ECONOMICS OF CLIMATE CHANGE ADAPTATION IN AHMEDNAGAR DISTRICT, MAHARASHTRA, INDIA

Authors
Arpan Golechha, Nikhil Nikam, Sourya Das, Vijay Solanky, Ajit Jadhav, Aradhana Yaduvanshi, Marcella D'souza, Prashant Kalaskar

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Executive Summary

It is well understood that climate change adversely impacts ecosystems and human wellbeing in diverse ways. Among other regions, these impacts have been observed in the vast semi-arid drought-prone parts of Maharashtra state. Maharashtra encompasses 16.7% of India's total degraded land. According to the Land Degradation Atlas prepared by ISRO, vegetation degradation and water erosion are the two most important processes of degradation and desertification. With changes in the rainfall pattern and rising temperature, agriculture is becoming less rewarding, particularly for large numbers of small and marginal farmers.

This study has been conducted in six selected villages where WOTR implemented a landscape climate change adaptation (CCA) project covering 25 villages in the Ahmednagar district of Maharashtra from 2010[1] to 2014. The selected villages are located in three topographies: the hills of the Western Ghats (Ghoti, Khadki Budruk), the plateau (Warudi Pathar, Mahalwadi), and the area near a rivulet (Kauthe Khurd, Kauthe Budruk) in the rain shadow of the Western Ghats. The objective of the study is to evaluate the impacts of the climate change adaptation measures implemented by WOTR in these locations. Importantly, the biophysical and socioeconomic impacts will receive special attention.

At first, the trend in the climatic condition of the study area is assessed by climate analysis and the community perception data on climate collected by focus group discussions and household interviews. Regarding the methodology for the biophysical aspects, land productivity dynamics, soil erosion, soil carbon, land use, and land cover changes are assessed from 2008 to 2018 using the Remote Sensing and Geographical Information System. The socioeconomic assessment is done using household interviews and focus group discussions. From each of the three geographical areas, one control village is selected with similar conditions to that of the respective project villages in order to develop a business-as-usual scenario. In this study, a comparison is made between the end-line (2018–19) and the baseline (2008–09), and the project versus control villages. The cost-benefit analysis for the period of 2010–11 to 2018–19 is carried out for both project and control villages in order to compare the economic viability of both scenarios.

The climate analysis shows that in the last 30 years, there has been increasing trend of temperature and precipitation. Though, the precipitation during the kharif showing an increasing trend; the precipitation in rabi in the hilly and plateau area are showing no trend and decreasing trend respectively. According to the there has been a change in the rainfall and precipitation pattern which has a severe or extremely severe impact on the livelihood.

The findings on the impact of CCA project are encouraging. We find that soil detachment has reduced in the plateau area project villages

[1] *Though the implementation started from 2010; but the baseline assessment was done in 2008. Therefore, 2008 has been taken as the baseline year for the comparisons.*

as compared to the control village, while in the case of hilly and rivulet project villages, the soil accumulation is higher than that of their respective control villages. Land productivity dynamics (LPD) analysis reveals that in the plateau and the rivulet villages, the majority of the area falls under 'stable' and 'stable but stressed' categories, with the former being more in the control village. In the hilly villages, majority of the total geographic area (TGA) of both project and control villages falls under the 'stable' category. land has increased in the plateau and hilly project villages where a significant increase in cropping intensity is observed, which is more than that in the corresponding control villages. In the rivulet area, both project and control villages show an almost similar trend in cropping intensity.

The productivity of the major crops is higher in the project villages than that in the control villages during both normal rainfall and drought years. The dependence on water tankers has also reduced in the project villages. We have conducted a cost-benefit analysis with the economic value of two major benefits- benefits from agriculture (in terms of crops and agricultural fodder) and benefits of household water availability. The cost-benefit analysis shows that the benefit-cost ratio (BCR) for all the villages is more than 1, indicating that the total benefit was higher than the cost incurred. The Net Present Value (NPV) per household values for all the project villages are higher than those for their corresponding control villages, which demonstrates the benefits of the climate change adaptation measures. It is also observed that the rivulet village communities have benefitted much more economically than those living in the hilly and plateau villages.

