Baseline Study for Regenerative Production Landscape in Chhindwara District of Madhya Pradesh

Technical Report

submitted to the

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Contact:
Alvin Poncin
Chief of Staff
Head, Portfolio Development and Management Office
Telephone: +63 (2) 8 580-5600; Fax: +63 (2) 8 580-5699
E-mail address: ipmo@irri.org
Courier address: International Rice Research Institute, University of the Philippines Los Baños Campus, Los Baños, Laguna, 4031 Philippines

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Executive summary

Baseline Study for Regenerative Production Landscape in Chhindwara District of Madhya Pradesh (MP)

To foster the transition towards Regenerative Agriculture (RA) in the identified compact site, IDH Sustainable Trade Initiative commissioned IRRI to conduct a baseline to identify the present status as benchmarks and derive the indicators and drivers for customization of RA practices by need-based assessment of the community. The partnership focused to develop a baseline of Soil health, Greenhouse Gases (GHGs), land use, and household (HH) survey to complement the data collected via focus groups and socio-economic indicators from two (2) blocks in the Chhindwara District, MP, India. The baseline is aimed to further identify suitable practices and interventions with high potential to mitigate GHGs emissions, improve soil health, regenerate the landscape through improved ecosystem services and increase household incomes.

Baseline Methods:

This report summarises the results of the baseline carried out in the Mohkhed and Sausar blocks of Chhindwara District, Madhya Pradesh. The aim of the baseline is to identify the starting point of the interventions for the target groups, so Regenerative Production Landscape Collaborative (RPLC) can further improve the program strategies.. The findings from the baseline provide us with the basis for developing a framework that works for people, nature and the economy. The present baseline evaluation design was set up across three (3) blocks (2 treatment blocks, 1 control block) of district Chhindwara, with one (1) treatment arm and one (1) control arm across three (3) groups of villages based on the area under irrigation. The 51 villages covered were located across the district Chhindwara, MP. Chhindwara Landscapes diagnostics analysis was completed using comprehensive and complementary approaches, i.e., household surveys (quantitative and qualitative), GIS & remote sensing and high-tech laboratory soil assessment. In all, 1,020 farmers are covered for the baseline. Representative soil samples were collected from the crop (400 points) and Forest land (30 points) of Mohkhed and Sausar blocks of Chhindwara District, MP at two (2) soil depths (0-15 cm & 15-30 cm) covering different land use, following stratified soil sampling procedures. Along with the HH survey and soil sample, the high resolution (5.6 meters) satellite images (Resources at 1 & 2, LISS-IV) are procured for the land use land cover classification for the treatment blocks where Regenerative production practices will be promoted.

Baseline Results:

Farm & Farm characteristics

Agriculture is the mainstay of much of the population (~92%) in the landscape and is dominated by crops like cotton, wheat, maize, vegetables, and soybean. Most the farmers integrate crop production with livestock. However, the existing unsustainable agriculture commodities production and ecosystem management system requires a systemic transformation if we must improve the small-scale producer yields and incomes, poverty, gender disparities and social inclusion, biodiversity conservation and ecosystem protection, and local governance, among others.

Greenhouse gas emissions

Agriculture is a significant contributor to the GHGs emissions in developing and developed countries, and the share will continue to increase if mitigation efforts are not applied. Improving the understanding and fostering of large-scale RA adoption requires soil quality monitoring systems that integrate farmers' and researchers' knowledge. Robust data on greenhouse gas emissions and reductions and practical methods for monitoring, reporting and verification (MRV) are required to transition to low emissions regenerative system development in agriculture. The

emissions also vary in Kharif and Rabi/Boro seasons, and different mitigation strategies need to be applied accordingly. The SOC stocks (0-30 cm) varied among the villages and ranged from 13-35 Mg C/ha in the Northern region (Mohkhed) and 7-13 Mg C/ha in the Southern region (Sausar).

Soil Health & water use efficiency

There was a considerable variation in the soil health parameters across the region. The differences observed could be due to variations in organic matter input, topography, vegetation composition, soil bulk density, soil moisture and soil depth. Sausar block soils seem to be more degraded than soils in the Mokhed block and need higher interventions to reverse degradation. The carbon stock map explains the spatial variability of carbon in the soil. The forest areas have higher carbon content, whereas areas of agriculture have variable carbon content, with Mohkhed in the north having slightly higher carbon content than the southern part of the study. Farmers' crop yield was significantly correlated (p-value <0.01) with soil organic carbon (SOC) stock at lower soil depth. Less frequent disturbance at 15-30 cm soil depth may have resulted in a significant correlation. The farmers' crop yield increases by 18.61 kg/acre with every point increase in SOC stock (15 to 30 cm depth). The regression analysis demonstrates that farmers with proper irrigation facilities get a higher yield than farmers who cultivate in rainfed conditions. The data also demonstrate the yield advantages of 129 kg/acre for farmers adopting regenerative-integrated nutrient management with both chemical and organic fertilizer to those using only chemical fertilizers. The data showed a scope to improve the soil health of both the landscapes through regenerative practices that enhance crop productivity while improving environmental sustainability. The water use efficiency (WUE) of key crops in the landscape was comparatively low as per the previously reported studies.

Change in Land use land cover

The Land Use / Land Cover (LULC) maps generated for the study region have revealed a significant increase in the Dense vegetation (6.6%), Sparse vegetation/ tree cover (6.5%), mainly showing the transition of the shrublands to sparse and dense vegetation where the cropland has decreased by -4.6 % in last ten years. The trend observed in the wastelands (-3.3%) and shrublands (-5.8 %) has declined drastically, showing the expansion of other classes like tree cover, grasslands, sand/mining and settlements in the region. In Kharif (monsoon cropping season), the Sausar showed 8.65% higher total GHG emissions than Northern region, but during Rabi (winter cropping season), the scenario was reversed. During Rabi, 58.7% higher total GHG emission was recorded in Mokhed compared to the Sausar region. Fire incidents after the Rabi harvest was relatively higher and increased over time. The higher number of fires after Rabi could be attributed to farmers' willingness to clear fields early for short term crops after Rabi when soil moisture is still optimum.

Results of household survey

The household survey data showed that most farmers in the Sausar block (94%) cultivate cotton in Kharif, and none of the farmers in the Mokhed block has engaged in cotton cultivation. Most of the plots have black soil in the Mokhed block, but a sizable proportion (approx. 36-40% amongst the first three (3) plots) also has red soil; the proportion of sandy soil is negligible. However, in the Sausar block, between 15-22 per cent of the plots (based on the first three (3) plots) have sandy soil. Consequently, the proportion of farmers having black or red soil is comparatively lower than those in Mokhed. The use of chemical fertilizer is high across the region (more than 95 per cent of farmers), mainly involving Urea and diammonium phosphate (DAP). The application rate of single superphoshate (SSP) is substantially higher for the Cotton crop in Sausar (80% farmers). Farmers in the both blocks use herbicides, but insecticide use is much higher in the cotton-growing belt though farmers' incomes are substantially higher. In Sausar, the proportion of farmers undertaking any biodiversity activities is much lower than that

in Mokhed, with just 15-22 per cent of the small, medium and large farmers reporting such activities. In Sausar, a much higher proportion of farmers reported floods than those in Mokhed. However, pest & disease infestation problem is more pronounced across the regions. Fifteen per cent of the large farmers have also reported acidity in the soil as a stress event they have suffered in the past five (5) years, indicating a pressing need for interventions to mitigate and adapt to climate change.

In contrast to Mokhed, the trend is different in decision making and implementation in Sausar. First, a substantially higher proportion of farmers reported that both men and women were involved in most of the decisions. Second, women also participate a lot in the decision about Post-Harvest Activities (Cleaning, Drying, Etc), which is the decision that women are most likely to involve significantly. Notably, women show only modest levels of participation in the selection of crops and varieties, Use of fertilizer, use of pesticides, and other agricultural-related and income activities. The man head of household entirely controls the selection of crops and varieties about half the time. A deeper understanding of the dynamics and efforts needed to support gender equity will help to develop a better plan of action.

The LULC maps generated for the study region have revealed a significant increase in the Dense vegetation (6.6%), Sparse vegetation/ tree cover (6.5%) showing mostly the transition of the shrublands to sparse and dense vegetation where the cropland has decreased by -4.6 % in last 10 years. Cotton, maize, wheat, soyabean, the major crops grown in the region also have the highest GHG emissions. Conventional tillage coupled with excessive fertilizer input leads to higher GHG emissions. The data on fire incidents has been derived from NASA's Fire Information for Resource Information System (FIRMS). Fire incidents after Kharif although the incidents increased over the years. Fire incidents after the Rabi harvest were relatively higher and increased over time. Straw burning incidence or practices is higher than reported in the HH survey, as observed during qualitative exercise. Farmers use high fertilizers (mainly Urea and DAP) and pesticides use is also high.

Baseline recommendations

This baseline shows that there are several farming practices to improve upon and plenty of service gaps to be filled. Soils found on compact site are generally poor to moderate. This may mean that a focus on improving soil health alone would not be sufficient to make notable improvements to farmer income. Income improvements will require a more holistic approach of farm diversification and sustainable intensification, in which good farming practices and the use of organic and inorganic inputs needs to be combined in such way that they increase farm profitability while maintaining soil health in the long-term. Such a strategy can promote both farmer livelihoods and food security.

Production Pillar

High crop yield gaps, poor cropping intensities, high cost of cultivations low diversification and low adoption of improved practices were observed in the cropping systems of the landscape. Under this pillar, based on the results of baseline there is a need to improve the land use planning, increase cropping intensity sustainably through intensification of fallow areas, increase irrigation facilities, improve crop productivity through introduction of improved crop varieties and crop management practices. Improvement in resource use efficiencies and optimization of crop calendar can help in boosting yield. Introduction of agroforestry and silvi-pastoral systems in participatory models can help to increase farm and household incomes.

Protection Pillar

Soils in the landscape were generally poor to moderate with reference to availability of primary nutrients but the soil organic carbon was predominantly low. Adoption of sustainable and regenerative management practices can help restore soil health, rejuvenate water resources and reduce carbon footprints. Practices like integrated nutrient management, residue management, agroforestry systems, reduced tillage can help restore soil build organic carbon and improve overall soil ecosystem services. These practices can be encouraged through on-farm demonstrations in collaboration with technical institutes.

Introduction of micro- irrigation systems and better water management practices can help increase water use efficiency in the landscape. Utilizing government schemes and subsidies for these intervention can catalyse the process. Greenhouse gas emission can be reduced through optimum fertilizer management and using renewable sources of energy in farms. These paired with agroforestry systems can help with carbon sequestration. Evidence hubs cum demonstrations on regenerative and sustainable production farm practices can increase adoption of sustainable systems. Introduction of on-site bio-input units, machineries for zero tillage and residue management along with biochar production units can encourage farmers to adopt regeneration practices.

Inclusion Pillar

For increasing net incomes of farming households, there is a need to develop equitable access to optimal resources and encourage inclusion. Increasing system productivity diversifying sources of incomes and decreasing input costs, access to input-output markets can promote overall households incomes and gender diversity.

Acronyms

AE: Agri-entrepreneur
AEGF: Agri Entrepreneur Growth Foundation
AWD: Alternate Wetting and Drying
CAN: Calcium Ammonium Nitrate
CAPI: Computer Assisted Personal Interview
CCAFS: Climate change, agriculture and food security
CEC: Cation exchange capacity
CFT: Cool Farm Tool
CGIAR: Consortium of International Agricultural Research Centers
CH_4: Methane
CO_2: Carbon dioxide
CSO: Community Social Organisation
DAP: Diammonium Phosphate
DG: Discussion Guidelines
FIRMS: Fire Information for Resource Information System
FPO: Farmer Produce Organisation
FYM: Farmyard Manure
GHGs: Greenhouse Gases
GT: Ground-truthing
HH: Households
IDI: In Depth Interviews
IPCC: Intergovernmental panel on Climate Change
IRRI: International Rice Research Institute
IRRI: International Rice Research Institute
LISS: Linear Imaging and Self Scanning Sensors
LST: Land Surface Temperature
MGNREGA: Mahatma Gandhi National Rural Employment Guarantee Act
MOT: Mitigation option tool
MRV: Monitoring, Reporting and Verification (MRV)
N_2O: Nitrous oxide
NDVI: Normalized Difference Vegetation Index
NDWI: Normalized Difference Water Index
NGO: Non-Governmental Organisation
NIs: Nitrification Inhibitors
NRLM: National Rural Livelihood
NRSC: National Remote Sensing Centre
PCFs: Polymer Coatings
PPI: Production Protection Inclusion
PSU: Primary Sampling Unit
RPL: People, Nature Economy
RPLC: Regenerative Production Landscape Collaborative
SCS: Soil carbon sequestration
SD: Standard Deviation
SDG: Sustainable Development Goal
SECTOR: Source-selective and Emission-adjusted GHG Calculator for Cropland
SHG: Self Help Group
SOC: Soil organic carbon
UIs: Urease Inhibitors
UNFCCC: United Nations Framework Convention on Climate Change
WUE: Water use efficiency

1. Background

Sustainability of contrasting agro ecologies of landscapes is threatened by multifaceted challenges offered by climate change and food insecurity. The global food production system is grappling with a wide variety of ills, from hunger, poverty and obesity; to industrial farming, over-dependence on chemical fertilizer and pesticides, poor quality (if not unsafe) food, environmental degradation, biodiversity loss, exploitative labour relations and animal welfare; to corporate dominance and a lack of resilience. In addition, greenhouse gas emissions and soil degradation compound the negative impacts of climate change on livelihood security. To address these challenges a paradigm shift from conventional agriculture to regenerative agriculture needs to be adopted holistically to reap the benefits of landscapes.

Food and agriculture are critical to the achievement of the 2030 Agenda for Sustainable Development (SDG) ranging from goals to ending poverty and hunger (SDG1 & SDG2), addressing climate change (SDG11) and sustaining natural resources. Failure to rapidly progress in reducing and eliminating hunger and malnutrition by 2030 adversely affects the prospects of achieving other SDGs. Similarly, progress in other SDGs provides a platform for ending hunger and extreme poverty.

The challenges of increasing world population, global climate change, shortages of irrigation water, and degradation of agricultural land increase the need to improve agricultural production, particularly in rainfed arable lands (Anderson, et al. 2016). Estimates indicate that about 80% of the required improvements in agricultural production would have to come from the intensification of current agricultural production systems if targets are to be met without further large-scale conversion of land to agriculture.

The sustainability challenge for the agriculture sector is to provide enough food for the growing population with fewer resources such as water, farmland and biodiversity. This requires transformative changes towards sustainability in agriculture and strengthening sustainable use and management of existing agricultural systems to sustain food production and the ecosystems in which the production occurs. The global food system currently releases about 25% of annual anthropogenic GHG emissions, causes about one-third of terrestrial acidification and is responsible for the majority of global eutrophication of surface waters (Poore and Nemecek, 2018). If our food system continues with current practices, using synthetic pesticides, artificial fertilizers, fossil fuels and producing food waste, the carrying capacity of the planet is likely to be surpassed (Campbell et al., 2017). Therefore, the key challenge for humanity is to produce enough safe and nutritious food for a growing and wealthier population within the carrying capacity of the planet (Willett et al., 2019). The importance of producing food within the carrying capacity of the planet is also increasingly acknowledged in policies - for example, the EU Circular Economy Action Plan (European Commission, 2015), the Paris Climate Agreement (United Nations, 2015) and the Common Agricultural Policy (European Commission, 2019a).

Soil degradation is another contributor to GHGs emissions. Soil degradation due to faulty land management practices results in the loss of soil carbon to the atmosphere and it is estimated that most of the agricultural soil has lost 50 to 70 % of the original soil organic carbon pool (R.Lal, 2010). Generally, the top layer of soil has the potential to store 248 Pg of carbon in the top 3 metres of soil but due to soil degradation, this capacity is seriously impaired (Koglo et al., 2016). Improved agronomic practices and use of precision input management along with enhanced resource use efficiencies can help in the reduction of GHGs reductions (Godfray et al. 2010). Use of cover crops, less or no-tillage, alternate wetting and drying (AWD), use of mulching, the addition of organic manures and judicial use of chemical fertilizers are some of the options to

maintain, control and improve the cropland's resilience against climate change as well as reduce greenhouse gas emissions in the atmosphere.

RA focuses on the environmental dimension of sustainability, which includes themes such as enhancing and improving soil health, optimising resource management, alleviating climate change, improving nutrient cycling and water quality and availability, articulated by both objectives (e.g. improving soil quality) and activities (e.g. use perennials). These themes promote food security by contributing to provisioning (e.g. food, feed and fibre), regulating (e.g. climate regulation, soil erosion and water purification) and supporting (e.g. nutrient cycling and soil formation) ecosystem services (Fig. 1.1).

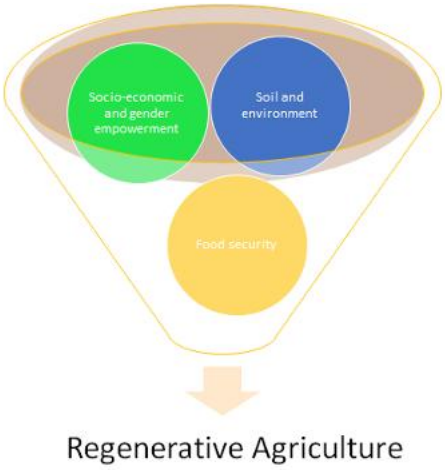


Figure 1.1 Baseline study dimensions of regenerative agriculture practices

The team also found a socio-economic dimension in RA to improve human health and improve economic prosperity, which relates to aspects of cultural ecosystem services. RA can be defined as an approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating and supporting services, with the objective that this will enhance not only the environment but also the social and economic dimensions of sustainable food production (Schreefel et al., 2020).

To foster the transition towards RA, the baseline study will help the team identify the present status as benchmarks and derive the indicators and drivers for customization of RA practices by need-based assessment of the community. The sustainability of production systems in these blocks especially for cotton production is scanty and not widely available.

2. Materials and Methods

2.1 Study site

This study was conducted in the Sausar and Mohkhed blocks of Chhindwara district, Madhya Pradesh. This is an ecologically sensitive area situated in Central India and home town to two (2) of the country's oldest nature reserves. The total area covered by the study area is 1833 Sq Kms (Fig. 2.1). Mohkhed is dominated by crops like wheat, maize, vegetables, soyabean and horticulture crops while Sausar is a cotton-growing belt. Most farmers integrate crop production with livestock.

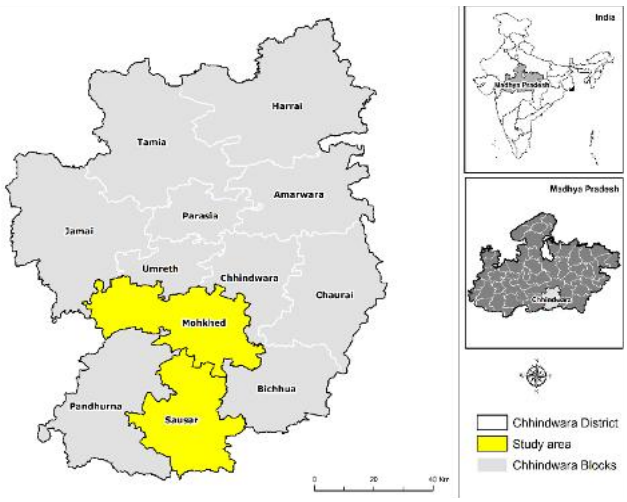


Fig. 2.1 Study location in Chhindwara district MP

Baseline Design

The principal objectives of this study are:

- a) to identify and quantify the agronomic and environmental performance of current agricultural practices,
- b) to understand the diversity of farming systems in each location,
- c) to the characterisation of regions in space and time
    - (i) biophysical characteristics such as soil characteristics and soil health and topography, climatic and weather variables, distribution of water bodies and natural vegetation; carbon pools and sink capacity, changes over time in land use and drivers of change
    - (ii) socio-economic characteristics such as population, main economic activities, farmers organisations, local governance, gender and markets
- d) Characterisation of dynamics in farming systems, the main crops produced, and animals reared as well as the main challenges they face in relation to climate change, and climate variability and opportunities documented.

The outputs of the baseline study are being used to develop strategies to reduce the carbon and water footprints and improve soil health through regenerative agricultural practices.

The present baseline evaluation design was set up across three (3) blocks of district Chhindwara, with one (1) treatment arm and one (1) control arm across three groups of villages based on the area under irrigation. The 51 villages covered are located across the district Chhindwara in Madhya Pradesh. A random sample of 20 households is selected in each village, subsequently administered a comprehensive household computer assisted personal interview (CAPI) survey. In all, 1,020 farmers are covered for the baseline. The 51 villages are randomly allocated to one (1) of three (3) groups – the first group (V1), comprising of 18 villages where villages have high irrigated areas and irrigation facilities provided, while in the second group (V2) of 18 villages, medium to the moderate area under irrigation, and 15 villages, having poor or almost negligible irrigated area.

- However, soil samples collection for comprehensive soil health assessment through the scientific method was undertaken in all groups of villages except the control block.

Along with the HH survey and soil sample, the high resolution (5.6 meters) satellite images (Resources at 1 & 2, LISS-IV) are procured for the land use land cover classification for the treatment blocks where regenerative production practices will be promoted. The high-resolution images are acquired for three (3) different periods ranging from ten-years (2011) back, five (5) -years (2016) back and current images (2021). The characterisation of land use land cover of the target geography was done by various land patterns and evaluated the observed change in the land use & land cover over time.

The timing of the baseline evaluation survey is as follows:

- In the beginning, high-resolution images covering the study were assessed.
- Then, processing of images for the generation of LULC maps along with various information (primary and secondary) for our target geography was collected on the information about current farming practices through ground-truthing.
- Simultaneously, a subset amongst these farmers sampled for the HH survey was approached to collect the soil samples from fields.
- For soil sampling, homogenous agro-ecologies are defined using a grid approach, and soil collection is performed from the respective fields while providing proportional landscape representation.

Differential Effects by Gender were captured to identify:

- Capacity for interventions defined by gender roles
- Cascading HH decisions, notably inputs and markets
- Gender inclusion can be enhanced in the compact
- Identifying key drivers to catalyse gender in decision-making rights in agriculture

2.2 Soil sampling and Analysis

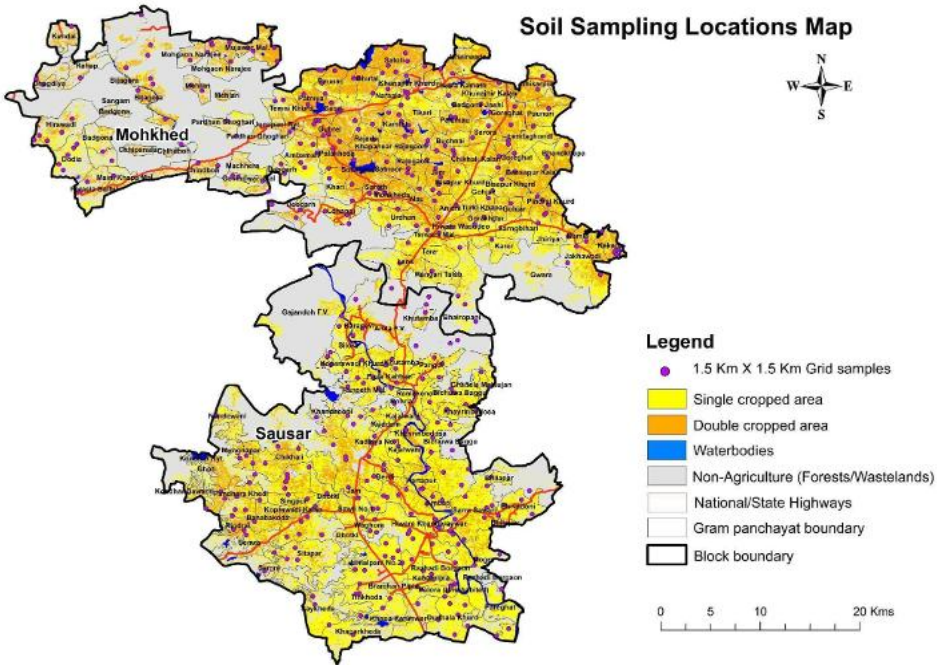


Fig. 2.2 Stratified soil sampling locations

Representative soil samples were collected from the crop (400 points) and Forest land (30 points) of Mohkhed and Sausar blocks of Chhindwara District, MP at two soil depths (0-15 cm & 15-30 cm) covering different land use following stratified soil sampling procedures (Fig 2.2). The collected soil samples were dried and sieved through a 2-mm mesh. The samples were subject to analysis for chemical (organic carbon content, macronutrient and key micronutrient), physical (bulk density) and biological (soil microbial biomass carbon and soil respiration) properties. The soil samples were analysed at the Soil Laboratory of IRRI-South Asia Regional Centre, Varanasi, Uttar Pradesh using standard methods and protocols (Table 1).

