soil's electrical conductivity (EC) is a measure of the soil water to carry electrical current and is an indirect indicator of the soil's several physical and chemical properties. The EC of soil-water mixtures indicates the salts in the soil. While it is primarily used as a measure of salinity, it can also be used as an indicator of soil moisture levels in non-saline soils. The Final Corrected Manual on Soil Testing by the Ministry of Agriculture classifies soils as salt-free when EC ranges between 0-2 decisiemens per metre (dS/m) (Table 3).

Table 3: Critical Limits for EC of Soil[33]

Parameter	Unit	Range	Interpretation	Crop Growth
EC	dS/m	0-2	salt free	No effects on crop growth except on some sensitive plants such as *beans and carrots*
		2-4	slightly saline	Yields of some crops such as *onions, bell peppers* impacted
		4-8	weakly saline	Yields of many crops such as *cotton and cereals* impacted
		8-15	moderately saline	Tolerant crops are able to main productivity – *potato and broccoli*
		>15	highly saline	Only very tolerant plants are able to grow – salt tolerant grasses, herbaceous plants, certain shrubs and trees

The average EC values in MP ranged between 0.19 to 0.64 dS/m across control and treatment villages. However, significant variations are seen in the samples in different villages. As seen in Figure 3, the control area data from Ratlam and treatment area data from Khargone show a wide range. In Ratlam, one control sample from Naharpura (upland) has EC of 0.95 dS/m, and in Khargone, three treatment samples show high EC content – Bedhanya Bujurga (medium) 2.6 dS/m, Bedhanya Bujurga (medium upland) 1.09 dS/m, and Ted (upland) 3.2 dS/m. (Figure 3). In Alirajpur, one treatment sample, Devlai (middle), has an EC value of 6.19 dS/m. Given that this data point is an outlier, it is not included in the analysis presented in the graphs below. On average, it is seen that both treatment and control areas have salt-free soils, with some samples showing slight salinity. However, only one sample in some villages (treatment and control) shows salinity, with the rest having low ES values, indicating that the soils of these areas are salt-free.

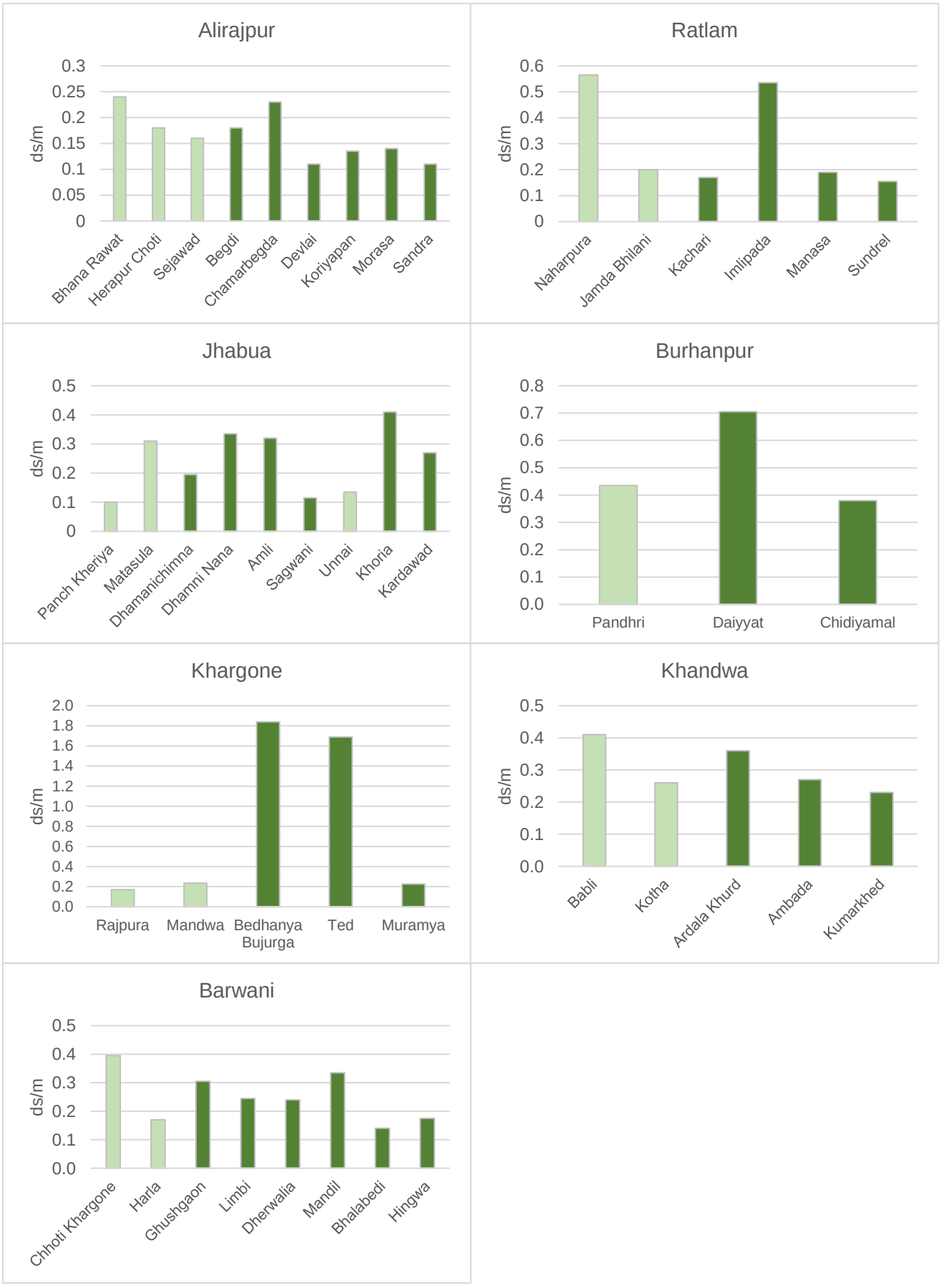
Figure 3: Average EC (dS/m) of Treatment and Control Areas in Districts in MP