It is found that the participation of the villagers in the CCA activities during the project period is very high. Most people of the project villages perceive the value of CCA as very high, especially of activities such as water budgeting, agro-meteorological (agro-met) advisories, crop planning, and the watershed development (WSD) structures. Villagers also perceive the economic value of agro-met advisories as far higher than its costs. Overall, it is also found that the CCA interventions are crucial for increasing the adaptive capacities of the villagers. However, residents of plateau villages informed the project team that the soil and water conservation structures are not well maintained. Therefore, attention must be paid to post project maintenance of the structures constructed right from the capacity building phase of grassroot institutions.

Overall, the study finds that a holistic climate change adaptation approach is beneficial in terms of biophysical and socioeconomic parameters. A proper mix of ecosystem restoration and community development improves the socioeconomic condition during normal rainfall years and aids resilience in times of climate extremes.

Introduction

Climate change has serious adverse impacts on land resources and human wellbeing, especially in developing countries. The changing climate and global warming have altered precipitation patterns and led to serious impacts on the vegetation, which are deeply linked with the conservation of land resources. Moreover, the frequent occurrence of extreme events like droughts and floods also increases soil erosion. Degradation of the soil and vegetation also has severe negative implications on the climate. As water resources and agriculture are largely dependent on the weather pattern and ecosystem services of the land resources, changes in the climate can significantly impact agriculture and water availability (Shukla et al., 2019).

The impact of climate change, however, may not be equal in different parts of the Earth. The temperate regions, where most of the developed countries are located may benefit from climate change, as more area becomes cultivable as a result of global warming. On the other hand, tropical countries are expected to experience severe negative impacts with changes in the temperature and precipitation patterns. These in turn are likely to have detrimental impacts on the land and agriculture, making large swathes of agricultural lands uncultivable (Sahai, 2019). Moreover, the lack of knowledge and the low human development indicators of developing countries have serious implications for people's adaptive capacities. As people's livelihoods in developing countries are highly dependent on their land resources, the risks of climate change will affect the wellbeing of these people, especially the marginalised (Reddy & Assenza, 2009).

A holistic climate change adaptation strategy incorporates both restoration of the ecosystems through sustainable land management (SLM)/ watershed development (WSD), and the improvement of community resilience to climate change. Sustainable land management aims to reduce the negative impacts of climate change on the soil and land resources by the control of soil erosion. It also aims to conserve vegetation and local biodiversity, and strengthen the normal hydrological processes like infiltration and recharge. Most importantly, it helps communities to use scarce water resources effectively. Ecosystems act as a buffer to protect human communities. A healthy ecosystem can absorb the shock of extreme events. Improving biological diversity helps in its revival through the restoration of its structure and functioning. Thus, a restored ecosystem will help humans to draw upon the different ecosystem services during years of normal and abnormal rainfall, if handled in a sustainable manner. Along with participatory ecosystem restoration, it is also important to implement other adaptation measures such as non-farm employment generation, creating awareness about climate change, developing early warning systems, water use management and budgeting, and crop planning. Crucially, socioeconomically marginalized populations must be included in the development process and women empowered, such that these goals complement ecosystem-based resilience (IUCN, undated).