Table 1: Soil standard protocols used for baseline analysis

Properties	Method used
Soil texture	Gavlak et al., 2005
Soil pH	Jackson, 1973)
Soil EC	Jackson, 1973)
SOC	Nelson and Sommers,1996
Bulk density	Blake and Hartage (1986)
Available N	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
Available P	Olsen's 0.5 *M* $NaHCO_3$ extractable (Olsen *et al.* 1954).
Available K	Ammonium acetate exchangeable potassium (Toth and Prince, 1949)
SOC stock in soil	Bulk Density × SOC (%) × Soil Depth (m) × 10 + InVest model
Soil respiration	Rapid titration method (Angers and Recous 1997)

2.3 Land use and land cover analysis

A reconnaissance field visit was conducted during mid-Dec-2021 to examine the landscape's spatial pattern and associated attributes. During the visit, a village-level information survey was conducted in study blocks covering 25 villages. Information (spatial & non-spatial) on cropping patterns in Kharif and Rabi seasons, irrigation sources, soil types, abiotic stresses, and patterns in land-use change was collected. This information was supported by geotagged photographs in the region.

Based on the reconnaissance survey the geospatial activities were categorized into the following

2.3.1 Acquisition of satellite imageries for characterizing and targeting the landscapes

Linear Imaging and Self Scanning Sensors (LISS)- IV images of Resourcesat-1 & 2 at 5.8 meters spatial resolution was ordered and received from the National Remote Sensing Centre (NRSC), India. The images cover the study region (Table 2) in two scenes/tiles for the years 2011-12, 2016-17 and 2020-21. The available cloud-free images and dates of passes of each scene are provided in Table 2. A total of 29 cloud-free images for different years and cropping seasons were procured for geospatial analytics.

Table 2. Image acquisition dates of satellite imageries

Path & Row	2011-12	2016-17	2020-21
99-57-A	11-Oct-11	25-Nov-16	23-Oct-20
	15-Jan-12	31-Dec-16	9-Nov-20
	3-Mar-12	12-Jan-17	10-Dec-20
		6-Apr-17	27-Dec-20
			27-Jan-21
			13-Feb-21
			2-Apr-21
99-57-B	4-Nov-11	1-Nov-16	16-Nov-20
	22-Dec-11	24-Dec-16	3-Dec-20
	27-Mar-12	24-Jan-17	20-Jan-21
		5-Feb-17	20-Feb-21
		13-Mar-17	9-Mar-21
		25-Mar-17	8-May-21

2.3.2 Ground sampling scheme through preliminary geospatial analytics

Preliminary geospatial analytics was executed for the recent year 2020-21 to derive the broad landscape segments for planning the field surveys. With aid from temporal images of 2020-21, ground data points and geotagged images, these segments were further classified into broader LULC classification. For ground-truthing (GT) data collection on soil samples as well as geo-coordinates for training satellite images were mainly targeted using single and double cropping land use patterns derived from LULC categories. A 1.5 X 1.5 km grid-based sampling point was generated and overlaid on the LULC map to collect an approximate 600 sampling locations together for soil sampling and GT points for digital image processing of satellite imageries in the study region.

2.3.3 Ground truth data collection for Land Use Land Cover mapping

To calibrate and validate the satellite derived LULC, cropping system and change detection classified outputs, two rounds of field campaigns are conducted in the study area. The team has

collected a total of 1150 ground truth points for various LULC spatial information and their attributes broadly mentioned below (Fig 2.3). This data has been collected using KOBO collect digital survey tool on smartphones and GPS devices.

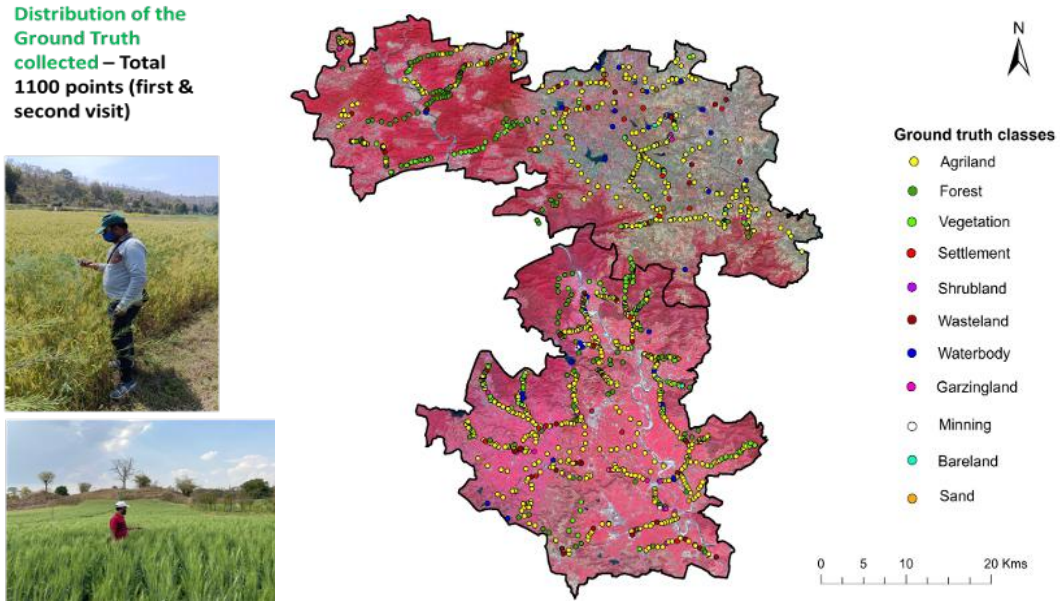


Fig. 2.3 Ground truth data collection for various LULC classes

2.4 GHG estimations

GHG emissions from crops were calculated using the Cool Farm Tool (CFT) (Hillier et al., 2011, CFT: https://www.coolfarmtool.org/). The CFT is a GHG emission calculator that allows users to estimate annual GHG emissions associated with the production of crops or livestock products (Hillier et al., 2011). It comprises a generic set of empirical models that are used to estimate full farm-gate product emissions constituting a mix of Tier 1, Tier 2, and simple Tier 3 approaches. The tool takes into account context-specific factors that influence GHG emissions such as pedo-climatic characteristics, production inputs and other management practices at the field and farm level. The model provides total GHG emission per unit area as well as per unit of the product allowing users to estimate the performance of the production system from a GHG emission perspective both in terms of land-use efficiency and efficiency per unit of product.

2.5 Water use efficiency (WUE)

Water use efficiency is defined as the amount of carbon assimilated as biomass or grain produced per unit of water used by the crop (Hatfield and Dold 2019). WUE for all key crops in the project site was calculated as a ratio of crop yield to water use per unit area.

2.6 Qualitative target and key strategies validation exercise with stakeholders

The study to validate the baseline targets and critical strategies for the Chhindwara compact was conducted over one (1) week from 25 May to 31 May 2022 across ten villages of block Mohkhed and Sausar block of district Chhindwara post the baseline targets and strategies were developed. The aim of the study was to identify stakeholders' perceptions of the relevance (satisfaction) of the various targets and critical strategies designed and assess their feasibility, credibility, and propriety in the landscapes.

A semi-structured questionnaire was developed to implement the validation exercise. This approach was selected because it was flexible and allowed interviewees to provide more

information than they would have from other procedures. In this semi-structured questionnaire, we included topics on various dimensions relevant for the validation, such as crops & their production, cropping pattern & diversification, use of farm inputs, land and forest conservation, ecosystem management practices, Market access, linkages, Sources of income & changes, financial security, Farmers Group & dynamics and role sharing in household tasks; the role of women in household decision making. Further, feedback was taken on the questionnaire from the local community social organisation's (CSO) partner Srijan (District lead and field team members), and additions were made based on their suggestions and feedback, such as livestock scenarios and farm mechanisation. Ten villages (more than 100 respondents) were selected based on the team's objective and region-specific constraints (Annexure). The team of researchers consisted of two (2) leads (one from CGIAR-IRRI and one from RPLC) and a team supporting staff for note-taking and video capturing.

The participants were divided into three (3) groups i.e., the first group was male, the second group was female, and the last group was mixed. After a general introduction, specific information was gathered on crop production, the status of biodiversity, crop diversification, cropping pattern, judicious use of input, help and adaptation of ecosystem, land and forest conservation, sustainable environmental service, skills of tracking costs analysis cost benefits, sources of income & changes, and access to loans; saving, financial security. Furthermore, responsibility for using natural resources, particularly Non-Timber Forest Product, the role of women in household decision making, and agro advisory services were discussed.

At the end of every focus group discussion, researchers and key informants assemble and collectively draw the discussion's salient findings which are presented under the respective component in the results section.

3. Results

3.1 Production Pillar

3.1.1 Crop Productivity

Yield data of various crops grown in the landscape shows high yield gaps in the major cultivated crops (Table 3). Except for groundnut, all the crops had yields lower than the state average and much lower (up to 11 quintals/acre) than the attainable yields of these crops.

There is a huge opportunity to increase the yield of crops in the Chhindwara landscape and thus improve the overall household income since >90% of households are dependent on agriculture as a main source of income.

Table 3. Productivity of different crops and scope for increment through RA

Crop	Yield (Quintals/Acre)			
	Reported in baseline	Attainable Yield	State Average	Scope for increase (over attainable yield) (quintal/acre)
Cotton	4.1	15.0	5	10.9
Wheat	8.3	20.0	11.3	11.7
Gram	1.5	8.0	5.3	6.5
Maize	8.6	20.0	10.9	11.4
Soyabean	4.2	14.4	5.2	10.2
Groundnut	6.2	14.0	6	7.8
Arhar	2.5	8.0	4	5.5

The regression analysis demonstrates that farmers with proper irrigation facilities get a higher yield than farmers who cultivate in rainfed conditions. The analysis demonstrates an increase in the availability of irrigation water can increase the yield, (by 0.82 quintals per acre) of farmers who cultivate in rainfed conditions.

The data also demonstrate the yield advantages of 1.29 quintal/acre were observed for farmers adopting regenerative-integrated nutrient management with both chemical and organic fertilizer than those using only chemical fertilizers. The data show that there is a scope to improve the soil health of both blocks through regenerative practices to improve crop productivity while improving environmental sustainability.

The average household's income in the landscape is around Rs 128,000 (Euro 1574) per annum. Most people in the landscape depend on farming as a major source of income. As a secondary occupation, 33 percent reported as an agricultural labourer. The most popular non-farm income source is a pension, where 18 percent of households report earning some income from a pension. The sale of livestock and livestock products (17 percent of households) and the sale of forest produce (11 percent of households), mainly for HHs living near the forest area, were the 2nd and 3rd most popular sources of non-farm income.

One potential consequence of intervening with crop productivity enhancement is to empower farmers with increased income. Translating the increased cotton yield into monetary values

assuming that a kilo of cotton is priced at 50 rupees (0.6 Euro), we can estimate that cultivating a one (1)-acre plot with better management practices, as opposed to traditional practice, provides a farmer with over Rs. 10,000 in terms of cotton output, valued at the market price. With the average landholding being 4.5 acres for the households in the sample, this translates to an additional income of Rs. 45,000 in cotton for a farmer who switches to improved practices from traditional practice. The social benefits from the higher yields are also significant as the majority of the HH's hail from disadvantaged socio-economic backgrounds and an improvement of their economic conditions is a crucial component of achieving inclusive growth.

During the qualitative discussion, we enquire the farmers about the yield they are getting for the crops they are growing. And across the landscapes, crop productivity is also low, as depicted in Table 3. It has been found that the villages having access to water show higher yields while the remaining villages' crop yield is inadequate. The critical strategies identified include better high yielding varieties, balanced & efficient use of fertilisers and pest management, optimisation of crop calendar and best paired intercropping.

It is evident that the farmers in the geography lack access to new varieties for most crops (maize, cotton, potato, wheat, soybean). Farmers mainly rely on private input dealers for seeds and other information due to the inactivity of the government extension system. Thus, farmers lack access to innovative drought-tolerant or pest-tolerant, high-yielding varieties developed by the various research institutes. It would be worthwhile to bridge the gap from the research institute to the farmer's field in the project. Farmers in the discussion reported the acute problems they face in cotton farming mainly due to increased pests and diseases in the crop. Strikingly, they are ready to replace it with another crop. Many farmers reported having grown Turmeric instead of cotton. However, they had to stop it due to the lack of market access.

In the case of wheat and soybean, lack of knowledge and access to quality seeds causes farmers to use their own produced sources, which are of poor quality, thus lowering crop productivity. Quality seeds can enhance crop productivity by up to 30 per cent. Again, inadequate knowledge of fertilisers and pesticide use and no access to quality inputs lead to inefficient use of fertilisers and pesticides. In the past few years, cooperative societies have not provided sufficient fertilisers, and input dealers are exploiting farmers by selling whole packages of fertilisers, pesticides, and other inputs. It was found during the discussions that farmers are keen to learn and apply improved knowledge on fertiliser and pest management, which can provide better yield and profit. Also, farmers across the landscape are willing to adopt integrated pest management options subject to low cost, less labour-intensive and yield-enhancing options.

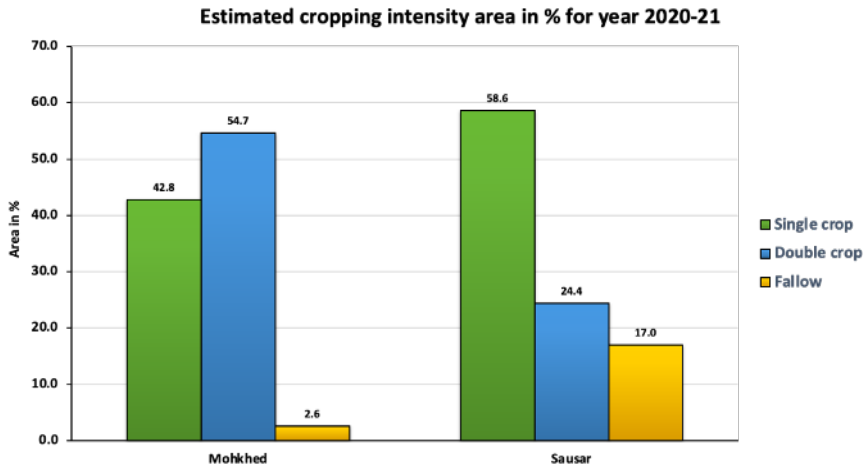
Probing around cover crop or intercropping reveals that only in cotton crop, the intercrop or cover crop practices are prevalent (cotton with Tur). While in maize, fewer farmers reported having taken a cover crop, again due to no guidance and lack of knowledge. However, none of the farmers were hesitant to take up the crop if provided with seeds and management practices. Orange farmers intercrop until the oranges start fruiting (max 3 years). Once fruiting starts, the field remains only for the oranges crop. Farmers during the discussion appreciated the best paring cover crop or intercrop, which can help build soil quality, diversify yield and income and can also be used as feed for livestock. On an average, orange farmers are getting a good yield of 2000 carats (25 kg each) in an acre of land, however, it takes at least three (3) years to start fruiting in oranges trees.

Farmers were quite sceptical about optimising/adjusting the crop calendar as Kharif crops mainly depend on rainfall conditions. Thus, planting or shifting the crop sowing time is out of their control and depends on weather conditions. However, accurate digital weather advisory services were suggested and liked by the farmers as it will help them start preparing the field and other operations well on time.

3.1.2 Cropping Intensity

In cropping intensity (Cropping Intensity = Gross Cropped Area/Net Sown Area x 100) in the landscape as mapped using GIS and RS land cover analytics showed that around 50% of the area in the northern region is under double cropping (two crop in a year) while it was only 24 in the southern region of the landscape. There is a large percent of the area (17%) that is kept fallow in the southern region of the landscape. Further analysis of the availability of moisture and suitability of crops will be useful to bring these fallow areas under cultivation to increase HH incomes and conserve soil (Fig 3.1).

Fig. 3.1 Estimated cropping intensity area for the year 2020-21



The cropping intensity of the landscape is 139 per cent (HH Survey 2022), and the target for the same is set to 160 per cent for a five (5)-year program. Major strategies against this target include site suitability mapping for land use, residue management & mulching, and increasing irrigation facilities. As per the qualitative discussion, farmers are not cultivating the subsequent crops in the landscape because of the unavailability of irrigation facilities. Generally, Kharif crops (Maize, Soyabean, Cotton, Rice) grow using rainfall water and do not require external irrigation and rainfall in the landscape is pretty good (~1125 mm). On the other hand, the rabi crops (Wheat, Chick Pea, and vegetables) require irrigation up to three (3) to five (5) times during the season, thus needing sufficient irrigation sources for farmers.

Noticeably, except for some villages and farmers in the landscape, water availability is poor and farmers have little to no access to irrigation water. The situation is worse when farmers do not provide supplementary irrigation for the Kharif crop (cotton) as required during later stages using conserved water. One of the proposed key strategies to enhance cropping intensity, i.e., residue

management and mulching, is to retain the moisture in the soil through reduced evaporation. Thus, same moisture can be used for the subsequent crop after the Kharif harvest. However, it can only be helpful when mulch is available, which seems to be an issue for cotton farmers, as cotton residue does not fit for mulching. And there is also a dearth of other crops straw, which can be taken as mulch. Therefore, it is required to produce enough mulch mainly through weeds cultivation each season. During the discussion, farmers respond that with proper guidance and knowledge, they can have mulch in the field on bunds or unused areas that can be used to enhance soil moisture and thus enhance the cropping intensity.

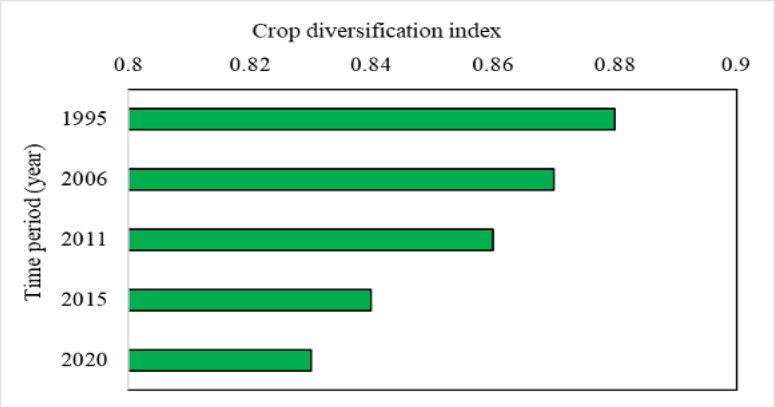
Maize and wheat straw can be utilised as mulch. Moreover, considering the soil moisture level, crops such as the moong bean, which is short duration and requires less irrigation, can be grown. Still, for crops like wheat or high value, farmers stated that access to irrigation is necessary to take decent production out of the crop. In this regard, several interventions for water access are available. They have been implemented in the region by CSOs, such as open well renovation or construction, drip irrigation or sprinkler, or construction of farm ponds.

The number of open well exits in the geography is limited. The construction of a new open well is an expensive affair considering the water depth of up to 900 feet in many villages. Even if it is constructed, the catchment area will be limited. Drip irrigation or sprinkler also works when water is available through rainwater conservation activities or other sources. Interestingly, the construction of farm ponds in villages can be a viable option where a small per cent plot of land is used for a pond (15m in length and breadth) to conserve rainwater to irrigate the field. Farmers shared cases of such facility which have been completed with the help of Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and CSO partnerships. It has been perceived that 160 per cent of cropping intensity is achievable, considering the implementation of critical strategies identified to achieve this.

3.1.3 Crop Diversification

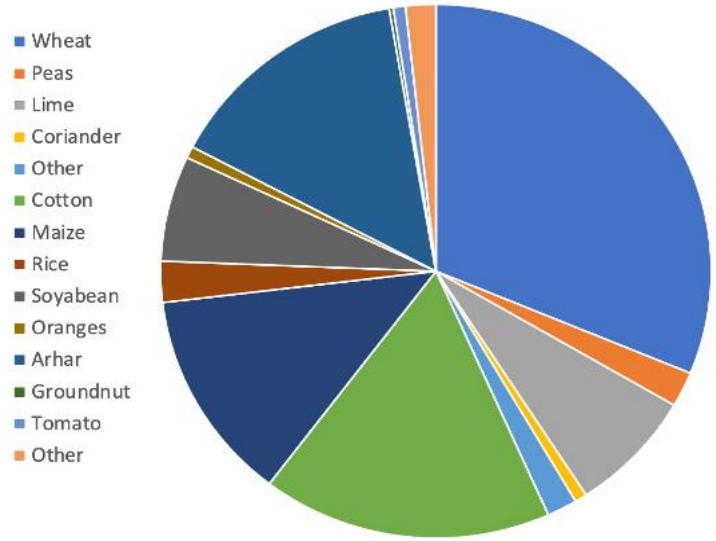
Over time there is a drastic decrease in crop diversification, thus, indicating that the landowners started to cultivate fewer and fewer crops. If this continues, it will lead to a loss in overall above and below ground diversification (https://www.statista.com).

Fig. 3.2 Crop diversification index for different years in Madhya Pradesh



98% of landowners cultivated their fields in Kharif season but only 53% cultivated their fields in Rabi season while the rest left the land fallow. Most of the landowners in the landscape cultivate only one to two (1-2) crops in a year (Fig 3.2).

Fig. 3.3 Crop diversity in the landscape of Chhindwara



Wheat, cotton, maize and arhar (legumes) were major crops grown by the majority of landowners in the landscape. The crop diversity in the landscape is low with other crops being cultivated by <10 percent of landowners (Fig 3.3).

During the study, in-depth interviews and visits with the farmers were conducted in the areas having complete fallow areas in the landscape, as depicted in GIS remote sensing analysis and maps. It is found that complete fallow areas are more prominent in ST (Adivasis) inhabited areas or forest nearby areas. Farmers in the region reported that they see no incentive in cultivating the crop and heavily depend on forest produce (Mahua, illegal timber logging) or Agri labour jobs or non-farm jobs, and livestock. These areas are mainly characterised by poor water availability coupled with high pests and diseases infestation and high input costs and therefore left fallow throughout the year. During the discussion, farmers agree to utilise their fields in agroforestry models or diversified cropping system subject to proper inputs and training, and water access. Farmers also welcomed the silvopastoral integration system as livestock is one of their main occupations. They also mentioned not planting trees as it requires investment in planting trees (150-200 Rs (Euro 1.8-2.5) per trees) of preferred species of Mango, Guava, Jamun and Lemon, and water shortage resulting in leaving the field fallow entirely. The reduction in fallow areas requires continuous efforts from all the stakeholders: the public sector (seedlings, dissemination strategy), private industry (finance), and CSO.

3.1.4 Cost of Cultivation and Productivity for Major Crops

The changes in monthly water extent across the study site presents the input cost, yield, and average selling price for main crops in Rabi and Kharif season in both regions (Table 4). Table 4 presents both mean and standard deviation for the input costs and yield, but the high standard deviation suggests variation due to remarkably different practices among farmers. Comparing Rabi production of wheat of both blocks, the input cost is slightly higher in northern region (Rs 8643 (Euro 106)) than in southern region (Rs 8019 (Euro 98.6)), but so is yield and average selling price. In northern region, under kharif season, the input cost for Soyabean is on average Rs 9206 (Euro 113) per acre and Rs 7800 (Euro 95.9) for Maize. The yield of Soybean is 4.2 quintals per acre but fetches a much higher price of Rs 4200 (Euro 51.6) per quintal compared to maize

whose yield is 8.6 quintals per acre but selling price is Rs 1550 (Euro 19) per quintal. Cotton grown in Kharif fetches the highest price at Rs 6400 (Euro 78.7) per quintal and produced at 4.1 quintals per acre. Arhar yield is low (2.5 quintals per acre) and comparable to that for groundnut (1.46 quintals per acre). Control area have slightly higher yield in both the season in all of the crops.