Error bars denote standard deviation.

[33] Final Corrected Manual on Soil Testing, Ministry of Agriculture: https://agriculture.uk.gov.in/files/Soil_Testing_Method_by_Govt_of_India.pdf

Figure 4: Average EC (dS/m) Across Control (light green) and Treatment (dark green) Villages in Different Districts in MP



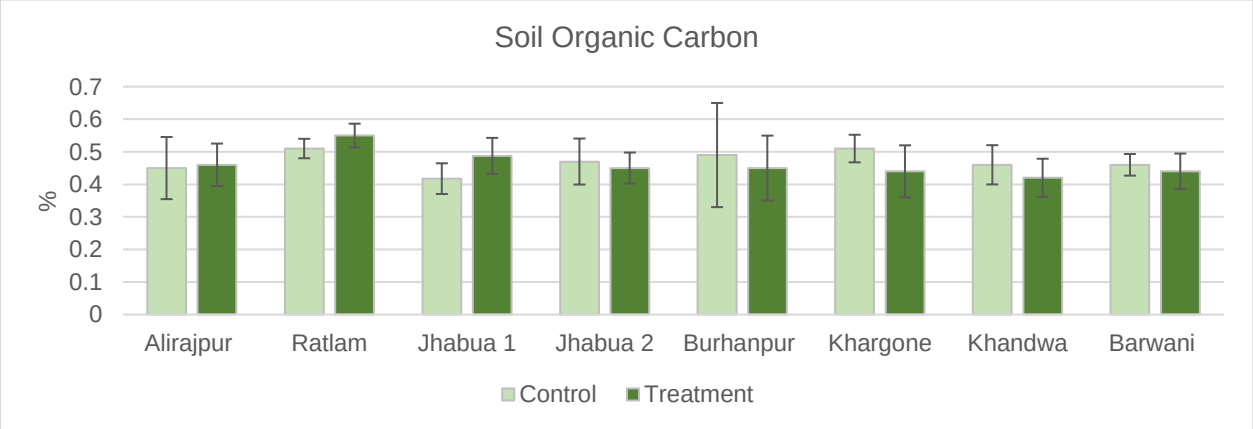
Soil Organic Carbon

Soil organic carbon (SOC), the largest carbon pool in the terrestrial biosphere, is a crucial component of the global carbon cycle. It is estimated that SOC pools store 1500 PgC (Petagrams of carbon) in the top one meter of soil, which is more than carbon stored in the atmosphere (800 PgC) or vegetation (500 PgC).[34] This is not a static reservoir but is constantly cycling between different pools. SOC is the principal constituent of soil organic matter, which is critical in soil productivity and a wide array of ecosystem processes. Soil organic matter contains about 55-60% carbon by mass. In most soils, there is a carbon stock with small amounts of inorganic carbon. Though organic matter makes up just 2-10% of most soil's mass, it has an important role in the physical, chemical, and biological functions of agricultural soil, including their water retention capacity and structural stability. Organic matter also contributes to nutrient retention and turnover, degradation of pollutants, carbon sequestration and soil resilience.