Table 4. Cost of Cultivation and Productivity of Major Crops, northern region

	Input cost Rs/Acre (std dev)	Yield Quintals/Acre (std dev)
Northern Region		
Rabi Season	Mean	Mean
Wheat	8643 (5539)	8.3 (5.1)
Gram	5400 (1380)	1.46 (0.6)
Kharif Season		
Maize	7800 (3706)	8.61 (5)
Soyabean	9206 (3254)	4.2 (2.5)
Southern region		
Rabi Season	Mean	Mean
Wheat	8019 (2844)	6.5 (4)
Ground nut	9853 (3243)	6.2 (3)
Kharif Season		
Cotton	9421 (3520)	4.1 (2.1)
Arhar	4797 (2300)	2.5 (1.8)
Control		
Rabi Season		
Wheat	8080 (2255)	9 (4.8)
Kharif Season		
Maize	7850 (3659)	10.5 (6)
Soyabean	9350 (3325)	4.25 (2.8)
Cotton	9526 (3650)	4.5 (2.6)

3.1.5 Adoption of various agricultural technologies by HHs

Adoption of various improved agricultural practices and technologies were below 15% (Table 5). Scaling of these technologies will directly impact the production, profitability, and environmental conservation. Adoption of technologies such as LCC, straw compost was comparatively lower in control region, whereas adoption of GAP was highest in control areas

Table 5. Percentage Adoption of Regenerative Agricultural Practices

Overall	Treatment %	Control %
High yielding improved varieties- Drought Tolerant	10.35	10.23%
High yielding improved varieties- Submergence Tolerant	4.66	2.05%
High yielding improved varieties- Salt Tolerant	0.29	0%
High yielding improved varieties- High grain quality	9.48	9.36%
Crop management - Leaf Color Chart (LCC)	1.02	0%
Crop management - Alternate Wetting and Drying (AWD)	6.56	1.17%
Crop management - green manure	3.35	2.34%
Crop management - Farmyard manure	15.01	6.43%
Crop management - Straw compost	7.14	2.34%
Crop management - Integrated Pest Management (IPM)	1.31	0.29%
Crop management - Good Agricultural Practices (GAP)	55.83	84.21%
Crop management - Construction of on-farm pond	0	0%
Crop management - Crop/Nutrient Manager Software	0.16	0%
Crop management - Weather advisories	2.33	0.29%
Machineries - Mechanical transplanter	0	0%
Machineries - Drum seeder	0.15	0%
Machineries - Combined harvester-thresher	0	1.46%
Machineries - Mechanical thresher	0.30	0%
Post-harvest technology - Plastic/Poly bag for seeds	0.73	0%
Post-harvest technology - Metal/Plastic drum for seeds	0	0%
Other technology	0.44	0%

Table 6. Regenerative agriculture practices awareness and adoption in the landscapes

Practices	Not Aware	Aware but didn't practice	Practiced partially	Practiced in entirety	Not Relevant
Soil testing	40.00%	38.20%		13.80%	1.80%
Conservation tillage	32.70%	17.10%	12.70%	36.90%	0.70%
Preserving natural flora	24.00%	21.60%	14.00%	39.10%	1.30%
Mulching	52.90%	14.90%	11.60%	17.60%	3.10%
Crop rotation	19.30%	18.20%	13.10%	46.40%	2.90%
Agroforestry	45.60%	26.40%	11.80%	13.60%	2.70%
Integrating livestock	33.60%	21.60%	16.20%	25.10%	3.60%
Reduce chemical, increase organic	24.40%	30.70%	19.60%	23.60%	1.80%

Table 7. Reason for not adopting the regenerative agriculture practices

Practices	Knowledge	Labour/Skill	Material/machine	Inadequate Return	Costly	Not relevant
Soil testing	49.40%	29.70%	9.90%	3.50%	31.40%	6.40%
Conservation tillage	33.80%	24.70%	5.20%	2.60%	24.70%	20.80%

Preserving natural flora	39.20%	32.00%	17.50%	12.40%	10.30%	15.50%
Mulching	13.40%	29.90%	23.90%	25.40%	20.90%	23.90%
Crop rotation	30.50%	32.90%	6.10%	34.10%	42.70%	18.30%
Agroforestry	23.50%	24.40%	12.60%	16.80%	22.70%	21.00%
Integrating livestock	13.40%	30.90%	14.40%	22.70%	30.90%	21.60%
Reduce chemical, increase organic	23.20%	31.20%	10.10%	27.50%	41.30%	15.90%

Table 6 and 7 summarizes the awareness and reasons for adoption and non-adoption of regenerative agriculture practice in the studied landscape. Capacity development is crucial to transform the conventional farming to regenerative production landscape.

During the qualitative inquiry, farmers were provided information on various regenerative practices and their benefits to the crop and environment. Still, farmers in the landscapes are more concerned about the immediate benefits of crop production and incomes, and environmental protection comes secondary to them. We also enquire about any village level committee and organisation structure to preserve and restore the ecological services. Unfortunately, neither male nor female farmers reported having such a collective mechanism to protect or enhance ecological services.

It has been observed that No-till or reduced tillage practices, a fundamental principle of regenerative agriculture, required concerted efforts for farmers to adopt. However, field ploughing using a tractor (2-3 times) is quite prevalent, which is also pronounced in HH survey results, and farmers find it more convenient than bullock (only a few farmers use it). Therefore, going back to bullock seems not possible for the farmers. However, technologies such as zero-till maize, soybean, and cotton planters need to be used to reduce tillage practices.

Other practices, such as intercrop and cover crop, are there in the region and more pronounced in Sausar. Nonetheless, the farmers in the different areas find it valuable and doable subject to proper knowledge. Similarly, the knowledge, availability, and no yield penalty for integrated nutrient management are farmers' main concerns.

Planting trees in the field, mainly in bunds, are welcomed by the farmers and can be scaled with proper dissemination of seedlings of farmer preferred species. However, various RA models, including agroforestry, intercropping, cover crop, reduced tillage, and bio-inputs usage, have to be demonstrated in the landscape and shared with the farmers about its benefits in yield, and profit and environment to induce the adoption.

Interventions related to improved seed varieties have been done in the area, and farmers benefited from yield gain. However, in the wake of changing weather patterns and pest susceptibility, they do not have standard access to new seed varieties available and suitable for the region. The farmers welcome new, improved varieties and better management practices, as they mentioned the example of PepsiCo Potato intervention, of better varieties and management that yield better production and income.

3.2 Protection Pillar

3.2.1 Soil health analysis

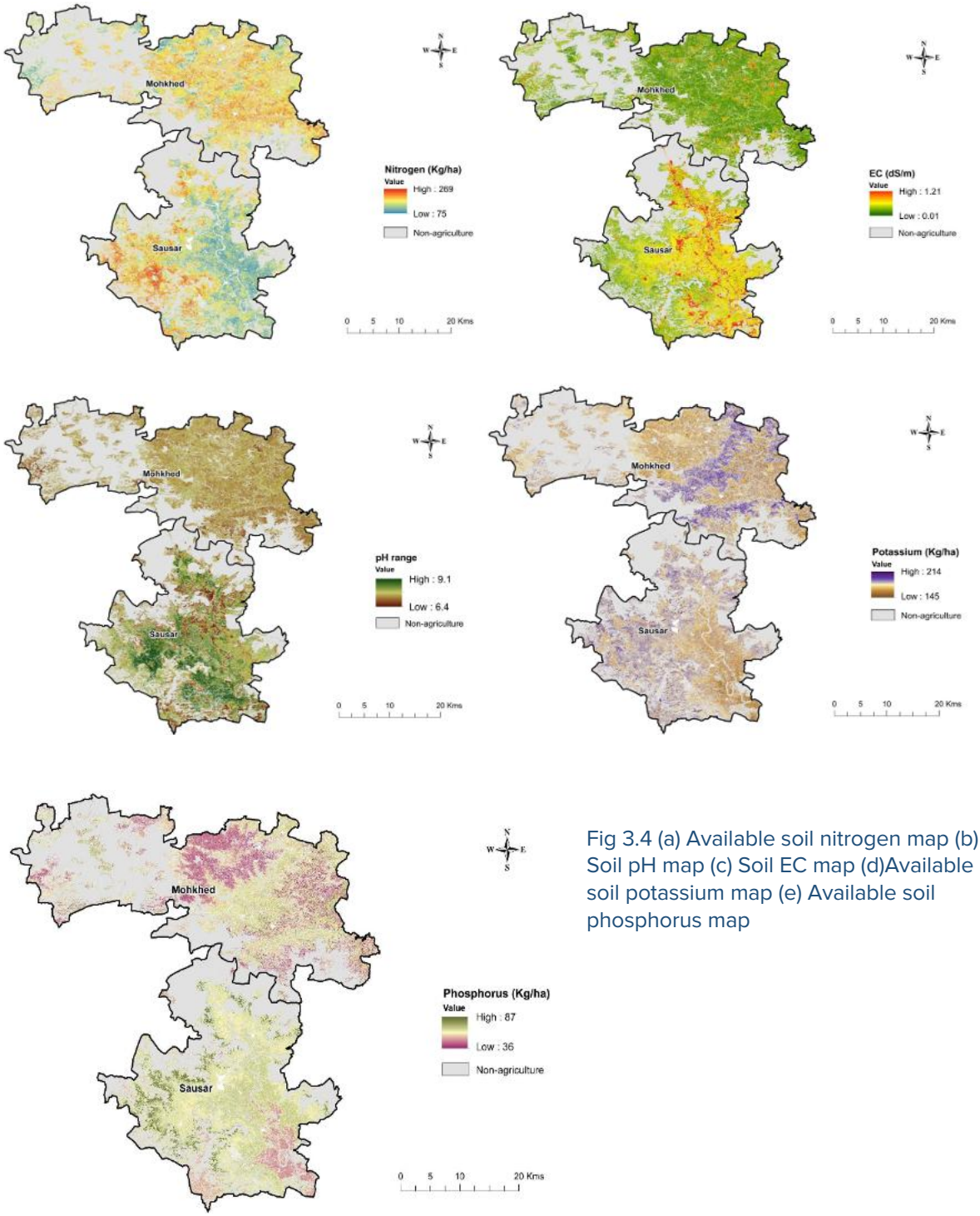


Fig 3.4 (a) Available soil nitrogen map (b) Soil pH map (c) Soil EC map (d)Available soil potassium map (e) Available soil phosphorus map

The available soil nitrogen map (Fig 3.4 a) shows a high variability across the landscape. Soil analysis revealed most of the soils in the landscape were low in available nitrogen. Thus, there

is a need to optimise the use of fertilizers and improve the nutrient use efficiency without increasing environmental footprints with overuse of nitrogenous fertilizers.

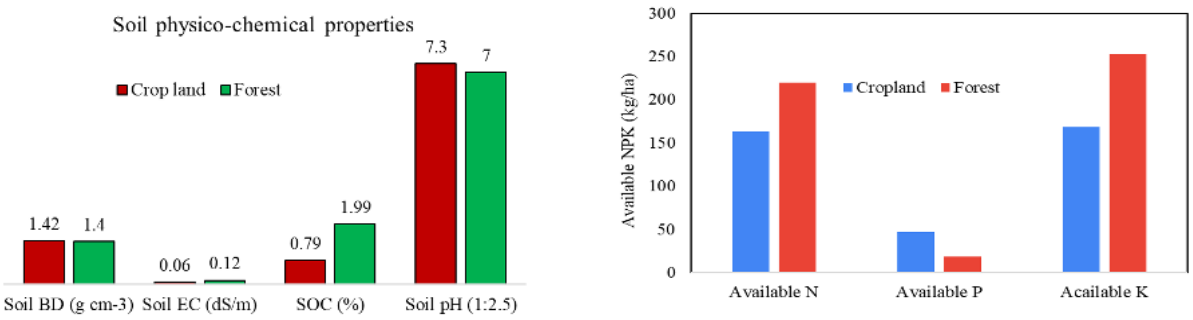


Fig. 3.5 Soil Physico-chemical properties and macronutrient availability in crops and forests

There was huge variation in the soil health parameters across the landscape (Figure 3.5). The soils in the southern part of the landscape have lower soil carbon stock and higher bulk densities than the northern soils (Fig 3.6 and 3.7). The SOC in the agriculture field is significantly lower than the forest soils, clearly indicating degradation in soil due to intensive tillage for cultivation (>90% of the landowners indicated intensive tillage in their fields). The carbon stock map explains the spatial variability of carbon in the soil. The forest soils have higher carbon content whereas the soils under intensive agriculture have low SOC. Farmers' crop yield was significantly correlated with SOC stock. The farmers' crop yield increases by 18.61 kg/acre with every point increase in SOC stock.

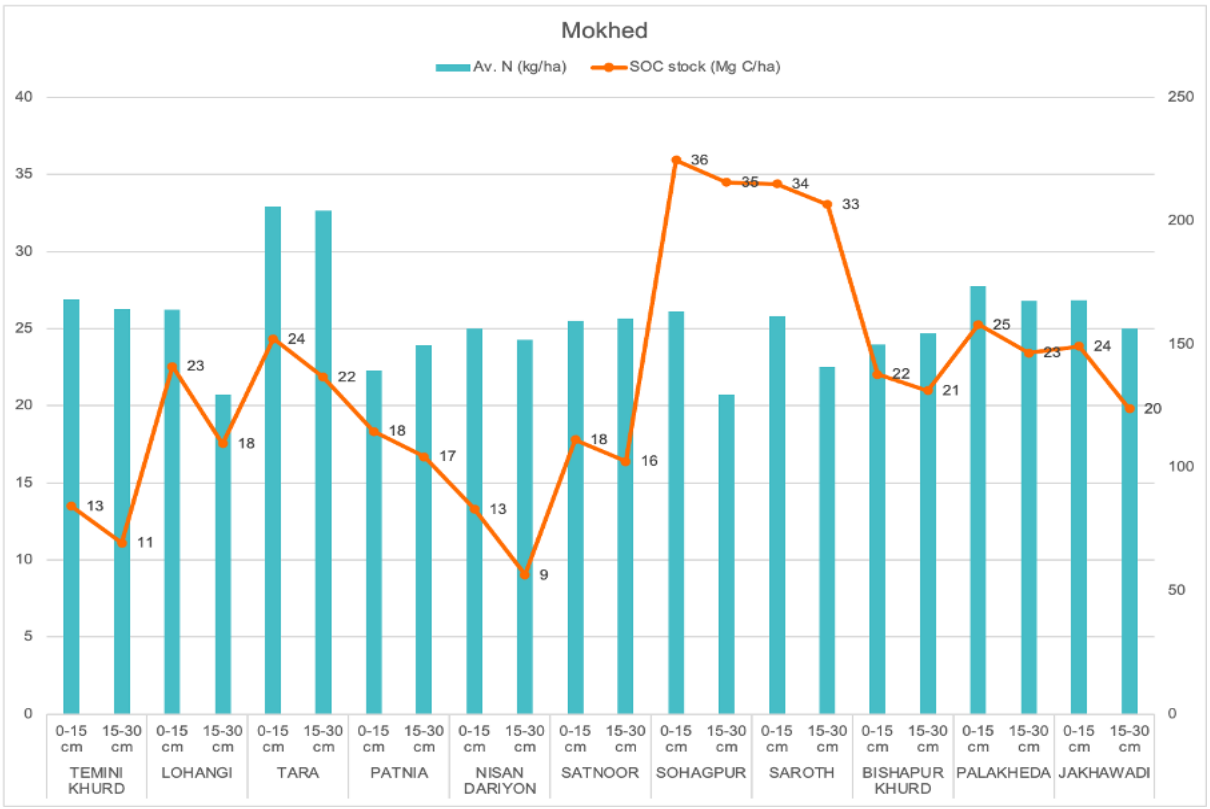


Fig 3.6 SOC stock and available nitrogen in Mohkhed

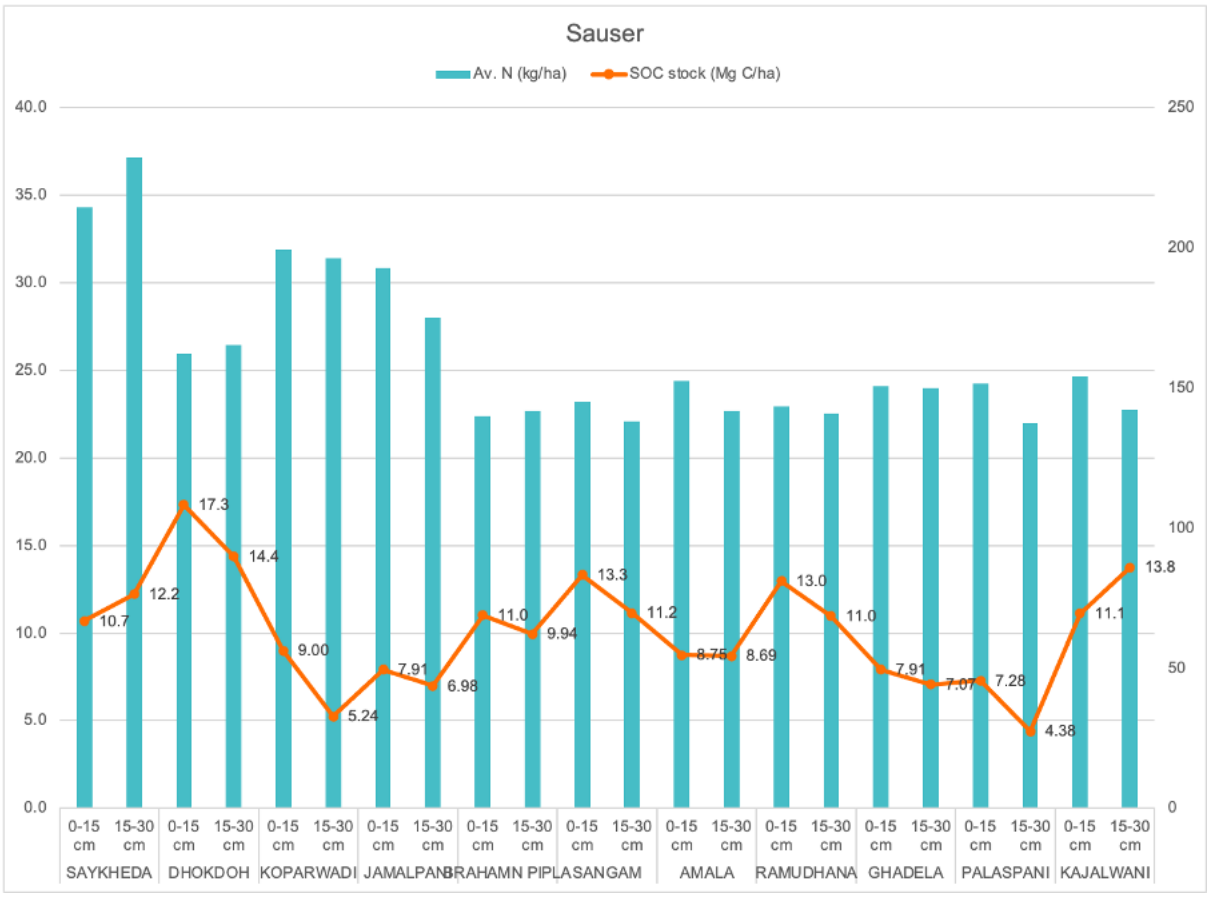


Fig 3.7 SOC stock and available nitrogen in Sausar

Soil carbon stock map was generated using carbon stock information collected from the ground and LULC data of 2021, generated using the LISS-IV data and InVEST model (Fig 3.8).

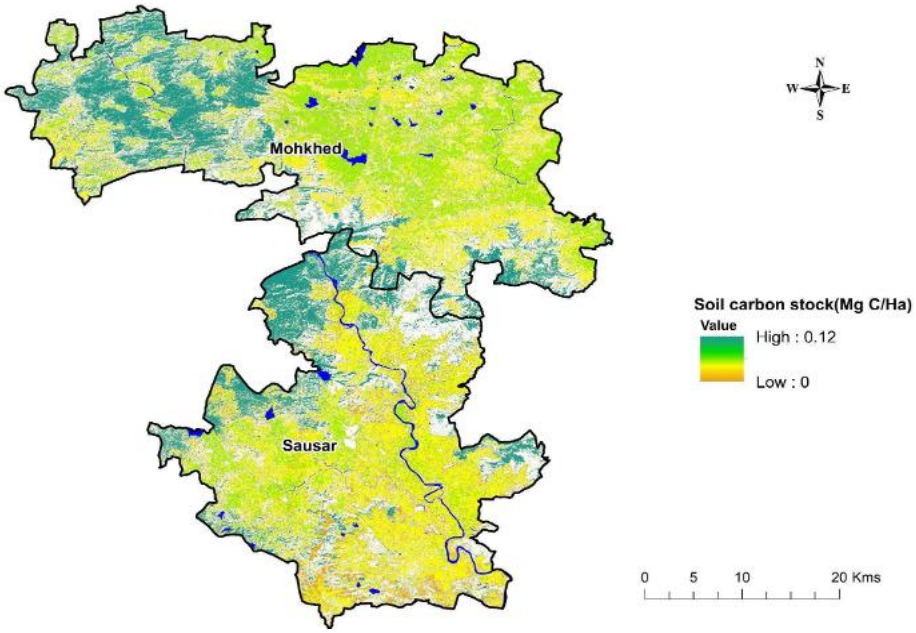


Fig 3.8 Soil carbon stock map

InVEST is a suite of free, open-source software models used to map and value the goods and services from nature that sustain and fulfil human life. This is developed by the Nature Capital project at Stanford University. InVEST models are based on production functions that define how

changes in an ecosystem's structure and function are likely to affect the flows and values of ecosystem services across a land- or a seascape. The models account for both service supply (e.g., living habitats as buffers for storm waves) and the location and activities of people who benefit from services (e.g., location of people and infrastructure potentially affected by coastal storms). The carbon model (https://naturalcapitalproject.stanford.edu/software/invest-models/carbon) of InVest was used to develop the carbon stock map. The InVEST Carbon Storage and Sequestration model estimates the current amount of carbon stored in a landscape and values the amount of sequestered carbon over time. First, it aggregates the biophysical amount of carbon stored in four carbon pools (aboveground living biomass, belowground living biomass, soil, and dead organic matter) based LULC maps provided by users.

The carbon stock map explains the spatial variability of carbon in the soil. The areas of forest have higher carbon content whereas areas of agriculture have variable carbon content, with Mohkhed in the north having slightly higher carbon content than the southern part of the study which has lower carbon stock values.

3.2.2 Regression analysis: effects of Soil organic content stock (Mg C/ha) on the crop yield

Intensive household survey was conducted along with soil sampling to capture various farm management practices and crop production data. To identify the effects of SOC stock, a regression analysis was performed to discern the results on the crop yield. Fixed-effect regression analysis was conducted while controlling several theoretically relevant variables and unobserved factors to identify the effect.

Column 1 shows that farmers' crop yield was significantly correlated (p-value 0.01) with SOC stock at lower soil depth (Table 8). Less frequent disturbance at 15-30 cm soil depth may have resulted in a significant correlation. The farmers' crop yield increases by 18.61 kg/acre with every point increase in SOC stock (15 to 30 cm depth). In column 2, the analysis also demonstrates that farmers with proper irrigation facilities get a higher yield, (by 82 kgs per acre) than farmers who cultivate in rainfed conditions; however, the effect was not significant. The data also demonstrate the yield advantages of 129 kg/acre were observed for farmers adopting regenerative-integrated nutrient management with both chemical and organic fertilizer than those using only chemical fertilizers. It also shows an increase in the yield with every point increase in land size (Table 8).

The data show that there is a scope to improve the soil health of both blocks through regenerative practices to improve crop productivity while improving environmental sustainability.

Table 8. Regression analysis

	Yield per/acre (Rabi-wheat)	Yield per/acre (Rabi-wheat)
	(Column 1)	(Column 2)
SOC Stock (15-30cm)	18.61 ** (8.37)	19.82** (10.75)
Total Land	-	11.69 (23.29)
Irrigated	-	82.465 (218.35)
Fertilizer use (Chem+Org)	-	128.89 (150.14)
Other backward class	-	182.57 (131.50)

Agriculture Primary	-	42.19 (190.86)
Cluster Fixed effects	No	Yes
Mean Dependent Variable	776.32 (142.54)	419.255 (228.26)
Observation	80	80
R- Squared	0.1	0.1

3.2.3 Soil microbial biomass carbon (SMBC)

SMBC generally comprises 1–4 % of soil organic matter and is the most active component of soil organic carbon that regulates biogeochemical processes in terrestrial ecosystems (Fig 3.9). The SMBC is one of the most promising indicators of soil quality because it responds promptly to environmental changes, often much earlier than bulk soil organic matter. Soil microbial biomass is a source and sink of soil nutrients. The measurement of microbial biomass is useful for describing biomass turnover in different ecosystems. Microbial biomass represents the fraction of soil responsible for the energy, nutrient cycling and regulation of organic matter transformations. SMBC is the living portion of soil organic matter, constituted by archaea, bacteria and eukaryotes, excluding roots and smaller animals. Decrease of SMBC as a fraction of total organic carbon implies a reduction in microbial transformation and intensity which was reported by our study. The value of SMBC in the baseline was typically low (less than half) as compared to forest soils.

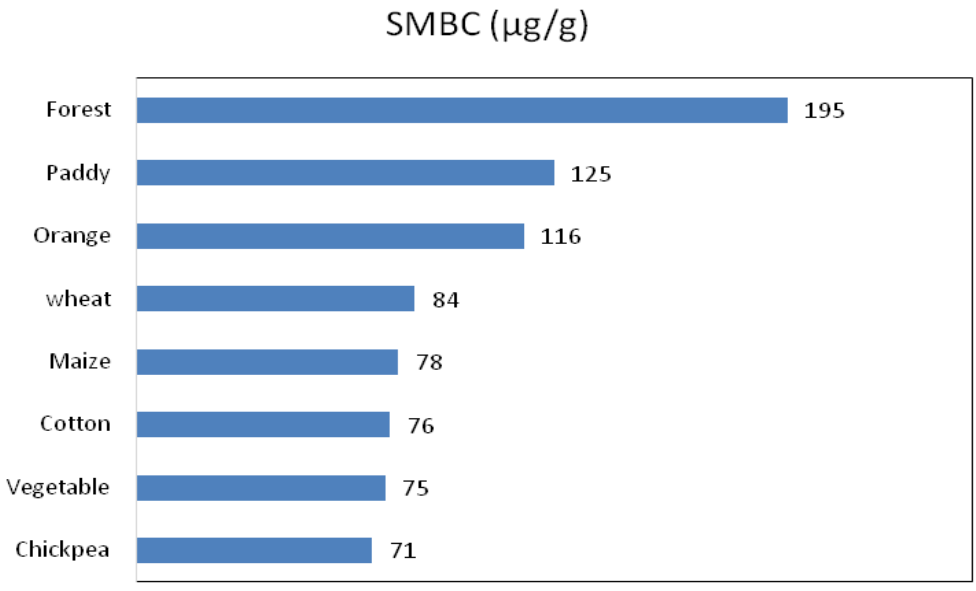


Fig. 3.9 Crop Wise Soil Microbial Biomass Carbon in Chhindwara, M.P.

Participants during the qualitative discussion were provided with the fact report of the Soil Health conditions described in the baseline report using the field soil samples. Though farmers do not have the means to verify that values. However, in all the discussions, every farmer accepted the fact of soil being degraded over the years with the practices that are being followed in the landscape. Farmers even acknowledge the excessive use of chemical fertiliser and pesticides has had an enormous role in degrading soil health. In addition, farmers mentioned that their field

soil compaction has increased and hardened. The hardened soil and less porous soil hinder the root penetration and affect water absorption and water table recharge.

Interestingly, farmers in Mohkhed are already looking for alternatives (OBC villages) to chemical inputs with organic fertilisers. Farmers in the group showed the containers of last season's purchased organic inputs (costlier than chemical) they have been using to protect the soil. However, they face the unavailability of cheap and effective organic inputs in the vicinity. Whatever is available is very expensive and not actually organic (physical verification was done by the team).

While asking about their willingness to adopt various farm practices such as reduced tillage. In contrast, farmers in the discussion view that reduced tillage can negatively affect crop production. They are under the impression that more tillage leads to better soil quality and reduced pest infestation. However, farmers mentioned that the first and foremost thing for them is the crop yield as their expenses also have increased compared to the past, and they have to meet the today's requirements, and higher crop yield and profit is the only option they have. They would follow the sustainable farm practices subject to similar profit or better market prices. They were reluctant to try new methods or interventions at the cost of profit. Farmers talked about and liked the PepsiCo model of potato cultivation and buy back scheme, where they were trained on each and every aspect of potato cultivation. Therefore, it requires several demonstration plots at the focal point in the villages so that farmers can see the performance of regenerative practices on the crop and productivity, which can enhance adoption.

Interestingly, farmers in the region agree and noticed the changes in the soil those who managed to add the required farmyard manure (FYM) in the soil. The only problem they face is the availability of bio-inputs. Even soil analysis of one farmer (Farmer -Kamal Pathe) in the village Beesapur Khurd, Mohkhed shows SOC (%) ~1.7% equivalent to forest soil due to good use of compost and reduced use of pesticides.

3.2.4 Land Use Land Cover mapping

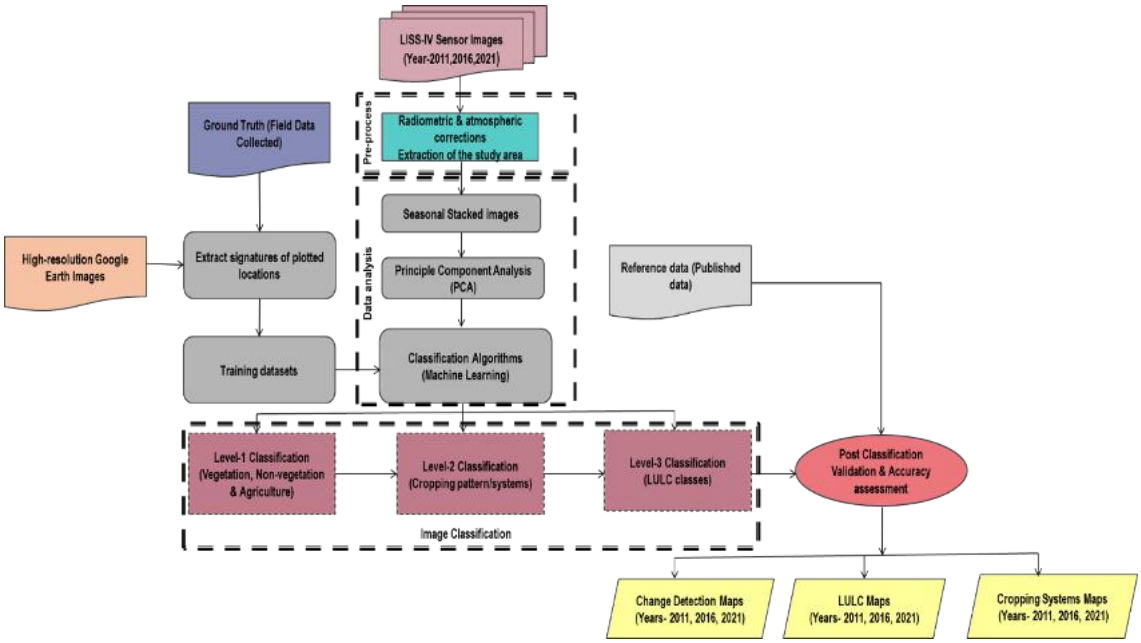
The pre-processing of the temporal Liss-IV imageries for individual years are performed through different processing levels - Radiometric corrections of raw digital numbers conversion to reflectance, Atmospheric corrections to remove the atmospheric disturbances like haze dark pixels. Later the seasonal stacks of the temporal images are generated and clipped to the study region. The principal component analysis method was applied to the datasets to remove the redundant spectral information from the multiband datasets and reduce the dimensionality (Fig 3.10) .

The LULC classification was performed on the PCA stack imageries using the popular machine learning algorithm random forest decision tree technique. The Random Forest (RF) algorithm constructs an ensemble model of decision trees from the random subsets of features and sample training datasets which leads to improved classification accuracy. The RF classifier implements the filter-based selection and runs through the iterative computation for devising key decisions with boosted trees to obtain feature scores. This approach can reduce the class bias and is highly advantageous for analysing the imageries with heterogeneously distributed.

The training sites used in the analysis are generated from ground truth collected for 2020-21 and for other years (2011-12 & 2016-17) the multi-temporal google earth imageries are used to select the suitable training sites for RF algorithms for classification and to assess the accuracy of the classified outputs.

Three (3) levels of classifications are executed, level classification vegetation, non-vegetation and agriculture land signature classes are separated first and then in the level classification, a detailed classification of all the LULC classes is performed.

Fig 3.10 Methodology flowchart diagram



3.2.2.1 LULC- Three (3)-year maps

Using Geospatial techniques, the high-resolution mapping of LULC is helpful in detecting the magnitude of Spatio-temporal dynamics of LULC changes in the study region during the span of 10 years from 2011 to 2021.

The LULC maps generated for the study region have revealed a significant increase in the Dense vegetation (6.6%), Sparse vegetation/ tree cover (6.5%) showing mostly the transition of the shrublands to sparse and dense vegetation where the cropland has decreased by -4.6 % in last 10 years. The trend observed in the wastelands (-3.3%) and shrublands (-5.8 %) has declined drastically showing the expansion of other classes like tree cover, grasslands, sand/mining, and settlements in the region.

The Random forest decision tree algorithms were effective in achieving the overall accuracy of the LULC maps for the each of the years 2020-21 is 91%, 2016-17 with 87.7 % and 2011-12 with 85.6%, And the post-classification accuracy assessment matrix table for each analysed years are presented in Table 9. The change detection of LULC percent change area distribution of each class with respect to the total land coverage of the study area and percent area estimations is shown in the graphical plot in Fig. 3.11.

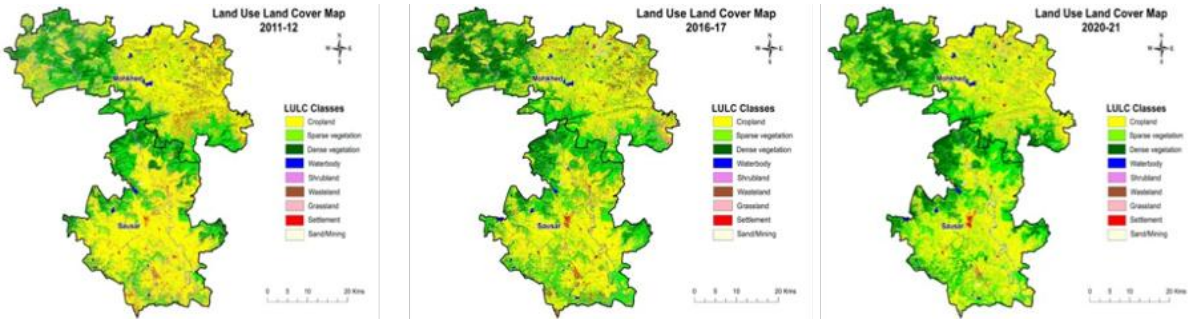


Fig 3.11 **Temporal** land use land cover change

Table 9. Temporal land use land cover change under different LULC classes

Sno	LULC classes	2011-12 (Area in %)	2016-17 (Area in %)	2020-21 (Area in %)
1	Dense vegetation	12.87	17.31	19.39
2	Sparse vegetation	20.62	24.63	27.09
3	Waterbody	1.14	1.16	1.16
4	Shrubland	7.06	2.25	1.24
5	Cropland	50.69	46.23	46.05
6	Grassland	1.06	1.20	1.21
7	Wasteland	4.66	5.50	1.28
8	Settlement	1.16	1.30	1.33
9	Sand/mining	0.74	0.41	1.25

3.2.5 GHG emission estimations

Agriculture is a major contributor to the GHGs emissions both in developing and developed countries and the share will continue to increase if mitigation efforts are not applied. Improving the understanding and fostering of large-scale adoption of RA requires soil quality monitoring systems that integrate farmers' and researchers' knowledge. Robust data on greenhouse gas emissions and emissions reductions and practical methods for MRV are required to transition to low emissions regenerative system development in agriculture. The emissions also vary in Kharif and Rabi/Boro seasons and different mitigation strategies need to be applied accordingly.

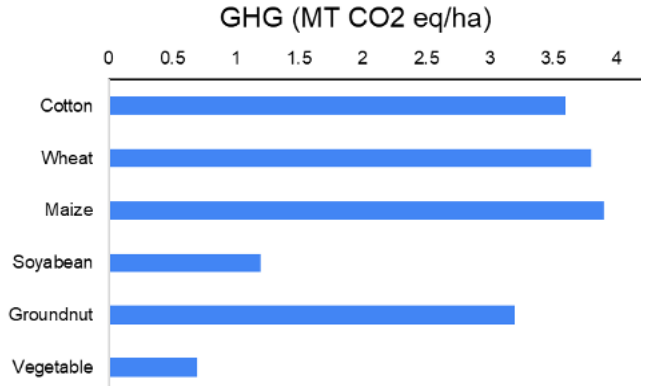


Fig 3.12 GHG emissions per hectare from different crops

Cotton, maize, wheat, soyabean, the major crops grown in the region also have the highest GHG emissions (Fig. 3.12). Conventional tillage coupled with excessive fertilizer input leads to higher GHG emissions. The production of synthetic nitrogen (N) fertiliser incurred significant GHG emissions, mainly as CO2 from the use of fossil fuels in the production of ammonia and N2O emissions during the production of nitric acid. Several factors impact the GHG emissions from fertiliser production, namely the type of fertiliser, the technology and feedstock used and the presence or absence of N2O abatement technologies (Brentrup et al., 2004).

Reducing tillage intensity, optimizing nitrogen fertilizer application, improving soil health through increased SOC, changes in cropping systems, and diversification can help in reducing the GHG emission from the Chhindwara landscape.

In qualitative inquiry, we inquire whether farmers are experiencing the changes in weather conditions and how their practices of using chemical fertilisers and farm practices contribute to it by emitting harmful gases and how they can mitigate this by adopting better management practices. Though farmers are aware that cutting trees contributes majorly to climate change, they do not have much knowledge about the contribution of the farm practices they follow to climate change. However, as described earlier, farmers' main reason for adopting new techniques is to improve yield and profit. Therefore, they are ready to adopt sustainable agricultural practices if those practices benefit them. Farmers were keen to use bio-inputs to reduce emissions only if they were as potent as chemical fertilisers.

3.2.5.1 Burning incidences maps

The data on fire incidents has been derived from NASA's FIRMS. Archived data from SUOMI VIIRS C2 data from 2012 to 2021. The datasets were processed to drop out the points which were having low confidence levels and the rest were used over the latest (2020-21) LULC to separate out the fire incidences in agricultural areas and non-agricultural areas. The data points falling were considered for further analysis to count the number of incidences. The cumulative sum of these incidents was plotted against the time period after Kharif and Rabi for three (3) years namely: 2012, 2016 and 2021.

The map (Fig 3.13) depicts the distribution of fire incidents, and it is clearly visible that there are almost negligible fire incidents after Kharif although the incidents increased over the years. Fire incidents after the Rabi harvest were relatively higher and increased over time. Around 14 and eight (8) percent of farmers in the landscape reported burning the fields to clear the residues. The higher number of fires after Rabi could be attributed to farmers' willingness to clear fields early for short term crops after Rabi when soil moisture is still optimum.

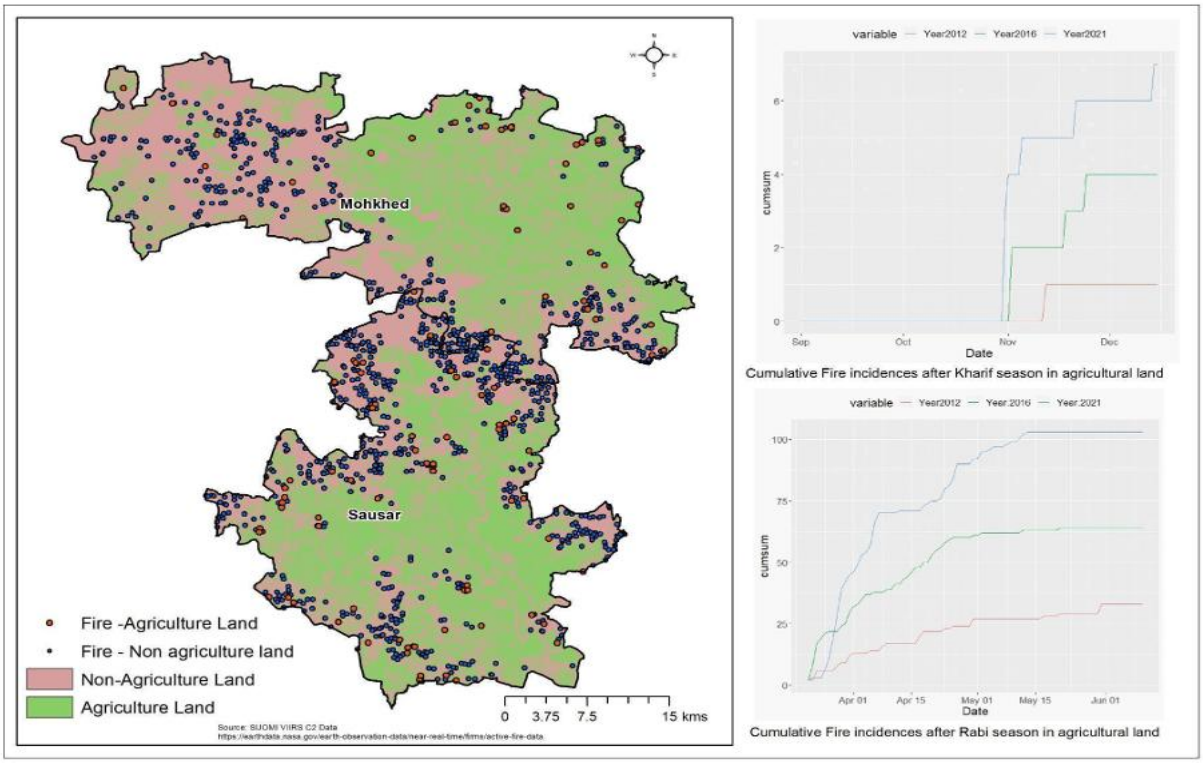


Fig 3.13 The distribution of fire incidents in study site

Straw burning incidence or practices is higher than reported in the HH survey, as observed during qualitative exercise. It is common practice for Cotton farmers to burn the residue, whether on the field or as cooking fuel and they do not have alternatives to utilise it, similar to Soyabean and Tur. Many farmers have reported using a crop like Maize and Wheat for livestock. Those who do not have livestock follow the burning practice. Farmers said to be interested in utilising it productively if provided with a potential solution like Biochar or composting. There are many solutions to using the crop residue, which is being tested by the Regenerative agricultural scientists & experts (also part of the RPLC technical committee) in India, which can be introduced to our landscapes to reduce straw burning.

3.2.5.2 GHGs mitigation options under various RA interventions

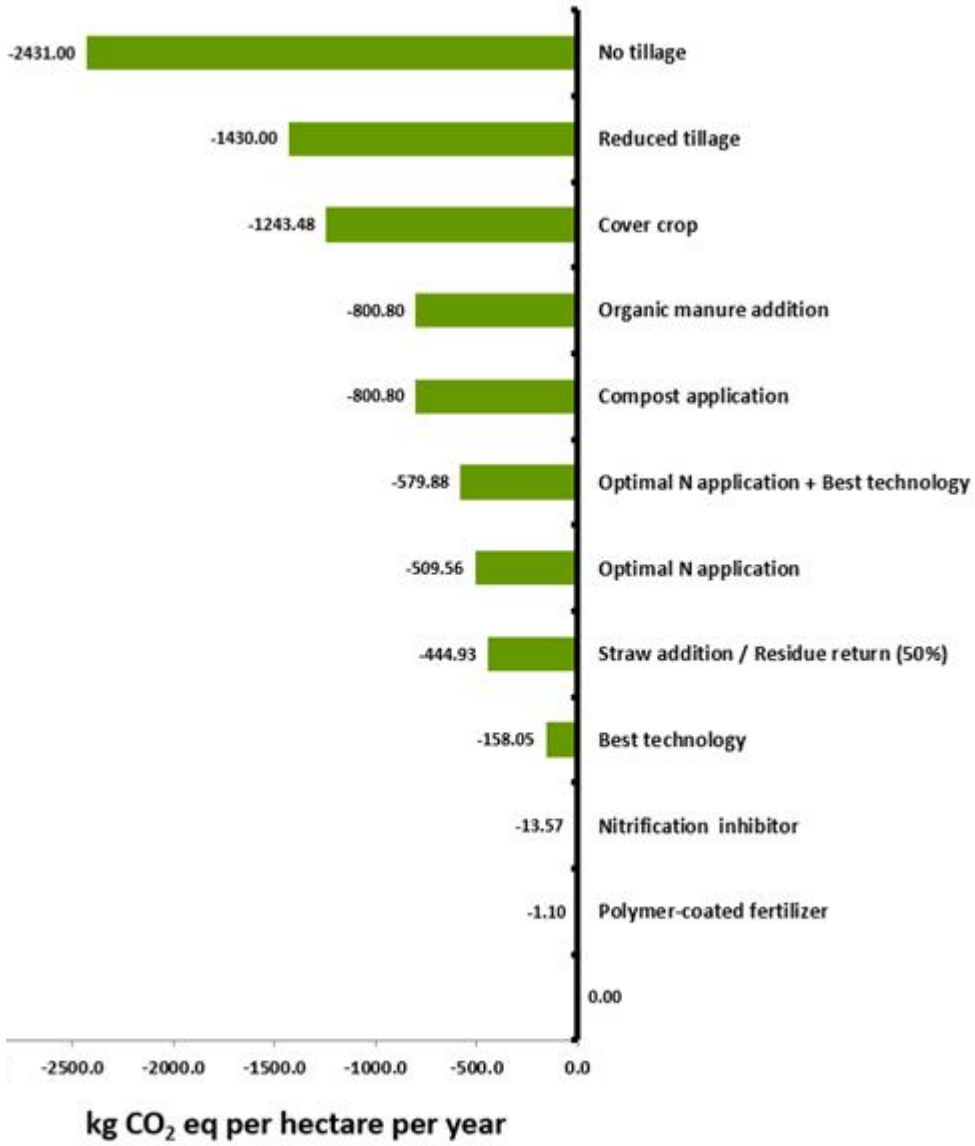


Fig 3.14 diverse technologies for mitigating GHG emissions

The graph above offers diverse technologies for mitigating GHG emissions at scale but site-specific technologies need to be evaluated and adopted (Fig 3.14). See Annexure 4 for:

- Mitigation potential of not burning the residues
- Mitigation potential of optimum N rate
- Mitigation potential of shifting from conventional tillage to reduced tillage and zero tillage

3.2.6 Soil respiration under different land uses

Soil respiration is a major contributor to carbon dioxide (CO_2) release into the atmosphere through heterotrophic soil organisms (e.g., bacteria, fungi, invertebrates), autotrophs (e.g. plant roots) and, to a lesser extent, abiotic degradation of organic matter and carbonate weathering. Like most primarily biological reactions, soil respiration is highly dependent on temperature and sufficient water availability and thus on seasonality, with a maximum respiration rate observed during periods of higher temperatures and intermediate soil moisture content. Throughout the

incubation period, C mineralization under rice was higher compared to other crops and forest soils. This might be due to the higher accumulation of fresh organic matter during the growth period which is subsequently released during incubation (Fig 3.15). In Sausar, forest soils followed by cotton and onion soils showed higher carbon mineralization. Increasing labile organic input and conducive micro-climate may have contributed to higher soil respiration as compared to other crops.