The amount of SOC present in the soil is dependent on the balance between the amount of carbon entering the soil and the amount leaving it through carbon-based respiration gasses released by microbial mineralisation. Carbon is also lost from soil due to erosion and gained through re-deposition; thus, its levels can be controlled and increased by managing the amount and type of organic residues added to soil. While the agricultural sector can impact the carbon cycle on a large scale, often through unsustainable management practices that release carbon, farmers have a vested interest in retaining and increasing SOC as both soil quality and yield tend to improve when SOC levels rise. Higher SOC results in improved soil aeration, water drainage and retention, stabilises pH levels and reduces the risk of erosion and nutrient leaching. If the soil has lower than 0.5% of organic carbon, it is considered poor-quality soil; between 0.5 to 0.75%, it is considered medium quality, and if it is above 0.75%, the soil is considered high-quality soil.[35] In India, it is estimated that, on average SOC content has gone down from 1 to 0.3% in the past 70 years.[36]

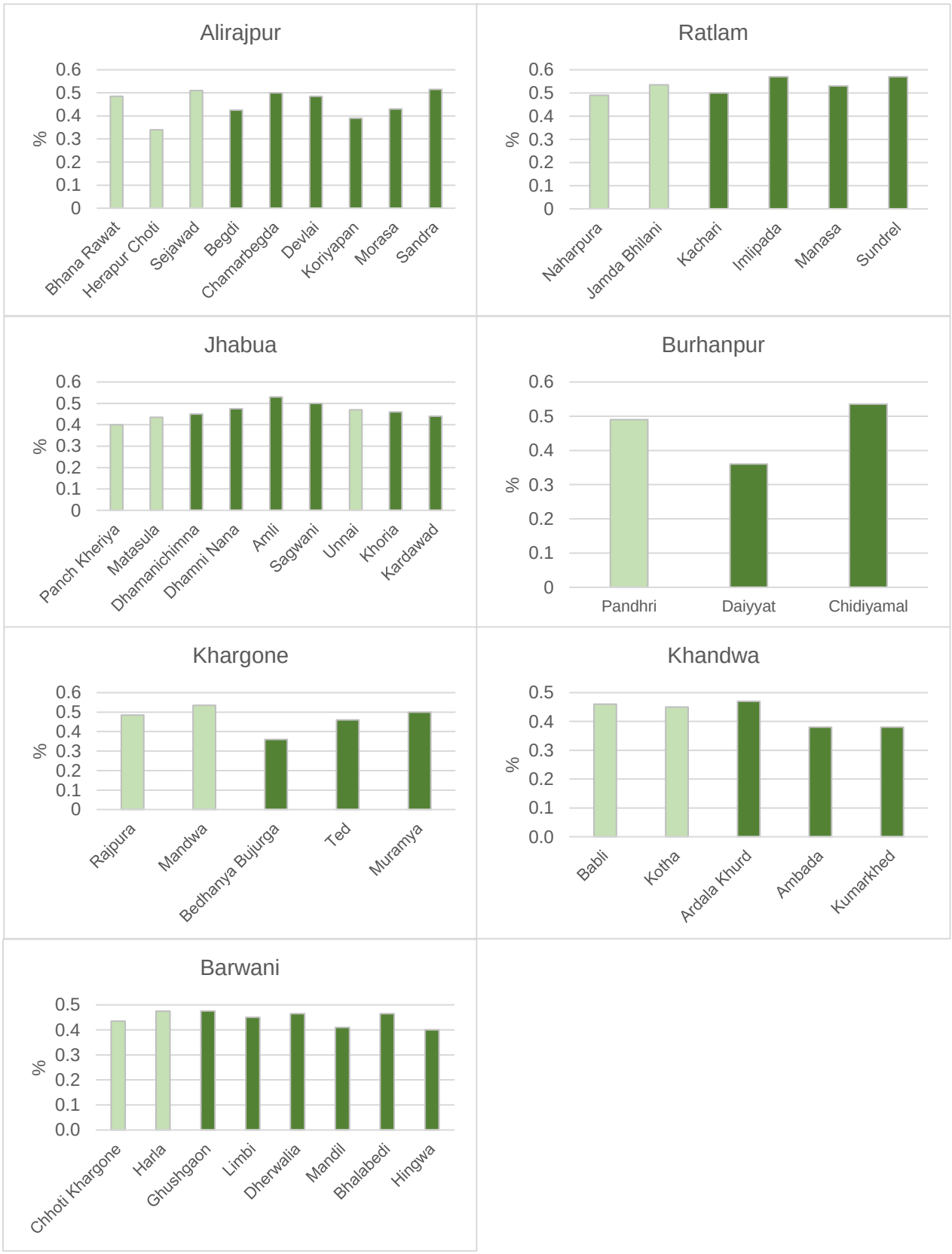
In MP (including both the treatment and control areas), the average soil organic carbon percentage is between 0.42 and 0.55% (Figure 4); only moderate variation is seen within the districts. These levels indicate that SOC in these regions is not very high, and the soil quality is medium. Significant variations are not observed in the state when looking at the SOC in different villages across districts. The highest value of 0.6% SOC is seen in one sample in Ratlam district – Sundrel (treatment, and one sample in Burhanpur district – Pandhri (control) (Figure 5).