Fig 3.15 Soil C mineralization under different land use in Mohkhed and Sausar at upper soil depth (0-15 cm)

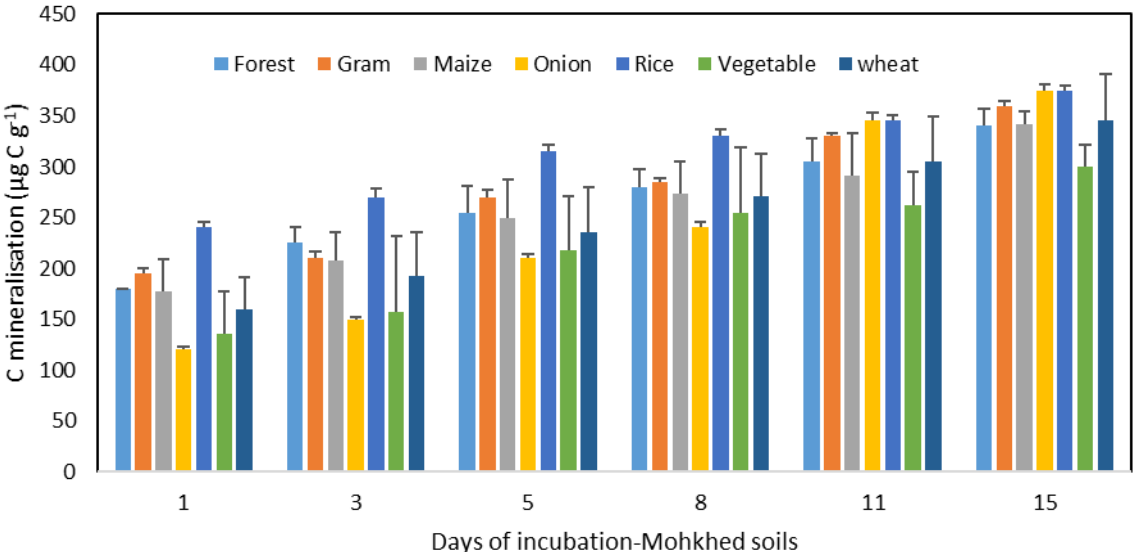
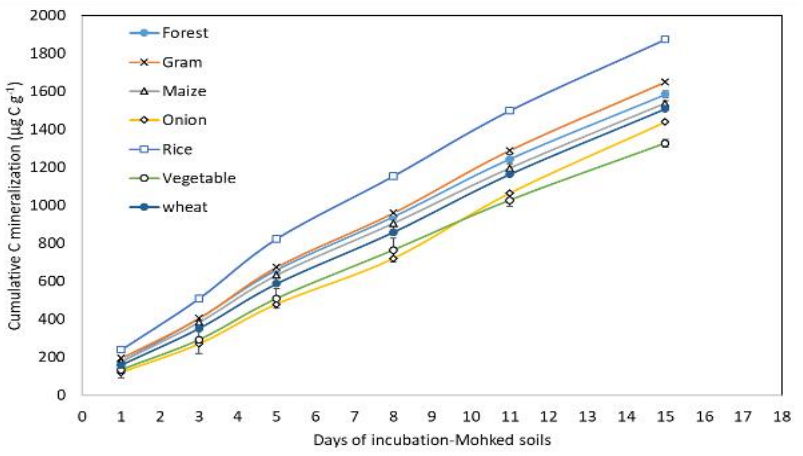
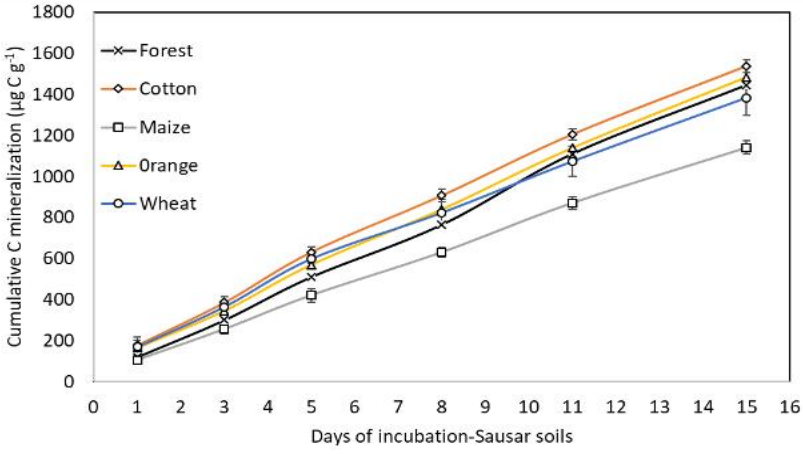


Fig. 3.16 Changes in cumulative carbon mineralization on different days under different crops in Mohkhed and Sausar. Vertical bars indicate standard deviation of the mean





A steep increase was observed in both the blocks for all the crops and forest soils till 15 days of incubation, and that indicates more time required for further C mineralization (Fig. 3.16). Soils under forest, rice, cotton and onion with higher mineralization of organic carbon leading to more nutrient availability to plants. But higher mineralization also produces higher CO2 to the atmosphere. Therefore, in situ measurement of CO2 and GHGs under different land use deserves further experimental study to verify the findings of the baseline.

3.2.7 Use of Agrochemicals

Table 10 presents the usage of different types of fertilizers and pesticides in Rabi and in Kharif for the main crop in each block. In northern region, the major crop under Rabi is Wheat and Maize in Kharif. In southern region, the major crops are Wheat in Rabi and Cotton in Kharif.

More than 95 percent of the farmers in both northern and southern region use Urea and DAP in both seasons (table 11). However, the use of SSP is substantially higher for the Cotton crop in the southern region (80% farmers). Potassium is used by close to 64 per cent of the farmers during kharif crop in southern region. For the other four (4) fertilizers, the usage has been just one (1) per cent or lower for all crops except for Cotton cultivation in southern region where almost 11 per cent of farmers have used Complex fertilizer.

Among pesticides, the usage of herbicides is the highest (little less than 80 percent) in northern region followed by insecticides (18-32 percent) and rodenticides (2-12 percent). In southern region, the use of herbicide and rodenticide is relatively low, but almost 81 percent of farmers reported using insecticides for cotton crops. Irrespective of season, the pattern for use of fertilizer particularly urea was similar with Northern and Southern region. Seasonal variability was observed particularly Kharif had lower DAP use in control region.

Table 10. Use of fertilizers and Pesticides by Season in Mohkhed and Sausar and Control

	Northern		Southern		Control	
	Rabi Season - Wheat	Kharif Season - Maize	Rabi Season - Wheat	Kharif Season - Cotton	Rabi Season - Wheat	Kharif Season - Soyabean
Fertilizers Used						
Urea	99.00%	96.00%	97.00%	99.00%	97%	100%
DAP	98.00%	95.00%	93.00%	95.00%	99%	59%
SSP	15.00%	5.60%	23.00%	80.00%	38%	9%
Potassium	25.00%	19.00%	16.00%	64.00%	37%	9%
Liquid	0.40%	0.00%	0.00%	0.00%	7%	0%
Complex	1.50%	0.40%	2.00%	11.00%	0%	0%
Organic	3.00%	0.90%	0.00%	1.30%	0%	3%
Zinc	1.80%	0.40%	0.00%	0.90%	0%	0%
Pesticides Used						
Insecticide	18.10%	32.10%	12.90%	80.90%	17%	56%
Herbicide	78.60%	79.10%	21.80%	16.30%	60%	62%
Fungicide	0.00%	0.40%	0.00%	1.90%	3%	0%
Rodenticide	11.80%	1.70%	4.00%	0.00%	0%	0%
Bactericides	0.70%	0.40%	0.00%	84.30%	0%	0%

Table 11. Use of fertilizer and pesticides by crop and season in Mohkhed and Sausar

Season and Crop	Variables			
		Northern region	Southern Region	Control region
		mean	mean	mean
Rabi Season				
Wheat	Fertilizer use (Kg/Acre) - Urea	81.0	68.0	95.3
	Fertilizer use (Kg/Acre) - DAP	46.0	44.0	45.2
	Fertilizer use (Kg/Acre) - SSP	40	41.0	43.2
	Fertilizer use (Kg/Acre) – Potassium	30.0	37.0	36.6
	Fertilizer use (Kg/Acre) - Liquid	2.0	.	
	Fertilizer use (Kg/Acre) - Complex	40.8	66.7	
	Fertilizer use (Kg/Acre) - Organic	901.1	.	37.8
	Fertilizer use (Kg/Acre) - Zinc	3.2	.	
	Pesticide Use (Litres/Acre) - Insecticide	0.4	0.5	0.6
	Pesticide Use (Litres/Acre) - Herbicide	0.3	0.4	0.7
	Pesticide Use (Litres/Acre) - Fungicide	.	.	
	Pesticide Use (Litres/Acre) - Rodenticide	0.4	0.2	0.7
	Seed use kg/acre	46.0	30.0	43.6
	Pesticide Use (Litres/Acre) - Bactericides	0.2	.	0
Kharif Season				
Soybean	Seed use kg/acre	38		38.1
	Fertilizer use (Kg/Acre) - Urea	33.0		51.9
	Fertilizer use (Kg/Acre) - DAP	39.0		43.1
	Fertilizer use (Kg/Acre) - SSP	.		48.3
	Fertilizer use (Kg/Acre) - Potassium	10.9		20.6

	Fertilizer use (Kg/Acre) - Liquid	13.3		
	Fertilizer use (Kg/Acre) - Complex	13.3		20.0
	Fertilizer use (Kg/Acre) - Organic	1.7		
	Fertilizer use (Kg/Acre) - Zinc	5.0		
	Pesticide Use (Litres/Acre) - Insecticide	0.7		0.9
	Pesticide Use (Litres/Acre) - Herbicide	0.5		0.5
	Pesticide Use (Litres/Acre) - Fungicide	0.1		
	Pesticide Use (Litres/Acre) - Rodenticide	.		
	Pesticide Use (Litres/Acre) - Bactericides	.		
Cotton	Seed use kg/acre		0.7	0.72
	Fertilizer use (Kg/Acre) - Urea		62.0	120.7
	Fertilizer use (Kg/Acre) - DAP		60.0	72.3
	Fertilizer use (Kg/Acre) - SSP		59.0	70.1
	Fertilizer use (Kg/Acre) - Potassium		35.0	51.2
	Fertilizer use (Kg/Acre) - Liquid		.	
	Fertilizer use (Kg/Acre) - Complex		44.0	45.1
	Fertilizer use (Kg/Acre) - Organic		48.8	10.0
	Fertilizer use (Kg/Acre) - Zinc		114.4	
	Pesticide Use (Litres/Acre) - Insecticide		0.7	0.7
	Pesticide Use (Litres/Acre) - Herbicide		0.8	0.9
	Pesticide Use (Litres/Acre) - Fungicide		0.4	
	Pesticide Use (Litres/Acre) - Rodenticide		.	
	Pesticide Use (Litres/Acre) - Bactericides		0.5	
Maize	Seed use kg/acre	6.0		8.03

	Fertilizer use (Kg/Acre) - Urea	100.0		115.3
	Fertilizer use (Kg/Acre) - DAP	47.0		50.5
	Fertilizer use (Kg/Acre) - SSP	23.7		50.4
	Fertilizer use (Kg/Acre) - Potassium	32.0		37.8
	Fertilizer use (Kg/Acre) - Liquid	.		
	Fertilizer use (Kg/Acre) - Complex	28.0		7.6
	Fertilizer use (Kg/Acre) - Organic	37.8		340.5
	Fertilizer use (Kg/Acre) - Zinc	5.0		20.0
	Pesticide Use (Litres/Acre) - Insecticide	0.5		0.6
	Pesticide Use (Litres/Acre) - Herbicide	0.5		0.5
	Pesticide Use (Litres/Acre) - Fungicide	0.4		
	Pesticide Use (Litres/Acre) - Rodenticide	0.2		
	Pesticide Use (Litres/Acre) - Bactericides	1.0		

As per the HHs survey, the N application rate is low as compared to state fertilizer recommendations for different crops. For instance, the N recommendation for maize and wheat is 150 and 120 kg/ha, which is about 326 and 260 kg urea/ha. The findings are also evidenced by soil analysis. The soils with <250 kg N/ha are deficient in nitrogen, which is not sufficient to support crop yield gains. Chemical fertilizer application rate was higher in control region across the crops and season whereas the organic inputs was considerably lower.

During qualitative inquiry, optimum and reduced use of chemical fertilizers and pesticides integrated with organic ones has shown mixed results in previous interventions, as reported by farmers. The more potent organic fertilizers and pesticides with proper dosage and usage information are required to reduce the pesticide usage. Farmers in Mohkhed are more inclined to the use organic pesticides, and many farmers reported to have using organic pesticides, the cost of which is RsRs 1800 per bottle, which is higher than chemical pesticides (most commonly used chemicals are Emamectin Benzoate, Imidacloprid, Monocrotophos 36%, and Beta-Cyfluthrin).

During the discussion with farmers on regenerative practice adoption, none of the farmers seems hesitant to adopt. However, a package of practices and assurance of no yield penalty is the primary concern. As discussed above, farmers in the northern region are already moving

towards integrated nutrient and pest management and purchasing organic pesticides from the market.

3.2.8 Water use efficiency (WUE)

Water utilization by the crop is generally described in terms of water use efficiency or productivity. WUE can be increased in two (2) ways, either by increasing yield or by saving water. Irrigated agriculture is far more productive than rainfed agriculture, but in India, more than 65 % of the area is under rainfed agriculture and there is an equal need of increasing the productivity of water.

In this baseline, the WUE of key crops in the landscape was comparatively low as per the previously reported studies (Reddy and Reddy 2004). There is a scope for increasing the WUE in crops like vegetables, wheat, gram and oranges through the use of micro-irrigation systems and implementation of in-situ soil moisture options like mulching and increasing SOC.

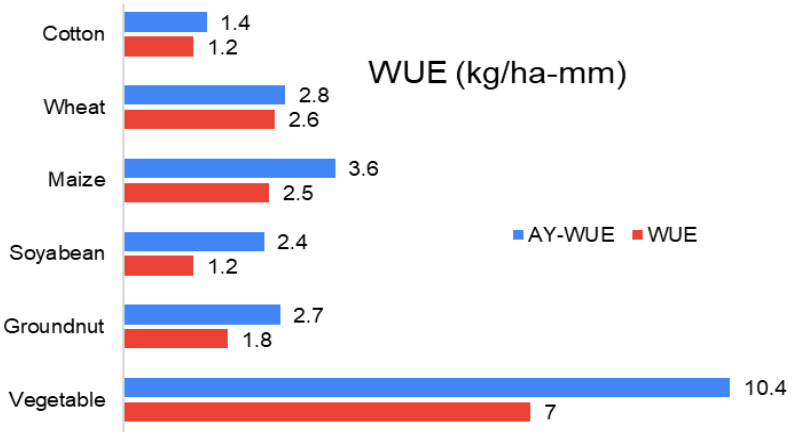


Fig. 3.17 WUE for attainable and observed yield of different crops

*For the details of Season and crop-wise WUE in Mohkhed and Sausar block of Chhindwara MP, go to Annexure 5

Practical strategies for enhancing WUE have also been discussed in the above section, such as soil moisture conservation and yield enhancement technologies such as varieties and practices. However, farmers require proper guidance in chart form or brochure on irrigation scheduling, especially for rabi crops, those who have irrigation facilities to enhance WUE. Similarly, micro-irrigation technologies are gaining popularity among the farmers, and the team sees no challenges in promoting the micro-irrigation facility except by linking it to government subsidy or financing. However, most of them suffer from poor water availability, Thus, working towards enhancement of water access and then providing solutions to optimised irrigation is required to achieve optimum WUE.

Srijan intervention (farm pond model) in several villages has gained popularity among farmers due to enhanced cropping intensity and crop productivity. More and more farmers are coming forward to construct farm ponds in the five (5) per cent area of their field. Similarly, many farmers shifted to tomato cultivation and earning well in the last few years and invested in drip irrigation. The trend to installing drip irrigation increased as it secured timely and optimised irrigation.

3.2.9 Temporal changes in water bodies map

The temporal change in the water body was extracted using data from the Global Surface Water portal of the European Commission's Joint Research Centre. The map depicts the changes in monthly water extent across the study site. There has been considerable variation in the extent of water spread. The area chart on the map for four of the prominent water bodies in the region shows high water spread during the monsoon and winter seasons (November to January) while summers (May-June) have usually lower spread (Fig. 18).

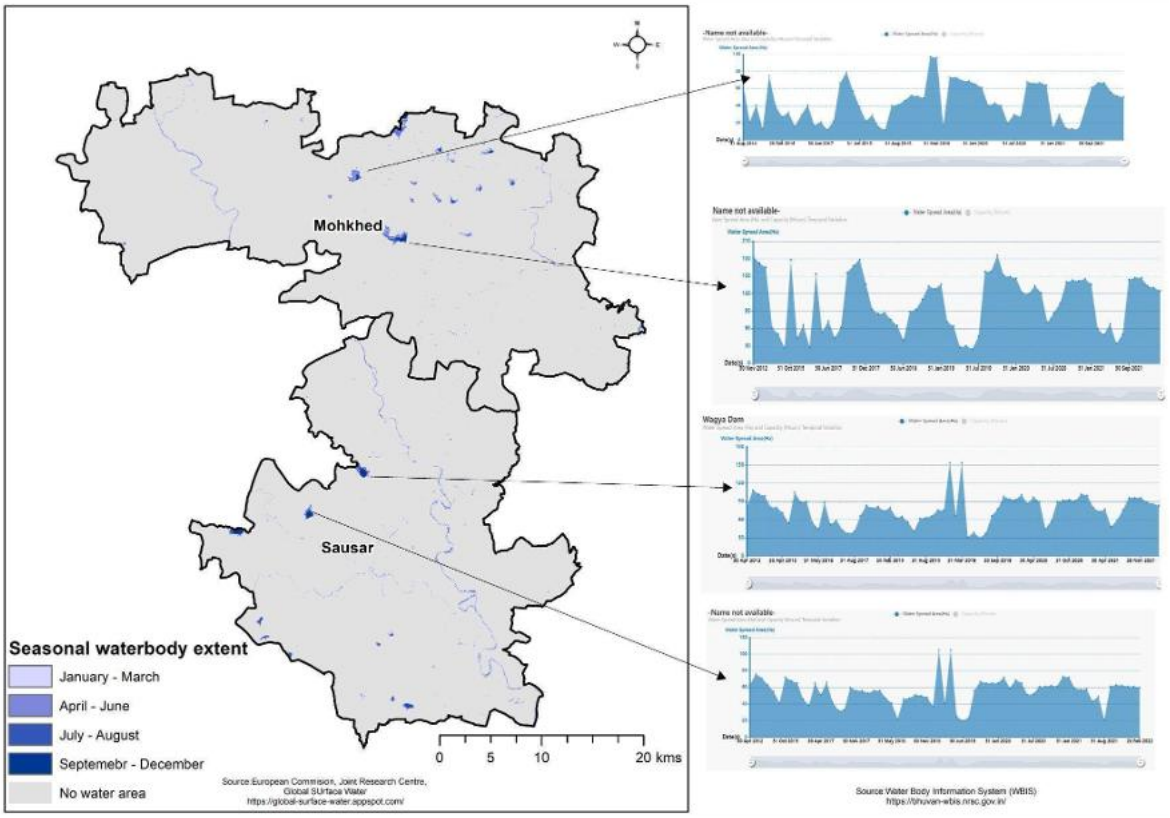


Fig 3.18 Changes in monthly water extent across the study site

3.2.10 Biodiversity activities undertaken by farmers

Table 12 presents frequency distribution of farmers undertaking different types of biodiversity activities by farmers. Around 10 percent of farmers report to have undertaking agroforestry and eight (8) per cent livestock rearing. The proportion of farmers have undertaken activities such as earthworms' propagation is close to two (2) per cent while beekeeping, and propagation activities is nil.

Table 12. Farmers undertaking different types of biodiversity activities

Activities	Treatment%	Control%
Type of biodiversity activity - Agroforestry	10.05	18%
Type of biodiversity activity - Livestock	8.30	38%
Type of biodiversity activity - Fisheries	0.14	0%
Type of biodiversity activity - Species	1.74	7%
Type of biodiversity activity - Earthworm	2.04	1%
Type of biodiversity activity - Bees	0	0%

In southern region, the proportion of farmers undertaking any biodiversity activities is much lower than that in northern region (Annexure 6).

Wild boar and Indian Antelope are frequently causing losses in the farmers' fields and landscapes. The intrusion of animals has increased over the years. As a result, farmers are forced to hurt these animals to protect their crops from them. Farmers also stated that intrusion has increased due to the loss of trees surrounding the village. Significant interventions are required to protect the wild animals and the farmer's field by developing the natural fencing of bamboo trees or community plantations surrounding the villages.

Farmers reported to have practised planting trees or keeping the trees (mainly mango, Jamun, and Lemon) in the bunds of their field, but the nuisance of monkeys in their area caused them to log trees in their field. However, they now realise the ill effects (in terms of soil quality), bee population and rainfall patterns. Interestingly, farmers are willing to plant trees of new Mango varieties, Jamun, and Guava (early maturing and semi-dwarf) in their field if provided with improved seedlings.

3.3 Inclusion Pillar

3.3.1 Ownership of Farming Assets

Table 13 presents the list of assets owned by HHs in all three (3) blocks. Comparatively, HHs in the northern block own a greater proportion of the assets. For example, 57 per cent of HHs in the northern block own Draft Animals compared to 47 per cent of the southern block and 55 per cent of control block. Approximately 63 per cent of HHs in the northern block own electric motor pump compared to 34 per cent of the farmers in the southern block. The southern block HHs own the highest proportion in only few of the farm assets such as Diesel Motor Pump and Thresher (Pedal). Similarly, the control block HHs own the highest proportion in only Weeder and Power Spayer.

Table 13. Assets owned by households

	Northern	Southern	Control
Ownership for Farm Assets			
Draft Animal	57%	47%	55%
Four Wheel Tractor	11%	3%	7%
Two-Wheel Tractor/Power Tiller	0%	0%	0%
Truck	0%	0%	0%
Blade-Harrow	0%	0%	0%
Treadle Pump	1%	0%	0%
Rower Pump	0%	0%	0%
Sprinkler	13%	17%	12%
Submersible Pump	12%	8%	10%
Electric Motor Pump	63%	34%	35%
Diesel Motor Pump	0%	2%	0%
Transplanter	0%	0%	0%
Seed Drill	4%	0%	1%
Drum Seeder	0%	0%	0%
Rotavator	4%	2%	2%
Weeder	0%	1%	2%
Power Sprayer	23%	10%	28%
Harvester	0%	0%	0%
Thresher (Pedal)	0%	1%	0%
Mechanical Thresher	4%	1%	2%
Husking Machine	0%	0%	0%
Mechanical Dryer	0%	0%	0%
Fodder/Chaff Cutter	1%	0%	0%
Any Other	1%	1%	0%

3.3.2 Cultivable plots characteristics and stress

Tables 14 , 15 and 16 presents characteristics and stresses suffered for up to six (6) plots a farmer may cultivate for the northern block, southern block and control block, respectively. In all three (3) blocks, less than six (6) per cent of farmers report shared cropping on a plot. While no one in the southern block and northern block has reported outright renting

of a plot, almost four (4) per cent and 13 per cent farmers rented in and rented out plots in the control block respectively. This majority of the cultivated farms are owned. In all three (3) blocks, majority of the farmers report having medium grade land and a small minority report having low grade land. In the northern and control blocks, majority of the plots have black soil but a sizeable proportion (approx. 36-40% amongst first three (3) plots) also has red soil, proportion of sandy soil is negligible. However, in the southern block, between 15-22 per cent of the plots (based on first three (3) plots) have sandy soil. Consequently, proportions of farmers having black or red soil is comparatively lower than those in the northern block and the control block. Considering the first two (2) plots where sample size is somewhat reasonably large to have stable descriptive statistics, majority of the three (3) blocks have not suffered any climate change related stresses yet. However, 12-15 per cent farmer in the northern block, 31-47 per cent in the southern block and 13-28 per cent in the control block report that their plot has suffered from flood in the past year. No farmers have reported other stresses such as drought, acidity, heat stress, pest diseases or infestation.

Table 14. Cultivable plots characteristics and climate change stresses, northern region

	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Plot 6	
	N	mean	N	mean	N	mean	N	mean	N	mean	N	mean
Area of the Plot (Acres)	339	2.74	198	2.08	53	1.37	19	2.56	9	0.87	4	0.81
Plot Ownership												
Rented In	343	0%	206	0%	55	0%	20	0%	9	0%	4	0%
Rented Out	343	0%	206	0%	55	0%	20	0%	9	0%	4	0%
Shared	343	2%	206	1%	55	2%	20	5%	9	0%	4	0%
Type of Land												
High	343	22%	206	24%	55	16%	20	20%	9	11%	4	0%
Medium	343	71%	206	67%	55	73%	20	70%	9	78%	4	100%
Low	343	7%	206	9%	55	11%	20	10%	9	11%	4	0%
Type of Soil												
Red	343	40%	206	36%	55	42%	20	15%	9	11%	4	25%
Black	343	53%	206	54%	55	55%	20	75%	9	78%	4	50%
Sandy	343	6%	206	6%	55	2%	20	0%	9	11%	4	0%
Other	343	2%	206	4%	55	2%	20	10%	9	0%	4	25%
Land Fertility												
High	343	34%	206	31%	55	22%	20	20%	9	22%	4	25%
Average	343	51%	206	47%	55	53%	20	60%	9	44%	4	25%
Low	343	15%	206	22%	55	25%	20	20%	9	33%	4	50%

Table 15. Cultivable plots characteristics and climate change stresses, southern region

	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Plot 6	
	N	mean	N	mean	N	mean	N	mean	N	mean	N	mean
Area of the Plot (Acres)	341	3.70	76	2.55	9	2.01	3	1.35	1	1.00	1	2.00
Plot Ownership												
Rented In	343	0%	79	0%	9	0%	3	0%	1	0%	1	0%
Rented Out	343	0%	79	0%	9	0%	3	0%	1	0%	1	0%
Shared	343	0%	79	1%	9	0%	3	0%	1	0%	1	0%
Type of Land												

High	343	26%	79	14%	9	0%	3	0%	1	0%	1	0%
Medium	343	62%	79	73%	9	89%	3	100%	1	100%	1	100%
Low	343	12%	79	13%	9	11%	3	0%	1	0%	1	0%
Type of Soil												
Red	343	25%	79	19%	9	22%	3	0%	1	0%	1	0%
Black	343	39%	79	44%	9	33%	3	67%	1	0%	1	100%
Sandy	343	18%	79	15%	9	22%	3	33%	1	0%	1	0%
Other	343	18%	79	22%	9	0%	3	0%	1	100%	1	0%
Land Fertility												
High	343	31%	79	44%	9	33%	3	67%	1	100%	1	100%
Average	343	40%	79	34%	9	56%	3	33%	1	0%	1	0%
Low	343	29%	79	22%	9	11%	3	0%	1	0%	1	0%

Table 16. Cultivable plots characteristics and climate change stresses, Control

	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Plot 6	
	N	mean	N	mean	N	mean	N	mean	N	mean	N	mean
Area of the Plot (Acres)	341	3.08	110	2.21	30	2.03	8	2.50	2	1.63	2	1.70
Plot Ownership												
Rented In	342	0%	115	4%	32	3%	8	0%	2	0%	2	0%
Rented Out	342	0%	115	1%	32	3%	8	13%	2	0%	2	0%
Shared	342	3%	115	3%	32	6%	8	0%	2	0%	2	0%
Type of Land												
High	342	23%	115	18%	32	6%	8	13%	2	50%	2	0%
Medium	342	71%	115	70%	32	72%	8	50%	2	50%	2	100%
Low	342	6%	115	12%	32	22%	8	38%	2	0%	2	0%
Type of Soil												
Red	342	37%	115	41%	32	38%	8	63%	2	50%	2	50%
Black	342	56%	115	48%	32	56%	8	25%	2	50%	2	50%
Sandy	342	3%	115	4%	32	3%	8	0%	2	0%	2	0%
Other	342	4%	115	7%	32	3%	8	0%	2	0%	2	0%
Land Fertility												
High	342	22%	115	21%	32	9%	8	13%	2	0%	2	0%
Average	342	63%	115	64%	32	63%	8	75%	2	100%	2	100%
Low	342	15%	115	15%	32	28%	8	13%	2	0%	2	0%

Table 17 presents whether and what type of climate change related stress the farmers suffered in past five years. In all three blocks, nearly two-fifth of the small farmers reported pest diseases and drought as most common. In the southern block, much higher proportion of farmers reported floods compared to those in the northern and control blocks. Fifteen per cent of the large farmers have also reported acidity in soil as a stress event they have suffered in past five (5) years in the northern block. Among those who reported a stress even, we also asked number of occurrences over past five (5) years. The numbers typically range from two to four (2-4) suggesting that these stress events are common occurrences.

Table 17. Details of stress occurred, as reported by respondents

	Northern region			Southern region			Control		
	Small Farmer	Medium Farmer	Large Farmer	Small Farmer	Medium Farmer	Large Farmer	Small Farmer	Medium Farmer	Large Farmer
% Farmers who suffered any sort of stress event	35%	41%	43%	40%	40%	30%	34%	29%	43%
Floods									
% Reporting stress	24%	31%	29%	41%	49%	42%	35%	37%	28%
No of occurrences in 5 years	2.7	2	3.2	2.1	2.3	2.2	2.4	1.9	2.4
Drought									
% Reporting stress	41%	30%	29%	38%	25%	23%	35%	42%	33%
No of occurrences in 5 years	3.7	3.7	2.0	2.3	2.7	2.2	3.8	3.7	3.9
Acidity in Soil									
% Reporting stress	8%	2%	15%	0%	12%	4%	0%	0%	5%
No of occurrences in 5 years	1.7	2	3.6	.	1.6	3	0	0	1.5
Heat Stress									
% Reporting stress	3%	6%	3%	0%	5%	4%	0%	2%	5%
No of occurrences in 5 years	5	506	2	.	1.7	5	0	5.0	2.0
Pest Diseases									
% Reporting stress	43%	27%	38%	41%	40%	46%	35%	40%	43%
No of occurrences in 5 years	2.5	2.4	3.1	2.2	2	1.9	1.4	1.7	1.5

3.3.3 Income of Farmers

Table 18 depicts the income from farming, secondary and other sources for both regions. Farmers are subdivided into categories based on the region. Comparing the means, farmers in southern region earn more than farmers in northern region from farming activity and secondary sources of income (See Annexure 6). The questionnaire also asked about income from additional sources not covered under farming or secondary sources (in Table 19). Among those who reported such income, the average income from such other sources is higher in northern region. However, when total across all incomes is considered, farmers in southern region have substantially higher income.

Table 18. Income from farming, secondary and other sources (in Rs)

Source	Overall	Cotton Farmer	Maize Farmer
Primary Source	84,400	104,440	59,815
Secondary Source	43,844	51,270	34,571
Other Sources	13,368	9,825	17,722
Total	128,000	149,542	100,957

In Table 19, more details on type of no-farming sources of income is presented. The table depicts that the HHs in northern block comparatively have a greater proportion of income from other sources. For example, HHs that receive income from remittances are just 1.5 percent in southern block, 4.09 in control block, compared to 9.4 per cent in northern block. For most of the sources, southern block is at the bottom of the three comparatively except in the case of pensions (17 per cent). The control block has highest proportion in sources like Household Business (8.92 per cent) and Other sources (8.48 per cent).

Table 19. Proportion of Farmers Reporting Income from Other Sources

Type of Income Source	Northern	Southern	Control
Sale of Forest Produce	17.0%	7.3%	13.16%
Rental income (house, land, machinery, etc)	2.0%	0.6%	0.29%
Sale of assets (land, machinery, etc)	0.4%	0.0%	0%
Pension	18.0%	17.0%	16.67%
Remittances	9.4%	1.5%	4.09%
Interest from savings	0.0%	0.0%	0.29%
Gifts or donations received	1.2%	0.0%	0%
Household business (small shop)	2.0%	1.5%	2.92%
Buying and selling of vegetables	12.0%	0.6%	2.63%
Buy and sell business	1.6%	1.5%	0.88%
Sale of livestock and livestock products	28.0%	9.4%	12.87%
Others	3.0%	0.0%	8.48%

The team enquired about the total annual income of a household from the qualitative participants. Most of the farmers in our discussion had cultivable land, around five (5) acres up to 10 acres. And based on the cropping pattern and intensity, each farmer shared different income figures, especially those in vegetable cultivation, who reported higher amounts up to three (3) lacs per annum. In contrast, single cropping farmers reported 60,000 to 80,000 (Euro 738 to 984) per annum for an average of five (5) acres of land. Therefore, the Rs 128,000 (Euro 1574) as the average income of households in the landscape seems precise considering the heterogeneity of farmers' profiles in the landscapes.

Followed by the discussion on annual income, we enquired about the potential to enhance household income. Since agriculture is the primary source of livelihood for most farmers, all farmers have emphasised better market prices for their produce and higher yield. To enhance households' income, farmers agreed that enhancing crop production would impact the revenue as it has been low compared to the potential. The provision of new varieties, better practices and quality inputs will significantly impact the production. However, the assured markets have a crucial role in realising the increased output to monetary values. Local traders are the primary

avenue for selling the produce. Even in mandies, they face challenges; thus, traders are the bestselling options even if the price is lower.

Farmers also emphasised that livestock rearing could also provide a potential earning source. However, it has drastically reduced due to a shortage of localised available feed and lower prices of livestock products, mainly milk and value-added products. Farmers are getting the price per litre of selling milk is 20 to 25 rupees. Also, the money they get from the sale of milk produced does not justify the maintenance cost of livestock. Farmers have suggested that the opening of dairies or bulk buyers will significantly impact income from livestock (Cow, Buffalo milk) with reasonable produce prices. That will also provide them ample FYM to add to their field, as most farmers buy the FYM at Rs 2500 per trolley from ST (Adivasis) villages. The farmers also welcome the idea of Napier grass on the field. Farmers have also shown interest in goat and sheep rearing as they require low maintenance and give high profits.

3.3.4 Decision-Making by gender in farm and household activities

Tables 20 and 21 lists 38 farming related decisions and presents the proportion of households where the decision is taken by men, women, or both. In northern region, for most of the farming decisions, it is the man taking the decision and implementing it. For example, in over 60 percent of the HHs men and only in five (5) per cent of the HHs women take decisions related crop variety, use and application of pesticides. However, when it comes to implementation, the team observe a shift in northern region. Proportion of households where both men and women implement a decision is comparable and sometimes even higher than the proportion of households where only men implement the decisions.

In contrast, the trend is different in decision making and implementation in the southern region. Substantially higher proportion of farmers reported that both men and women are involved in most of the decisions with barely one-third of the households reporting decisions by only men. The team observed the same trend in implementation of the decisions. For many of the instances, in almost two-thirds of the households both men and women implement the decision. Interestingly, house maintenance is the decision that women participate in the most, largely because both men and women make that decision, women also participate a lot in the decision about post-harvest activities (cleaning, drying, etc) across the regions, and this is the decision that women are most likely to be involved in significantly.

Overall, in northern region, decision-making is still a male dominated but joint decision making is close behind, whereas in southern region joint decision making is more established.

Table 20. Farm Related Decision-Making by Gender, northern region

Decision Instances	Who decides (%)			Who implements (%)		
	Men	Women	Both	Men	Women	Both
Choice Of the Crop Variety	67%	5%	28%	55%	11%	34%
Use Of Own or Purchased Seeds	67%	5%	28%	51%	14%	35%
Use Of Fertilizer	66%	5%	29%	48%	15%	37%
Use Of Pesticide	67%	5%	28%	52%	13%	35%
Use Of Hired Labour & Which Activity to Use Hired Labour	66%	5%	29%	50%	14%	36%

Rent-Out Owned Machines	64%	5%	30%	50%	13%	37%
Rent-In Machines	65%	5%	30%	51%	12%	37%
Farm Implements to Purchase	64%	5%	31%	49%	14%	38%
Obtain Loan to Pay for Material and Labour Inputs	64%	5%	31%	45%	17%	39%
Sowing Date of Crop	61%	6%	34%	41%	14%	44%
Method Of Establishing the Crop	63%	6%	31%	46%	15%	40%
Hand weeding	55%	10%	35%	33%	24%	43%
When To Apply Pesticides	63%	5%	33%	43%	16%	41%
When To Apply Inorganic Fertilizers	63%	4%	33%	41%	16%	43%
Use Of Mechanical Plant Protection Measures	62%	4%	34%	44%	16%	40%
Start Of Irrigation	62%	5%	34%	38%	17%	45%
Harvesting And Threshing	59%	6%	35%	37%	17%	46%
Post-Harvest Activities (Cleaning, Drying, Etc)	43%	23%	33%	35%	27%	39%
Selection Of Seeds to Store for Next Season	57%	7%	36%	37%	16%	48%
Adoption Of New Technology in Crop Production	58%	8%	35%	38%	16%	46%
Disposal Of Crops Cultivated	57%	6%	37%	36%	14%	50%
Disposal Of Animals Raised	56%	6%	38%	37%	15%	48%
Disposal Of Livestock Products	54%	6%	40%	36%	14%	50%
Marketing Of Farm Produce	56%	5%	40%	39%	13%	48%
Decision On Who Keeps the Net Income	51%	8%	42%	35%	14%	51%
Allocation Of Farm Income	50%	7%	43%	34%	13%	53%
Allocation Of Total Household Income	46%	10%	43%	33%	14%	53%
Allocation Of Time Between Work and Leisure	35%	15%	50%	26%	13%	61%
House Maintenance	31%	36%	34%	23%	38%	38%
Education Of Children	45%	9%	46%	29%	10%	61%
Local Or International Migration	44%	11%	45%	34%	11%	56%
Coping With Disasters	41%	6%	53%	27%	9%	64%
Mortgage Of Property for Frame Investment	48%	5%	47%	36%	8%	56%
Loan Repayment	42%	7%	51%	31%	10%	59%
Need To Change the Same to Crop Variety	49%	5%	46%	35%	9%	56%
Que Needed on Mortgage, Loans, Marketing, Investments;	55%	5%	40%	42%	9%	49%
Other activities	48%	4%	49%	33%	9%	57%

Table 21. Farm Related Decision-Making by Gender, southern region

Decision Instances	Who decides (%)			Who implements (%)		
	Men	Women	Both	Men	Women	Both
Choice Of the Crop Variety	46%	3%	51%	45%	3%	52%
Use Of Own or Purchased Seeds	49%	4%	48%	48%	4%	49%
Use Of Fertilizer	50%	4%	47%	48%	4%	48%
Use Of Pesticide	51%	3%	46%	48%	3%	49%
Use Of Hired Labour & Which Activity to Use Hired Labour	47%	2%	50%	45%	3%	52%
Rent-Out Owned Machines	48%	2%	50%	44%	4%	52%
Rent-In Machines	48%	2%	50%	45%	2%	53%
Farm Implements to Purchase	46%	2%	52%	43%	3%	55%
Obtain Loan to Pay for Material and Labour Inputs	45%	2%	52%	42%	2%	56%
Sowing Date of Crop	41%	3%	57%	37%	3%	60%
Method Of Establishing the Crop	39%	3%	58%	36%	4%	60%
Hand weeding	27%	9%	63%	25%	10%	65%
When To Apply Pesticides	43%	2%	55%	42%	2%	56%

When To Apply Inorganic Fertilizers	45%	2%	53%	43%	2%	55%
Use Of Mechanical Plant Protection Measures	46%	2%	52%	44%	2%	54%
Start Of Irrigation	44%	2%	53%	41%	4%	55%
Harvesting And Threshing	33%	4%	64%	30%	5%	65%
Post-Harvest Activities (Cleaning, Drying, Etc)	28%	12%	60%	28%	11%	61%
Selection Of Seeds to Store for Next Season	34%	5%	62%	32%	5%	63%
Adoption Of New Technology in Crop Production	38%	3%	58%	37%	4%	59%
Disposal Of Crops Cultivated	30%	3%	67%	29%	4%	68%
Disposal Of Animals Raised	34%	4%	62%	33%	3%	64%
Disposal Of Livestock Products	33%	4%	63%	32%	3%	64%
Marketing Of Farm Produce	37%	2%	61%	35%	3%	63%
Decision On Who Keeps the Net Income	30%	3%	67%	29%	3%	69%
Allocation Of Farm Income	29%	3%	67%	28%	3%	69%
Allocation Of Total Household Income	24%	9%	66%	24%	8%	68%
Allocation Of Time Between Work and Leisure	26%	4%	70%	26%	4%	71%
House Maintenance	20%	14%	66%	20%	12%	69%
Education Of Children	24%	3%	73%	23%	4%	73%
Local Or International Migration	32%	2%	66%	32%	3%	65%
Coping With Disasters	31%	2%	66%	31%	2%	66%
Mortgage Of Property for Frame Investment	32%	2%	65%	32%	2%	66%
Loan Repayment	35%	2%	64%	33%	2%	64%
Need To Change the Same to Crop Variety	35%	2%	64%	34%	3%	63%
Que Needed on Mortgage, Loans, Marketing, Investments;	34%	2%	64%	34%	2%	64%
Other activities	34%	2%	64%	34%	2%	64%

Table 22 lists 38 farming related decisions and presents proportion of households where the decision is taken by males, females, or both in the control block. In the control block, for most of the farming decisions, it is the male taking the decision and implementing it. For example, in over 50 per cent of the HH men and only in 3 per cent of the HH women take decisions related to choosing crop variety, however, a sizeable proportion (approximately 46 per cent) of households also reported that both men and women take decisions related to this activity.

The project team observed the same trend in implementation of the decisions. Overall, in the control block, decision-making is dominated by joint decision making. Females are almost equally involved with males in implementing the decisions.

Table 22. Farm Related Decision-Making by Gender, Control

Decision Instances	Who decides (%)			Who implements (%)		
	Male	Female	Both	Male	Female	Both
Choice Of the Crop Variety	50%	3%	46%	47%	6%	47%
Use Of Own or Purchased Seeds	43%	4%	54%	45%	8%	48%
Use Of Fertilizer	43%	4%	53%	44%	8%	48%
Use Of Pesticide	42%	4%	55%	45%	7%	48%
Use Of Hired Labour & Which Activity to Use Hired Labour	43%	4%	54%	43%	7%	50%
Rent-Out Owned Machines	41%	4%	55%	43%	7%	50%
Rent-In Machines	42%	3%	55%	43%	7%	50%
Farm Implements to Purchase	41%	4%	56%	41%	7%	51%
Obtain Loan to Pay for Material and Labour Inputs	42%	4%	54%	40%	9%	52%

Decision Instances	Who decides (%)			Who implements (%)		
	Male	Female	Both	Male	Female	Both
Sowing Date of Crop	39%	4%	57%	36%	8%	56%
Method Of Establishing the Crop	39%	3%	58%	38%	9%	54%
Hand weeding	36%	7%	57%	28%	15%	57%
When To Apply Pesticides	37%	4%	60%	38%	8%	54%
When To Apply Inorganic Fertilizers	37%	3%	60%	38%	8%	54%
Use Of Mechanical Plant Protection Measures	39%	3%	58%	39%	8%	52%
Start Of Irrigation	37%	4%	60%	35%	9%	56%
Harvesting And Threshing	37%	4%	59%	32%	9%	59%
Post-Harvest Activities (Cleaning, Drying, Etc)	27%	15%	57%	28%	18%	54%
Selection Of Seeds to Store for Next Season	33%	5%	61%	32%	10%	59%
Adoption Of New Technology in Crop Production	38%	4%	58%	35%	9%	56%
Disposal Of Crops Cultivated	35%	4%	61%	30%	8%	62%
Disposal Of Animals Raised	34%	4%	62%	32%	8%	60%
Disposal Of Livestock Products	34%	4%	63%	31%	8%	61%
Marketing Of Farm Produce	35%	4%	62%	33%	8%	59%
Decision On Who Keeps the Net Income	33%	4%	63%	30%	8%	62%
Allocation Of Farm Income	34%	5%	61%	29%	8%	63%
Allocation Of Total Household Income	30%	8%	61%	26%	11%	63%
Allocation Of Time Between Work and Leisure	29%	8%	63%	25%	7%	68%
House Maintenance	25%	21%	54%	21%	23%	56%
Education Of Children	30%	8%	62%	24%	7%	69%
Local Or International Migration	34%	5%	61%	30%	7%	63%
Coping With Disasters	32%	4%	64%	28%	6%	66%
Mortgage Of Property for Frame Investment	36%	4%	60%	32%	6%	63%
Loan Repayment	35%	4%	62%	30%	6%	64%
Need To Change the Same to Crop Variety	33%	5%	62%	32%	6%	63%
Que Needed on Mortgage, Loans, Marketing, Investments;	34%	4%	62%	34%	6%	60%
Other activities	34%	4%	62%	30%	6%	63%
Other activities: Loan we can add, marketing is there	35%	4%	62%	31%	7%	62%

Poor knowledge among women on agricultural aspects, and low women's decision-making in crucial agrarian activities, as described in the above tables also found true during the qualitative discussions. The women across the landscapes follow the daily routine. It starts at 6 or 7 AM, main activities include house cleaning, cooking, and sending children to school; from 10 AM to 6 PM, women engage in field activities with other labourers, whether in their own field or someone else field (in case of landless or single cropping). Women perform all the activities except ploughing, and still, none of the women provides any information on the usage of inputs (type, dose, relevance, etcetera). Mainly male farmers decide the input types and dosage and ask women to follow the same and implement it with the help of another hired labourer. In the remaining time in the evening, they cook for the household, teach their kids (in the case of kids), and go to sleep at 10 PM.

Women self-help groups (SHGs) are formed by National Rural Livelihood Mission (NRLM) or other CSOs in all the villages. However, the women report none of the other activities except for monthly savings activity. Women welcomed the idea of entrepreneurship and having access to training related to improved agriculture practices to enhance their value in the households. However, most of the women show concern about the time schedule. It's difficult for them to skip their 10 AM to 6 PM work schedule in the field, especially those who own land. Landless women are open to engaging in bio-inputs production subject to higher earnings than labour jobs. A significant proportion of women showed interest in goat rearing activities.

A bio-input resources centre managed by a women SHG facilitated by a local CSO was visited during the study. It was found that the facility is producing various bio-inputs such as vermicompost, Beejamurit, Jeevamrit, among others. However, the scale at which bio-inputs are being made is relatively less and cannot meet the demand. The facility needs to be equipped with more infrastructure and advanced training from the experts on bio inputs. Also, the introduction of various newer biological pesticide strains that are released and have proven results. CGIAR IRRI and RPLC technical committee members (regenerative agriculture researchers and experts) can play a significant role in imparting the training and facilitating the technology transfer amongst the farmers. These interventions help the women add value to the work they have been doing in their field and enhance the adoption of regenerative agricultural practices to a great extent as they implement and see the results of various interventions in the area, thus acting as an extension agent.

During the discussion, farmers across the landscapes reported using yellow sticky traps as a potential tool to reduce pest infestation in their crops which can also be seen in the field. Currently, they are purchasing these traps from the input dealer shop at the cost of Rs 50 per piece. However, our RPLC regenerative agricultural experts can train the women SHGS to manufacture these traps at the expense of Rs 5 per piece. Seeing the vast potential and demand for these traps could be a good entrepreneur model for women.

Similarly, farmers have raised the issue of unavailability of livestock feed throughout the year and buying from the market every time is not possible due to higher costs. Therefore, the production and sale of livestock feed at the village or cluster level through a cost-effective and innovative hydroponics model was also a suitable model for women SHGs. Several agricultural universities have developed and promoted these feed production plants among smallholders' framers. Apart from this, vegetable cultivation, mainly tomato, and cauliflower, has increased over the years in the landscapes and farmers who are cultivating shared their constraints in getting a good quality seedling. Farmers have to travel to another block to get the seedlings for their crops. As the landscape trends of taking up vegetables are gradually increasing, the requirement for quality seedlings will also increase, an opportunity for another entrepreneurship model for women.

Both male and female farmers agree that the use of agricultural inputs and other related decisions are mainly made by male farmers, and females just have to perform it on the field with the help of another labourer. However, female farmers stated the lack of opportunity to learn through any training program in the village or community. Otherwise, they would be willing to learn and contribute to the improved agricultural practices adoption to enhance their abilities.

Male farmers have supported the idea of women's training and involvement in entrepreneurial activities in their villages, where women can actively participate and contribute to the community and household welfare. Other household decisions, such as children's education, and purchase of any HH items, remain a consultative process among husband and wife or other elders members of the households. Overall, women during the discussion are not hesitant to put forward their views and ideas. Many women showed interest in learning through the short training in their village or nearby areas, as they also have to take care of children and family members and thus cannot move outside for more extended periods. Many women farmers liked the idea of livestock rearings, such as goats or hens, as they are easy to maintain and have high profitability. In several discussions, women put forward the idea of training on value addition product selling such as papad and pickle, Ghee & milk products. However, they all have the same voices on the time availability as they cannot compromise on the 10 AM to 6 PM schedule of working in their own field. Even the landless are committed to working as a labourer in other areas. They are only willing to engage themselves in other activities if they earn higher.