Figure 5: Average SOC (%) of Treatment and Control Areas in Districts in MP



[34] FAO, Soil Organic Carbon: the hidden potential. Food and Agriculture Organisation of the United Nations Rome, Italy: https://www.fao.org/3/i6937e/i6937e.pdf
[35] Tamil Nadu Agriculture University Soil Rating Chart: https://agritech.tnau.ac.in/agriculture/agri_soil_soilratingchart.html
[36] Soil organic carbon content fell from 1% to 0.3% in 70 years in India: NRAA: https://www.business-standard.com/article/current-affairs/soil-organic-carbon-content-fell-from-1-to-0-3-in-70-years-in-india-nraa-122032600305_1.html

Figure 6: Average SOC (%) Across Control (light green) and Treatment (dark green) Villages in Different Districts in MP



Available Nitrogen, Phosphate and Potassium

Nitrogen, Phosphorus, and Potassium are considered the primary macronutrients essential for plant growth but can also be limiting factors for growth in cultivation systems. While these three work together, they each have specific roles for a plant and must be readily available. Nitrogen is a key component of amino acids, which form the building blocks of plant proteins and enzymes, and it constitutes 2-4% of plant dry matter. It plays a critical role within the plant to ensure energy is available when and where it needs it. Nitrogen is also a chlorophyll molecule component, enabling the plant to capture energy through photosynthesis, driving plant growth and yield. This crucial nutrient is even present in the roots where proteins and enzymes help regulate water and nutrient uptake.[37] Phosphorus is also one of the major plant nutrients present in soil. It is a constituent of plant cells, required for cell division and development of the growing tip of the plant, playing an essential role in seedling vigour and growth of young plants. Potassium is essential in nearly all processes needed to sustain plant growth and reproduction. Plants deficient in potassium are less resistant to drought, excess water, and high and low temperatures. They are also less resistant to pest and disease attacks. Potassium affects quality factors such as size, shape, colour and vigour of the seed and grain and improves the fibre quality of cotton. The amount of available potassium also impacts the nitrogen uptake by plants, and a plant's response to applied nitrogen decreases if the amount of potassium in the soil is below a critical level. The table below shows the amounts of Nitrogen, Potash and Phosphorus in soil that determine its fertility (Table 4).