Conclusion:

Improving the understanding and fostering large-scale adoption of regenerative agriculture requires soil quality monitoring systems that integrate farmers' and researchers' knowledge. Robust data on greenhouse gas emissions and emissions reductions and practical methods for monitoring, reporting and verification are required to transition to low emissions regenerative system development in agriculture. The emissions also vary in Kharif and Rabi/Boro seasons and different mitigation strategies need to be applied accordingly. The SOC stocks (0-30 cm) varied among the villages and ranged from 13-35 Mg C/ha in Mohkhed and 7-13 Mg C/ha in Sausar. Similarly, there was huge variation in the soil health parameters among the two (2) blocks. The differences observed could be due to variations in organic matter input, topography, vegetation composition, soil bulk density, soil moisture and soil depth. Sausar soils seem to be more degraded than Mohkhed soils and need higher interventions to reverse the degradation process. The carbon stock map explains the spatial variability of carbon in soil. The areas of forest has higher carbon content whereas areas of agriculture has variable carbon content, with Mohkhed in the north having slightly higher carbon than southern part of the study. Farmers' crop yield was significantly correlated (p-value 0.01) with SOC stock at lower soil depth. Less frequent disturbance at 15-30 cm soil depth may have resulted in significant correlation. The farmers' crop yield increases by 18.61 kg/acre with every point increase in SOC stock (15 to 30 cm depth). The regression analysis demonstrates that farmers with proper irrigation facilities get a higher yield, than farmers who cultivate in rainfed conditions. The data also demonstrate the yield advantages of 129 kg/acre was observed for farmers adopting regenerative-integrated nutrient management with both chemical and organic fertilizer than those using only chemical fertilizers. The data show that there is a scope to improve soil health of both blocks through regenerative practices to improve crop productivity while improving environmental sustainability.

The LULC maps generated for the study region has revealed the significant increase in the Dense vegetation (6.6%), Sparse vegetation/ tree cover (6.5%) shows mostly the transition of the shrublands to sparse and dense vegetation where the crop land has decreased by -4.6 % in last

10 years. The trend observed in the wastelands (-3.3%) and shrub lands (-5.8 %) has declined drastically shows the expansion of other classes like tree cover, grasslands, sand/mining and settlements in the region. In Kharif, Sausar showed 8.65% higher total GHG emissions as compared to Mohkhed but during Rabi the scenario was reversed. During Rabi, 58.7% higher total GHG emission was recorded in Mohkhed as compared to Sausar. Fire incidents after the Rabi harvest were relatively higher and also increasing over time. The higher number of fires after rabi could be attributed to farmer's willingness to clear fields early for short term crops after rabi, when soil moisture is still optimum.

The data from the household survey showed majority of farmers in Sausar (94%) have cultivated cotton in Kharif, none of the farmers in Mohkhed have engaged in cotton cultivation. Mohkhed farmers owned greater proportion of assests thus providing a scope for mechanization than Sausar. In Mohkhed, majority of the plots have black soil but a sizeable proportion (approx. 36-40% amongst first three plots) also has red soil, proportion of sandy soil is negligible. However, in Sausar, between 15-22 per cent of the plots (based on first three plots) have sandy soil. Consequently, proportions of farmers having black of red soil is comparatively lower than those in Mohkhed but the use of these fertilizers is relatively less in Sausar with only 84-89 percent farmers reporting use of Urea and 69-79 percent farmers reporting use of DAP. Use of SSP is substantially higher for Cotton crop in Sausar block (60% farmers). Farmers in Mohkhed and Sausar use herbicides but insecticide use is much higher in the cotton growing belt of Sausar though the income of farmers in Sausar is substantially higher. In Sausar, the proportion of farmers undertaking any biodiversity activities is much lower than that in Mohkhed with just 15-22 per cent of the small, medium and large farmers reporting such activities. In Mohkhed higher proportion of large farmers have undertaken activities such as agroforestry, livestock, or earthworms. In Sausar, much higher proportion of farmers reported floods compared to those in Mohkhed block. Fifteen percent of the large farmers have also reported acidity in soil as a stress event they have suffered in past five (5) years indicated a dire need for interventions to mitigate and adapt to climate change. In contrast to Mohkhed, the trend is different in decision making and implementation in Sausar. Substantially higher proportion of farmers reported that both males and females are involved in majority of the decision.

ANNEXURES

Annexure 1: Soil health status of cultivable land and forest lands

	Village	Soil BD (g cm-3)		Soil pH (1:2.5)		Soil EC (dS/m)		SOC (%)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Mohkhed	V1	1.43±0.2	1.52 ± 0.2	7.42 ± 0.2	7.52 ± 0.2	0.05 ±0.05	0.04 ±0.01	0.63±0.21	0.49±0.22
	V2	1.41±0.2	1.53 ± 0.3	7.30±0.10	7.30±0.1	0.05±0.02	0.04±0.2	1.08±0.24	0.76±0.24
	V3	1.42±0.25	1.51±0.18	7.30±0.10	7.30±0.1	0.04±0.01	0.04±0.3	1.14±0.26	0.96±0.28
	V4	1.41±0.23	1.53±0.25	7.20±0.02	7.20±0.1	0.03±0.02	0.04±0.03	0.87±0.26	0.73±0.24
	V5	1.41±0.02	1.53± 0.3	7.20±0.02	7.20±0.3	0.03±0.01	0.03±0.01	0.62±0.12	0.37±0.14
	V6	1.42±0.2	1.53± 0.2	7.70±0.3	7.90±0.4	0.05±0.01	0.06±0.02	0.83±0.19	0.72±0.25
	V7	1.42±0.3	1.53± 0.3	7.40±0.2	7.50±0.2	0.10±0.05	0.06±0.02	1.69±1.66	1.50±0.48
	V8	1.42±0.2	1.53± 0.2	7.50±0.2	7.60±0.2	0.03±0.01	0.03±0.1	1.61±0.37	1.44±0.28
	V9	1.42±0.2	1.52±0.2	7.50±0.2	7.60±0.3	0.07±0.02	0.07±0.02	1.04±0.14	0.92±0.15
	V10	1.43±0.4	1.53±0.2	7.60±0.4	7.70±0.2	0.04±0.02	0.04±0.03	1.18±0.17	1.01±0.12
	V11	1.29±0.4	1.39±0.4	6.61±2.1	6.67±2.2	0.04±0.04	0.04±0.04	1.12±0.42	0.86±0.35
	Across	1.41±0.04	1.51±0.04	7.10±0.28	6.51±1.66	0.04±0.02	0.04±0.01	1.07±0.34	0.85±0.29
Forest	Acros	1.43±0.46	1.48±0.25	6.95±0.25	6.35±0.21	0.15±0.19	0.07±0.03	2.10±0.56	1.44±0.41
Sausar	V1	1.42±0.03	1.53±0.3	8.30±0.6	8.40±0.3	0.07±0.02	0.08±0.03	0.50±0.24	0.53±0.22
	V2	1.42±0.2	1.53±0.03	8.20±0.6	8.10±0.7	0.04±0.02	0.04±0.02	0.81±0.84	0.63±0.66
	V3	1.40±0.2	1.53±0.2	8.80±0.1	8.70±0.1	0.09±0.03	0.10±0.03	0.43±0.38	0.23±0.20
	V4	1.41±0.2	1.52±0.2	8.40±0.3	8.30±0.3	0.07±0.04	0.06±0.04	0.37±0.31	0.31±0.30
	V5	1.42±0.3	1.51±0.5	8.60±0.3	8.60±0.2	0.03±0.01	0.04±0.01	0.52±0.50	0.44±0.43
	V6	1.41±0.2	1.51±0.3	8.20±0.3	8.10±0.3	0.10±0.10	0.09±0.90	0.63±0.30	0.49±0.24
	V7	1.41±0.2	1.53±0.2	7.30±0.4	7.30±0.3	0.13±0.14	0.06±0.07	0.41±0.10	0.38±0.11
	V8	1.43±0.3	1.53±0.2	6.90±0.2	7.00±0.2	0.03±0.01	0.031±0.01	0.61±0.11	0.48±0.19
	V9	1.42±0.3	1.53±0.2	7.70±0.7	7.80±0.7	0.03±0.02	0.04±0.06	0.43±0.14	0.24±0.13
	V10	1.40±0.2	1.53±0.3	8.00±0.4	8.20±0.4	0.06±0.03	0.06±0.03	0.35±0.14	0.19±0.08
	V11	1.43±0.02	1.52±0.03	6.40±2.9	6.30±2.8	0.19±0.31	0.11±0.04	0.50±0.16	0.42±0.18
	Across	1.42±0.01	1.52±0.01	7.50±0.81	7.58±0.69	0.08±0.05	0.06±0.03	0.51±0.14	0.39±0.18
Forest	Across	1.37±0.00	141±0.01	7.05±0.21	7.00±0.42	0.08±0.05	0.05±0.01	1.88±0.60	1.51±0.33

± values indicate standard deviation from the mean among the farmers within the village

The result shows that the average Soil BD is 1.40 and 1.51 g cm-3 at 0 to 15 cm and 15 to 30 cm depth, respectively, in block Mohkhed, while the average Soil BD in Sausar is 1.41 and 1.52 g cm-3 which is higher than the ideal range thus may affect root growth. The soil pH across the block is higher than 7 at both depths, suggesting the Alkaline nature of the Soil. The soil pH between 6 to 7 is most favourable for absorption of nutrients by the plants. The Electrical Conductivity (EC) of Soil is in the normal range in both the blocks (<1 ds/m) but Sausar has higher average EC than Mohkhed by 0.5 ds/m. The results indicate that soils of Mohkhed has higher organic content (1.1%) than the soils of Sausar (0.5%). Higher variation in soil organic carbon was observed across villages in Mohkhed . In Sausar, low soil organic carbon (<0.5%), may limit the nutrient availability to crop thus causing lower productivity and returns. Cultivated land showed lower SOC as compared to forest soils (by half) indicating a degradation in soil with intensive cultural practices

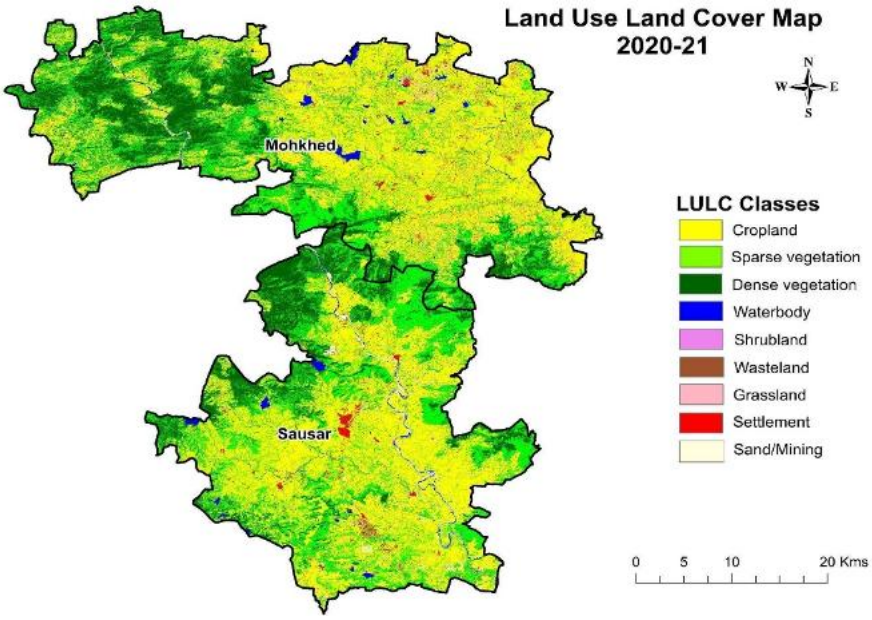
The SOC stocks (0-30 cm) varied among the villages and ranged from 13-35 Mg C/ha in Mohkhed and 7-13 Mg C/ha in Sausar (Fig 3.2 & 3.3). The differences observed could be due to variations in organic matter input, topography, vegetation composition, soil bulk density, soil moisture and

soil depth. Sausar soils seems to be more degraded than Mohkhed soils and need higher interventions to reverse the degradation process

Annexure 2: Spatio-temporal LULC Changes

Using Geospatial techniques, the high-resolution mapping of LULC is helpful in detecting the magnitude of spatio-temporal dynamics of LULC changes in the study region during the span of 10 years from 2011 to 2021. The LULC maps generated for the study region has revealed the significant increase in the Dense vegetation (6.6%), Sparse vegetation/ tree cover (6.5%) shows mostly the transition of the shrublands to sparse and dense vegetation where the crop land has decreased by -4.6 % in last 10 years. The trend observed in the wastelands (-3.3%) and shrub lands (-5.8 %) has declined drastically shows the expansion of other classes like tree cover, grasslands, sand/mining, and settlements in the region. The Random forest decision tree algorithms were effective in achieving the overall accuracy of the LULC maps for the each of the year 2020-21 is 91%, 2016-17 with 87.7 % and 2011-12 with 85.6%, And the post classification accuracy assessment matrix table for each analysed years are presented in Table 9. The change detection of LULC percent change area distribution of each class with respect to the total land coverage of study area and percent area estimations shown in the graphical plot in the Fig.3.6-3.10.

Fig 3.6 change detection of LULC percent change area distribution of each class with respect to the total land coverage of study area in 2020-21



For accuracy assessment the random ground truth points (30%) are used to quantitatively assess the classification efficiency of all the LULC classes. The overall accuracy (in percentage) for all years shown in below tables, and the identified accuracy ranged between 86% - 91 %.

Ground truth points	Dense vegetation	Sparse vegeation	Water	Shrubland	Agriculture	Grassland	Wasteland	Settlement	Sand/Mining	Total
Dense vegetation	54	10	0	0	0	0	0	0	0	64
Sparse vegeation	3	68	0	0	2	0	1	0	0	74
Water	0	0	23		2	0	0	0	0	25
Shrubland	1	1	0	45	0	0	0	0	0	47
Agriculture	0	1	0	2	162	5	1	0	0	171
Grassland	0	0	0	0	2	22	0	0	0	24
Wasteland	0	1	0	1	4	0	36	4	0	46
Settlement	0	1	0	0	2	0	1	34	0	38
Sand/Mining	0	0	0	0	0	0	0	2	12	14
Total	58	82	23	48	174	27	39	40	12	503
					Overall classification accuracy for LULC 2020-21					91 %

Fig 3.7 Cropping intensity percent change area distribution of each class with respect to the total land coverage of study area in 2020-21

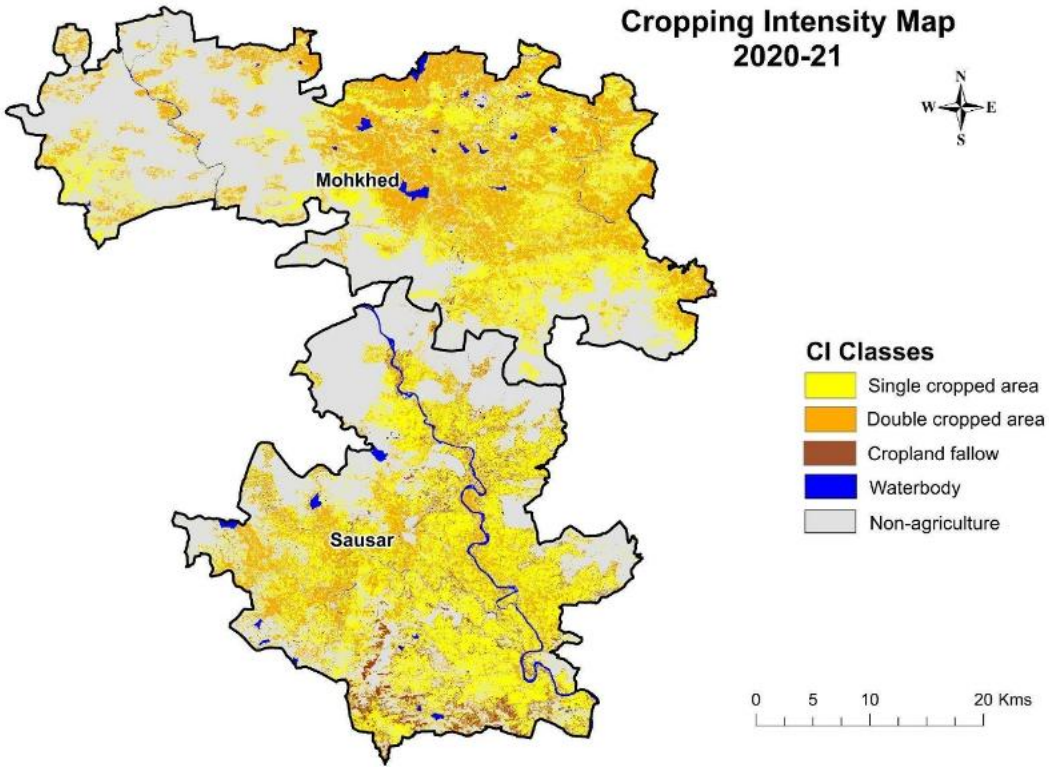
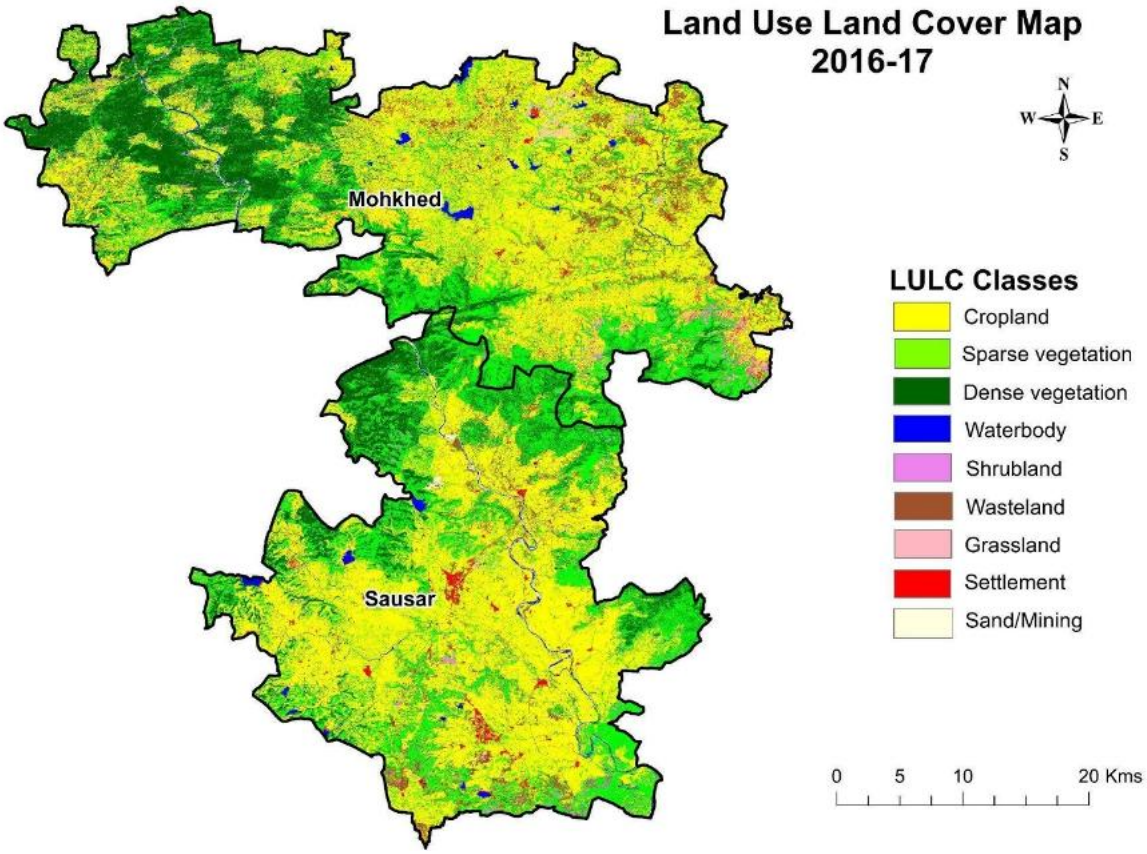
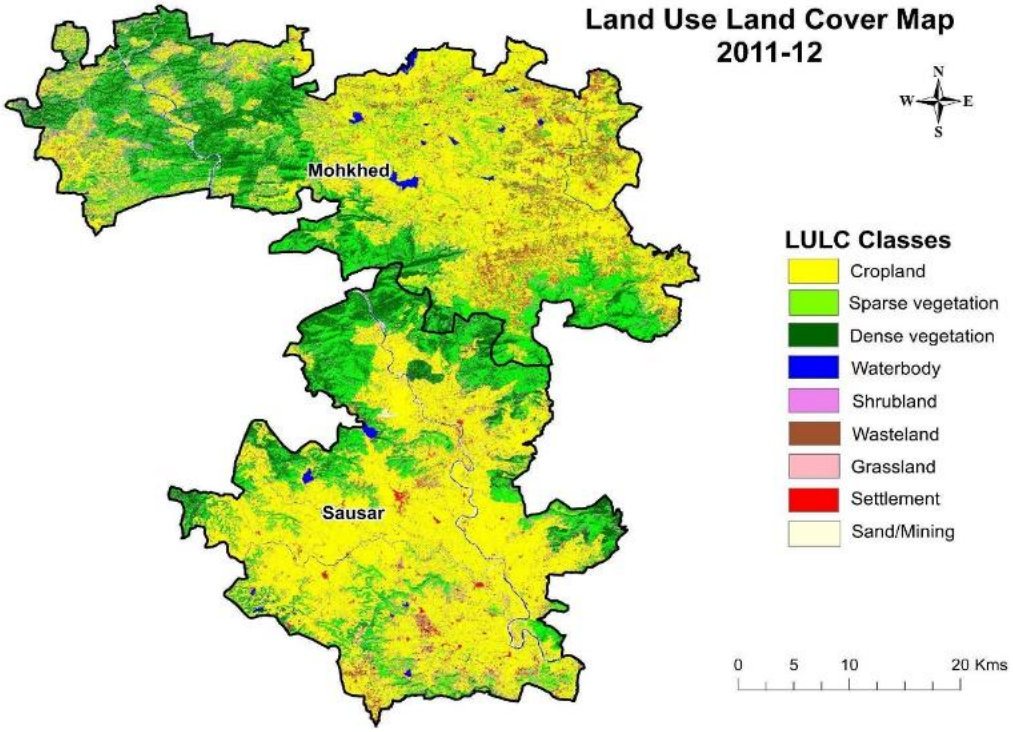


Fig 3.8 change detection of LULC percent change area distribution of each class with respect to the total land coverage of study area in 2016-17



Sno.	GT points	Dense vegetation	Sparse vegetation	Water	Shrubland	Agriculture	Grassland	Wasteland	Settlement	Sand/Mining	Total
1	Dense vegetation	**36**	2	0	6	0	0	0	0	0	**44**
2	Sparse vegetation	3	**27**	0	3	0	0	0	0	0	**33**
3	Water	0	0	**15**	0	0	0	0	0	0	**15**
4	Shrubland	2	0	0	**32**	0	0	4	0	0	**38**
5	Agriculture	1	4	0	7	**128**	0	0	0	0	**140**
6	Grassland	0	0	0	0	2	**16**	0	0	0	**18**
7	Wasteland	2	0	0	0	2	0	**24**	0	0	**28**
8	Settlement	0	0	0	0	0	0	0	**18**	4	**22**
9	Sand/Mining	0	0	0	0	0	0	0	3	**7**	**10**
	Total	**44**	**33**	**15**	**48**	**132**	**16**	**28**	**21**	**11**	**348**
						Overall classification accuracy of LULC 2016-17					87.07

Fig 3.9 change detection of LULC percent change area distribution of each class with respect to the total land coverage of study area in 2011-12



Sno.	GT points	Dense vegetation	Sparse vegetation	Water	Shrubland	Agriculture	Grassland	Wasteland	Settlement	Sand/Mining	Total
1	Dense vegetation	31	2	0	1	0	0	0	0	0	34
2	Sparse vegetation	1	27	0	2	1	0	0	0	0	31
3	Water	0	0	9	0	0	0	0	0	0	9
4	Shrubland	1	1	0	18	5	0	0	0	0	25
5	Agriculture	0	0	0	0	82	4	2	0	0	88
6	Grassland	0	0	0	2	4	14	2	0	0	22
7	Wasteland	0	0	0	1	1	2	10	0	0	14
8	Settlement	0	0	0	0	0	0	0	12	1	13
9	Sand/Mining	0	0	2	0	0	0	0	0	5	7
	Total	33	30	11	24	93	20	14	12	6	243
						Overall classification accuracy of LULC 2011-12					85.61

Fig 3.10 Graphical representation of the LULC classes percentage change in areas over 10 years