Table 4: Fertility of Soil Based on Nutrient Availability[19]

Nutrients	Low	Medium	High
Available N as per alkaline permanganate method (kg/ha)	<280	280-560	>560
Available P by Olsen's method (kg/ha)	<10	10-24.6	>24.6
Available K by Neutral N, ammonia acetate method (kg/ha)	<108	108-280	>280

According to the 29th Report on the Impact of Chemical Fertilisers and Pesticides on Agriculture and Allied Sectors in the Country[38], usage of NPK has shown an increasing trend across most of the country. Table 5 shows that while in MP, consumption has increased from 2011 to 2014.

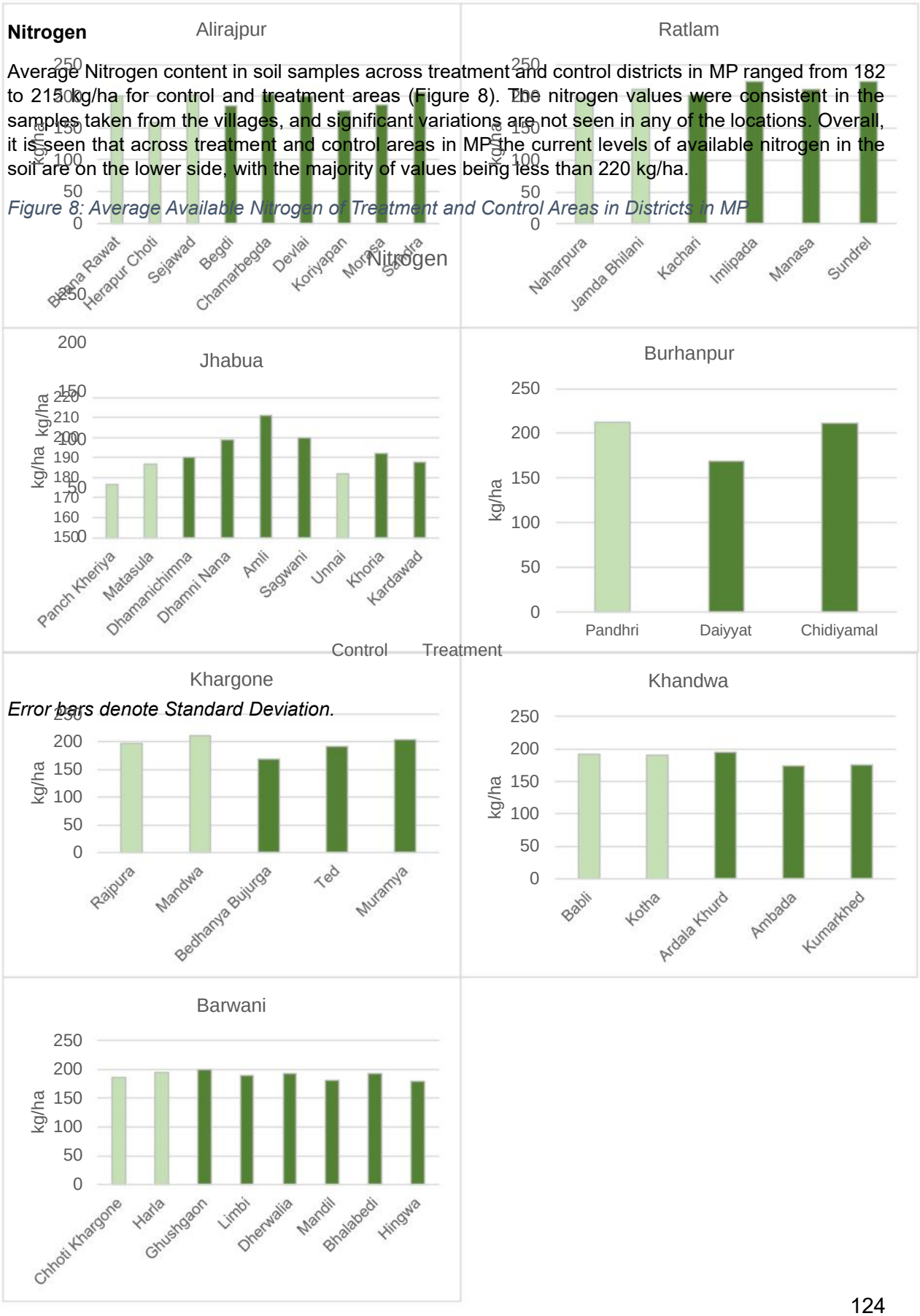
Table 5: NPK Consumption ('000 tonnes) Trends in MP[24]

States	2011-2012	2012-2013	2013-2014
Madhya Pradesh	1,892	1,869	1,901

An NPK ratio of 4:2:1 is generally considered ideal and accepted for macro-level monitoring of consumption of plant nutrients.[39] Imbalance of NPK in soil impacts plant growth as well as results in greenhouse gas (GHG) emissions due to the overuse of nitrogenous fertilisers and leads to increased pollution in water bodies due to run off. Studies show that the NPK ratio in 2014-15 in MP is 15.5:8.4:1, which is imbalanced and requires intervention.

[37] Final Corrected Manual on Soil Testing, Ministry of Agriculture: https://agriculture.uk.gov.in/files/Soil_Testing_Method_by_Govt_of_India.pdf
[38] 29th Report on Impact of Chemical Fertilisers and Pesticides on Agriculture and Allied Sectors in the Country: https://eparlib.nic.in/bitstream/123456789/64994/1/16_Agriculture_29.pdf
[39] National Academy of Agricultural Sciences: https://naas.org.in/Policy%20Papers/policy%2042.pdf.

Figure 7: Average Available Nitrogen in Control and Treatment Villages of Different Districts



Nitrogen

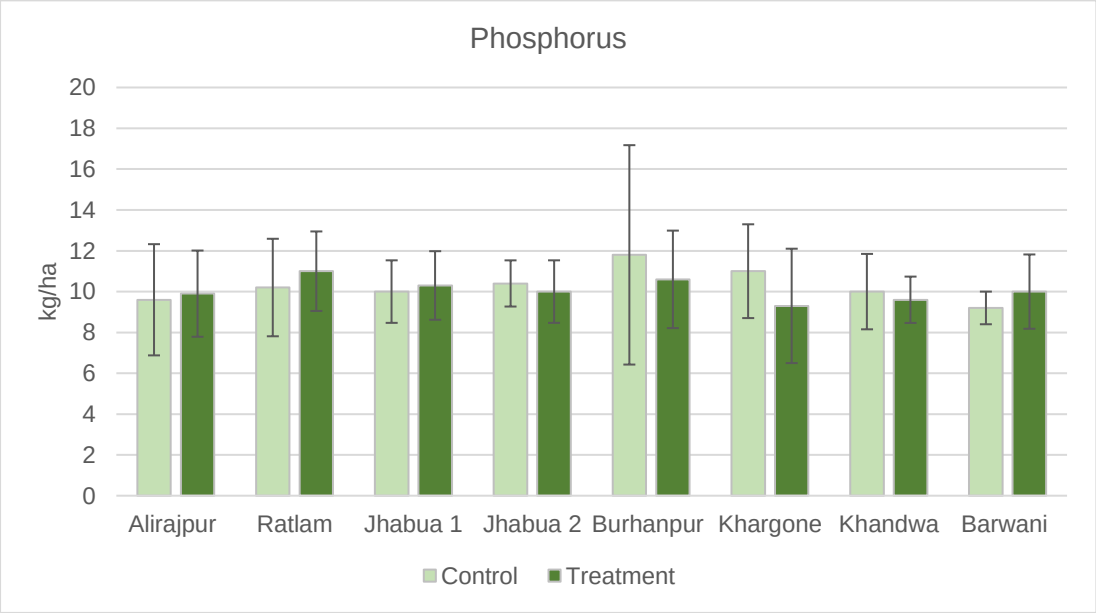
Average Nitrogen content in soil samples across treatment and control districts in MP ranged from 182 to 215 kg/ha for control and treatment areas (Figure 8). The nitrogen values were consistent in the samples taken from the villages, and significant variations are not seen in any of the locations. Overall, it is seen that across treatment and control areas in MP the current levels of available nitrogen in the soil are on the lower side, with the majority of values being less than 220 kg/ha.