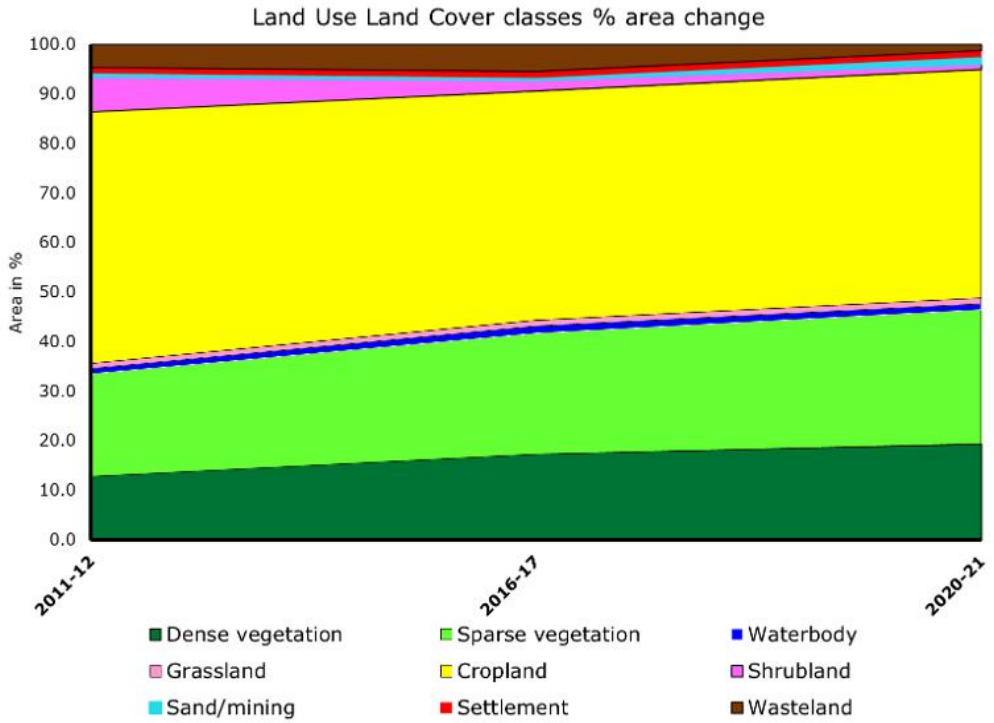
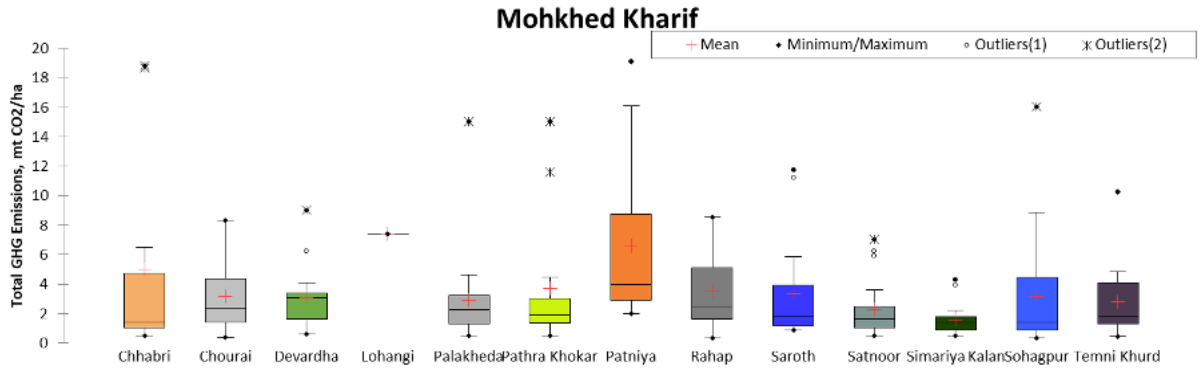


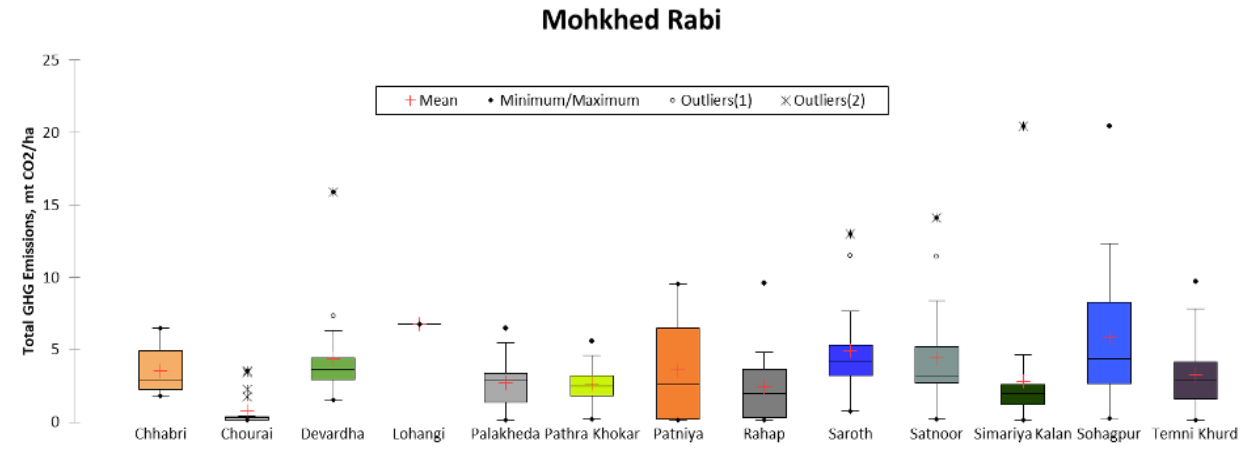
Table 23. Percentage areas estimated for all LULC classes in year 2011-12, 2016-17 and 2020-21

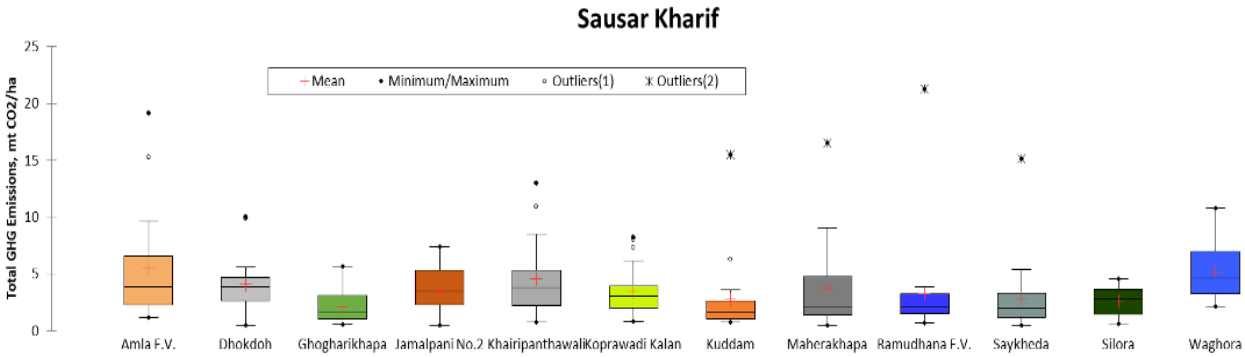
Sno	LULC classes	2011-12 (Area in %)	2016-17 (Area in %)	2020-21 (Area in %)
1	**Dense vegetation**	12.87	17.31	19.39
2	**Sparse vegetation**	20.62	24.63	27.09
3	**Waterbody**	1.14	1.16	1.16
4	**Shrubland**	7.06	2.25	1.24
5	**Cropland**	50.69	46.23	46.05
6	**Grassland**	1.06	1.20	1.21
7	**Wasteland**	4.66	5.50	1.28
8	**Settlement**	1.16	1.30	1.33
9	**Sand/mining**	0.74	0.41	1.25

Annexure 3: GHG emissions and reduction interventions

GHG emissions in agro ecosystem are contributed and controlled by various sources and factors. In Mohkhed, Patniya village showed highest GHG emission during kharif season followed by Sohagpur (Fig. 3.12). Similar GHG estimation was observed during Rabi season. Conventional tillage coupled with excessive fertilizer input led to higher GHG emissions. The production of synthetic nitrogen (N) fertiliser incurred significant GHG emissions, mainly as CO2 from the use of fossil fuels in the production of ammonia and N2O emissions during the production of nitric acid. Several factors impact on the GHG emissions from fertiliser production, namely the type of fertiliser, the technology and feedstock used and the presence or absence of N2O abatement technologies (Brentrup et al., 2004). In Sausar, Amala followed by Maherkhapa and waghora villages showed higher emissions compared to other villages during Kharif. Whereas, during Rabi, Koparwadi kalan followed by Jamlapani village showed higher emissions as compared to other villages (Fig. 3.11).







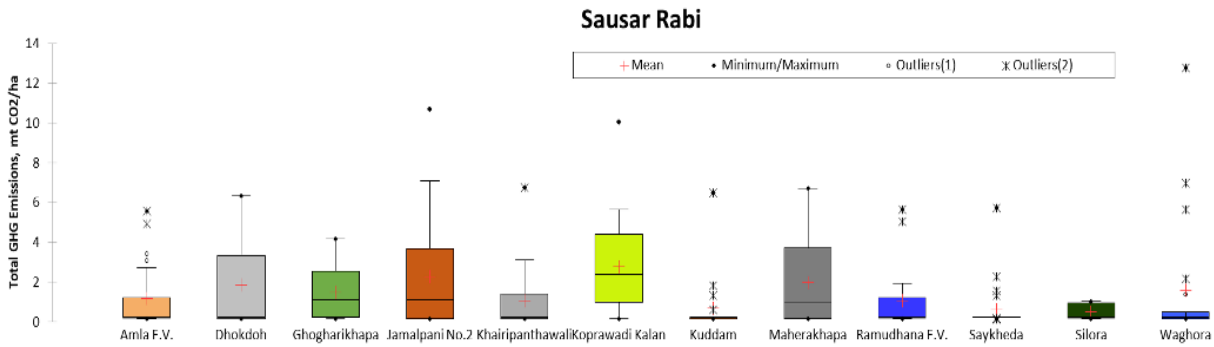
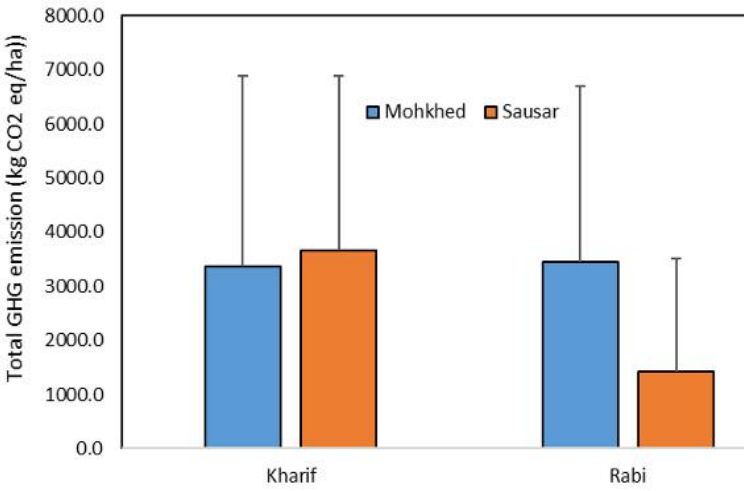


Fig 3.11. Season and village-wise total GHG emissions

3.3.1 GHG emissions from Mohkhed and Sausar



In Kharif, Sausar showed 8.65% higher total GHG emissions as compared to Mohkhed but during Rabi the scenario was reversed. During Rabi, 58.7% higher total GHG emission was recorded in Mohkhed as compared to Sausar (Fig. 3.12). The standard deviation was very high which might be due to diverse crops, soil and water management and variations in agronomic management.

Fig 3.12. Total GHG emissions from Mohkhed and Sausar in Kharif and Rabi

3.3.2 Mitigation potential of not burning the residues



Avoiding crop residue burning mainly maize or cotton residue, we can reduce total GHG emission by 200-422 kg CO2 eq/ha (Fig.3.13).

Fig 3.13. Scenarios for GHG mitigation by not burning the crop residues

3.3.3 Mitigation potential of optimum N rate

In most of the villages, farmers apply fertilizers in excess, particularly nitrogen. According to Moran et al. (2011), a reduction across the board in the rate at which fertiliser is applied could reduce the amount of N in the system and the associated N2O emissions. For example, if fertiliser is applied twice instead of three times a year, a reduction in N2O emissions could be

achieved (Moran et al., 2011). Optimal N rate can vary from region to region and crop to crop, which triggers GHG emissions. Optimal N rate application offers GHG mitigation ranging from 408-873 kg CO2 eq/ha/year for different crops (Fig.3.14). We used a MOT tool for generating GHG mitigation for optimal N rate with consideration of average yield of different crops, conventional tillage for crop establishment, FYM application @ 4 t/ha and NPK application rate of 150:75:75.

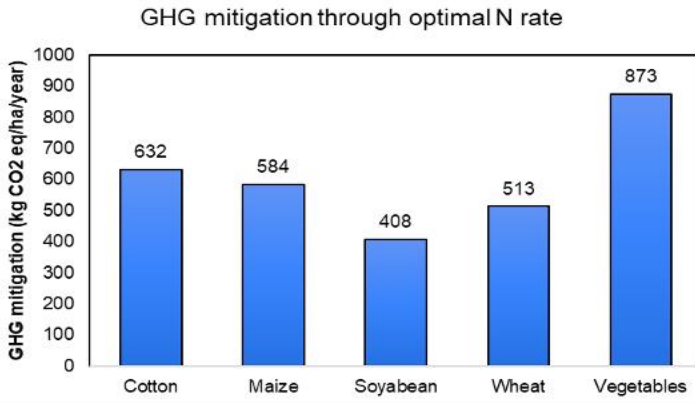


Fig 3.14. Scenarios for GHG mitigation through optimal N rate

3.3.4 Mitigation potential of shifting from conventional tillage to reduced and zero tillage

Reduced tillage consists of shallow cultivation or ploughing, reduced number of tillage operations, lower depth of harrowing but no ploughing, use of the chisel coulter drill or zone tillage (van Kessel et al., 2013). No-till is the direct seeding without primary tillage. No-tillage and reduced tillage have been promoted in agroecosystems to sequester additional soil C (van Kessel et al., 2013) and offers mitigation potential of 2431 and 1430 kg CO2 eq/ha/year, respectively (Fig. 3.15)

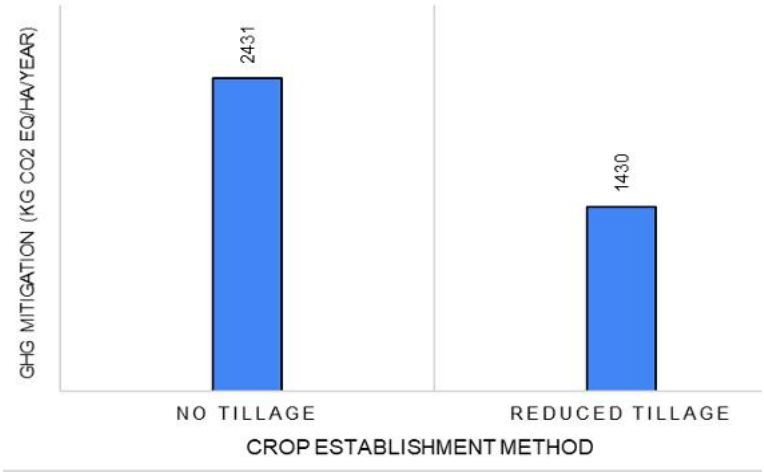


Fig 3.15 Scenarios for GHG mitigation by shifting tillage practices

Annexure 4: Water Use Efficiency (WUE)

Water utilization by the crop is generally described in terms of water use efficiency or productivity. WUE can be increased in two ways, either by increasing yield or by saving water. Irrigated agriculture is far more productive than rainfed agriculture, but in India, more than 65 % of the area is under rainfed agriculture and there is an equal need of increasing productivity of water.

In this baseline, the WUE of key crops in Mohkhed and Sausar during Kharif and Rabi was comparatively low as per the previous reported studies (Reddy and Reddy 2004). Higher WUE in vegetables might be due to use of drip irrigation whereas for cereals and cash crops still flooding methods were used (Fig 3.16).

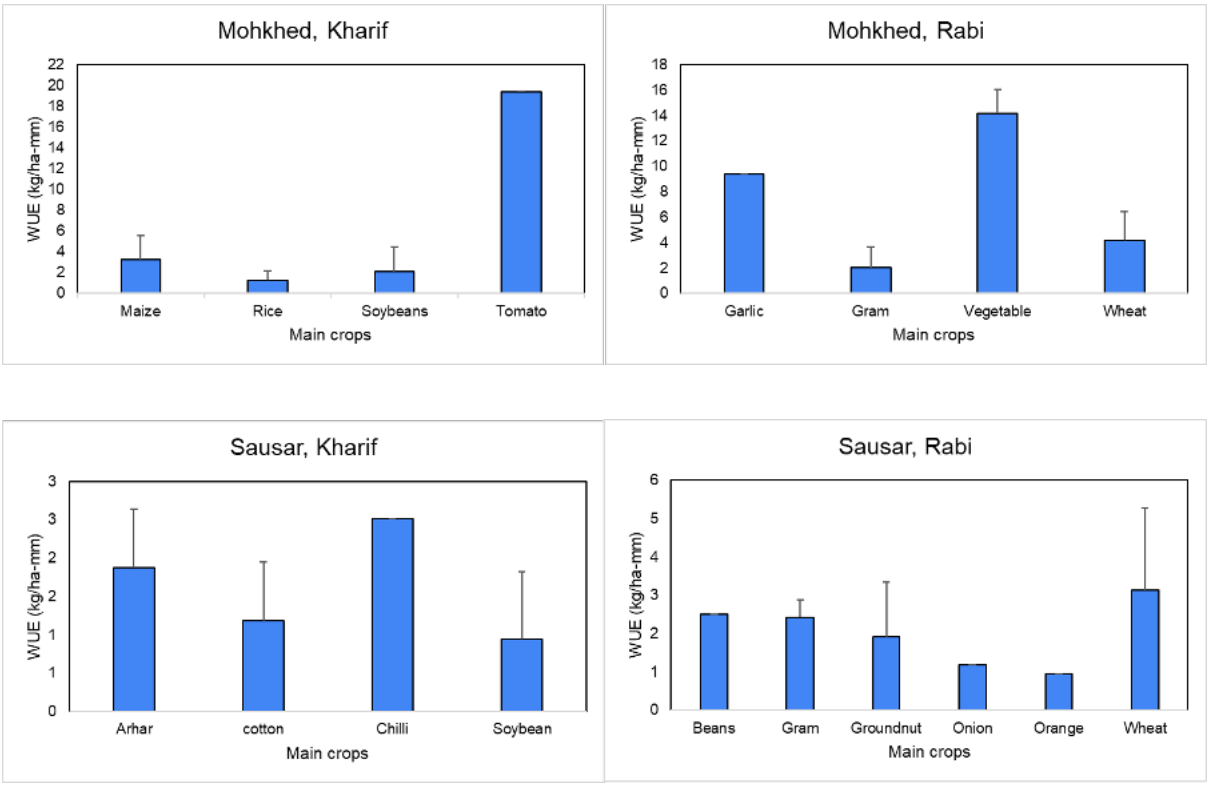


Fig. 3.16 Season and crop-wise WUE in Mohkhed and Sausar block of Chhindwara, MP

Precise water management in cotton in Sausar and cereal crops (mainly maize and wheat) in Mohkhed has potential to improve WUE. Improved varieties, straw mulching, reduced tillage, agronomic interventions, and soil moisture conservation strategies need to be adopted based on site-specific water use assessment.

Table 3.12 shows seasonal variation in WUE efficiency among different villages in Mohkhed and Sausar blocks. There is a huge variation in WUE among villages and seasons in both blocks indicating an opportunity to increase WUE through good and regenerative agriculture practices. The reported data can be used to design interventions to improve WUE for crops with low WUE.

Table 24. Village and season wise WUE in Mohkhed and Sausar

Mohkhed	WUE, kg/ha-mm		Sausar	WUE, kg/ha-mm	
Village	Kharif	Rabi	Village	Kharif	Rabi
Temni Khurd	1.87±1.03	3.26±1.38	Amala	1.13±0.71	2.83±1.65
Satnoor	2.83±1.56	4.67±2.24	Dhokdoh	1.37±1.58	2.91±1.37
Simariya Kalan	3.95±2.75	8.48±0.82	Ghogharikhapa	1.06±0.35	13.9±3.14
Sohagpur	2.44±0.35	2.86±1.28	Jamalpani no.2	1.11±0.09	2.24±0.99
Palakheda	1.62±0.908	1.74±0.85	Khairipanthawali	1.51±0.63	2.84±0.67
Pathra Khokar	1.74±0.87	1.80±1.09	Koparwadi	1.27±0.50	6.80±0.87
Patniya	3.28±1.66	5.25±3.24	Kuddam	1.37±1.16	2.05±1.20
Rahap	4.00±2.43	4.74±1.12	Meherkhapa	1.45±0.81	5.17±2.77
Saroth	2.89±1.37	12.7±1.35	Ramudhana	0.91±0.67	5.79±0.68
Lohangi	2.29±0.00	2.11±0.00	Saykheda	0.89±0.53	1.27±0.10
Devardha	3.19±1.80	5.23±2.36	Silora	0.89±0.14	4.19±0.12
Chourai	1.15±0.89	2.11±1.42	Waghora	1.39±0.27	5.96±1.43
Chhabri	1.38±0.51	7.60±1.86			

During Kharif, highest WUE was observed in Rahap followed by Simariya Kalan in Mohkhed whereas in Sausar, Khairipanthawali followed by Meherkhapa showed highest WUE

Annexure 5: Income from Farming and Other Sources

Type of Farmer	Income from Farming (Std Dev)	Income for Secondary source (Std Dev)	Income from Other Sources (Std Dev)	Total (Std Dev)
Mohkhed				
Marginal (<1 ha land)	21194.33 (6158.585)	27981.48 (20626.5)	12634.33 (20966.98)	56380.9 (33426.68)
Small (1 to 2 ha)	50157.69 (12929.23)	38893.33 (41233.54)	16713.01 (32260.8)	90706.4 (57979.11)
Semi-Medium (>2 to 5 ha)	93697.24 (12730)	23666.67 (16149.6)	13034.48 (16575.37)	118973 (27914.76)
Medium (>5 to 10 ha)	171528 (48723.82)	65222.22 (57631.97)	51504.35 (125158)	248554.1 (127659.7)
Sausar				
Marginal (>1 ha land)	34434.94 (10020.57)	49031.25 (21681.66)	6669.048 (15816.6)	80950.24 (32189.44)
Small (1 to 2 ha)	80258.83 (19087.44)	42852.27 (26288.65)	6540.127 (15622.86)	116239.4 (38383.17)
Semi-Medium (>2 to 5 ha)	150116.1 (25250.3)	68571.43 (84753.42)	8838.776 (24820.8)	196657.7 (108253.8)
Medium (>5 to 10 ha)	267406.3 (72279.05)	80727.27 (76750.36)	28194.44 (82201.45)	336199.3 (103379.1)

Annexure 6: Biodiversity activities undertaken by farmers, as reported by respondents.

Farmer Type	Type of Activity	Northern (Mohkhed)	Southern (Sausar)
Small Farmer	Any biodiversity activity undertaken	37%	15%
	Type of biodiversity activity - Agroforestry	43%	7%
	Type of biodiversity activity - Livestock	33%	0%
	Type of biodiversity activity - Fisheries	0%	0%
	Type of biodiversity activity - Specials	3%	0%
	Type of biodiversity activity - Earthworm	0%	0%
	Type of biodiversity activity - Bees	0%	0%
Medium Farmer	Any biodiversity activity undertaken	40%	20%
	Type of biodiversity activity - Agroforestry	41%	3%
	Type of biodiversity activity - Livestock	29%	22%
	Type of biodiversity activity - Fisheries	0%	0%
	Type of biodiversity activity - Specials	10%	0%
	Type of biodiversity activity - Earthworm	5%	16%
	Type of biodiversity activity - Bees	0%	0%
Large Farmer	Any biodiversity activity undertaken	39%	22%
	Type of biodiversity activity - Agroforestry	58%	32%
	Type of biodiversity activity - Livestock	55%	11%
	Type of biodiversity activity - Fisheries	3%	0%
	Type of biodiversity activity - Specials	13%	5%
	Type of biodiversity activity - Earthworm	10%	16%
	Type of biodiversity activity - Bees	0%	0%