Figure 8: Average Available Nitrogen of Treatment and Control Areas in Districts in MP

Phosphorus

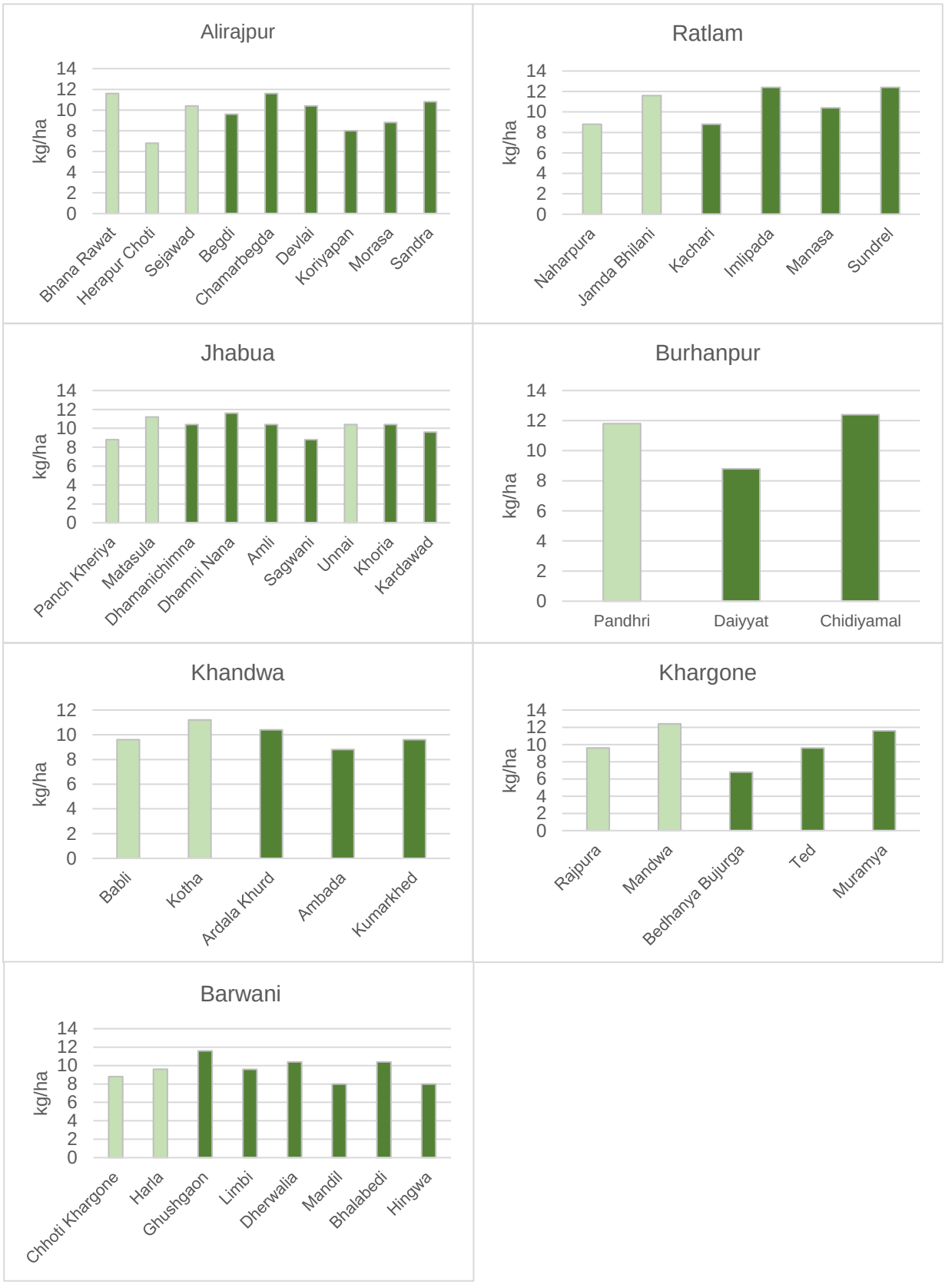
Average Phosphorus content in the soil samples from MP ranged from 9.3 to 11.8 kg/ha in controlled and treatment areas. While some variations are seen in the phosphorus content amongst the different samples, the majority of the areas tested showed phosphorus content lower than 15 kg/ha, with a large proportion of these having values lower than 10 kg/ha (Figure 9). Only one sample in MP in Burahanpur district had a value higher than this – 15.6 kg/ha in Pandhri (control). These results show that the phosphorus content of soils in treatment and control areas is on the lower side, with some areas showing it marginally in the medium range.

Figure 9: Average Available Phosphorus of Treatment and Control Areas in Districts in MP



Error bars denote Standard Deviation

Figure 10: Average Soil Phosphorus Across Control (light green) and Treatment (dark green) Villages in Different Districts in MP

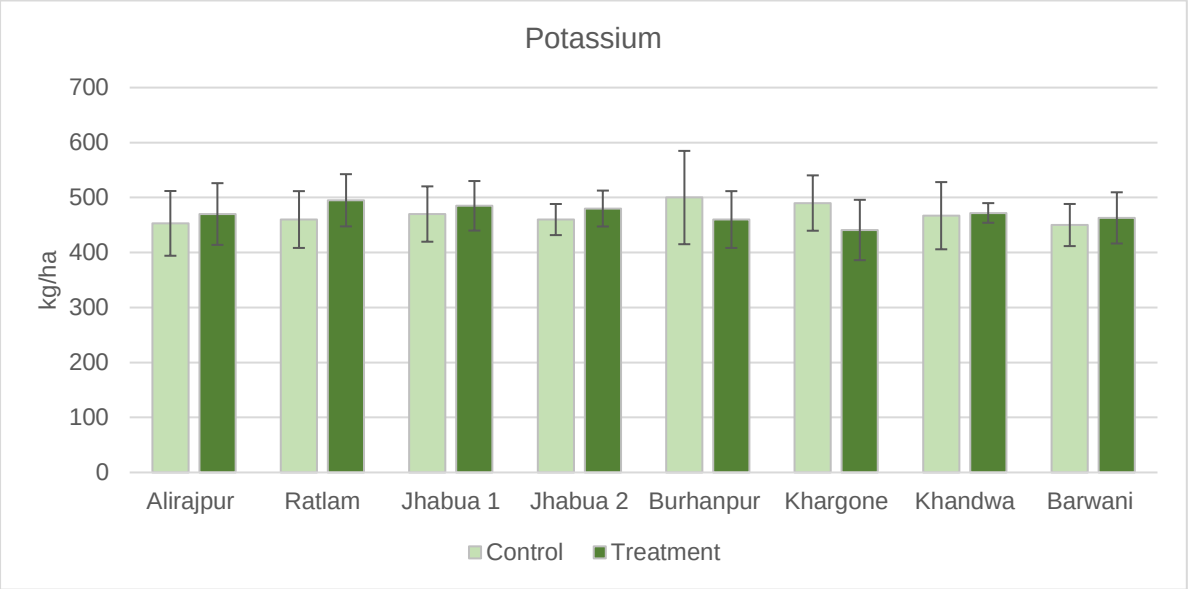


Potassium

Average Potassium content in soil samples from MP ranges from 450 to 500 kg/ha in control and treatment areas (Figure 17). Large variations in the potassium content are not seen in majority of the samples in different treatment or control villages selected in the state. Only one sample in Burahanpur district had a higher than average value at 560 kg/ha (Figure 17) – Pandhri (control) – this is the same sample that also showed higher than average phosphorus levels, along with slightly higher nitrogen level (230 kg/ha) compared to other samples in the district.

Overall, the potassium levels in all soil samples across control and treatment areas are in the higher range. This is the only macronutrient tested that is present in high quantities. As mentioned above, a critical level of available potassium is necessary for the uptake of nitrogen by plants. The presence of these high potassium levels indicates that applying natural or bio-fertilisers that increase nitrogen in soils will help improve plant growth, as the high potassium level will aid its uptake.

Figure 11: Average Soil Potassium of Treatment and Control Areas in Districts in MP



Error bars denote Standard Deviation.

Figure 12: Average Available Potassium Across Control (light green) and Treatment (dark green) Villages in Different Districts in Madhya Pradesh