Mainstreaming climate change adaptation is a robust strategy for an agricultural country like India. India has seen a rise in the average temperature of about 0.7°C between 1901 and 2018, causing a 6% reduction in the overall monsoon, more frequent dry spells and extreme events like droughts (Ministry of Earth Sciences, 2020). Changes in temperature and rainfall have been observed to have adverse impacts on the life and livelihood of millions of people who depend on land resources for their primary occupation, which is aggravated by the large population pressure on these resources (Sharma, 2011). Of the total cultivated land in India, 68 percent is dryland and supports 44 percent of the population and 60 percent of livestock. Agriculture in the dryland areas is always vulnerable to climate shocks like droughts, dry spells, and unseasonal and intense rainfall. (Singh et al., 2004). Almost 69 percent of the population of India lives in rural areas (Census, 2011), and 67 percent of them depend on agriculture and livestock rearing as their source of income (Indian Express, 2018). India is one of the mega-biodiversity hotspots in the world with vast geographical diversity (CBD, undated). However, poverty and economic disparities between different sections of the society pose serious problems for sustaining their ability to build climate resilience. CCA interventions are vital for reducing the inequality that exists and improving the quality of life of vulnerable sections of the society (Smith, 2003). To address the various developmental gaps, the central and state governments have prepared various missions, programmes and schemes with allocations of funds.

In recent years, Maharashtra state—which has a stronger economy—has become vulnerable to the impacts of climate change nevertheless. The state is relatively large, both in terms of its geographical area and its share of the country's Gross Domestic Product (GDP). Mumbai—the financial capital of India—is the administrative capital of the state. Maharashtra is also adversely affected by land degradation, primarily by water and vegetation erosion (ISRO, 2016), and much of its area is classified as semi-arid. The experience of frequent droughts and water scarcity has earned Maharashtra the notorious title of India's drought capital (Indian Express, 2015). Besides droughts, the state is severely affected by different climate extremes such as unseasonal rainfall, excessive rainfall and floods, as well as rising summer and winter temperatures. Some of the climate-affected regions of Maharashtra are more backward and have witnessed large numbers of farmers' suicides. To combat these challenges, both the state and central governments over the past two decades have implemented various developmental programmes and schemes. Yet, many rural households are still vulnerable to the challenges of climate change (Samuel, 2007).

The Watershed Organisation Trust (WOTR) initiated a climate change adaptation project in 25 villages of Maharashtra to address these challenges. The project focused on building up the resilience of the rural communities by ecosystem restoration through WSD, and better management of the soil and water resources through the adoption of climate-resilient agricultural practices, thus improving people's earning capacities. The CCA project was supported by the National Bank for Agriculture and Rural Development (NABARD) and the Swiss Agency for Development and Cooperation (SDC) and wherever possible, linkages were built to access government schemes. The project was implemented in the Akole and Sangamner blocks of the Ahmednagar district over six years from 2010 to 2015. The interventions included activities related to the following (Report, WOTR 2015):

1. Social mobilisation
2. Gender and women's empowerment
3. Watershed treatments for ecosystems restoration (including afforestation)
4. Adaptive sustainable agriculture (practices and demonstrations) with the promotion of organic formulations and agro-met advisories
5. Water management and budgeting
6. Disaster risk reduction

7. Livestock
8. Biodiversity inclusion
9. Renewable energy
10. Healthy and attractive village
11. Livelihoods

The CCA project, implemented through a landscape approach, covered 25 villages in the Ahmednagar district in two blocks: Akole block (9 villages) and Sangamner block (16 villages). The Ahmednagar district is predominantly in the rain shadow and is drought prone. The Akole block represents the Transition Zone-II[2], and is a high rainfall, hilly region in the Sahyadri mountain ranges (Western Ghats), whereas the Sangamner block lies in the rain-shadow water scarcity zone, and is mostly a raised plateau areas with flowing rivulets.

Importantly, the benefits of the CCA project interventions broadly contribute to the UN Sustainable Development Goals (SDGs). The benefits contribute to building the overall resilience of the local communities. However, the SDG linkages are intricate, interdependent and interconnected, as seen in Fig. 1. It is observed that the WSD treatments influence water budgeting and agricultural practices. Most of the interventions focus on natural resources which intend to improve the resource base and provide communities with the capability of using them efficiently and sustainably.

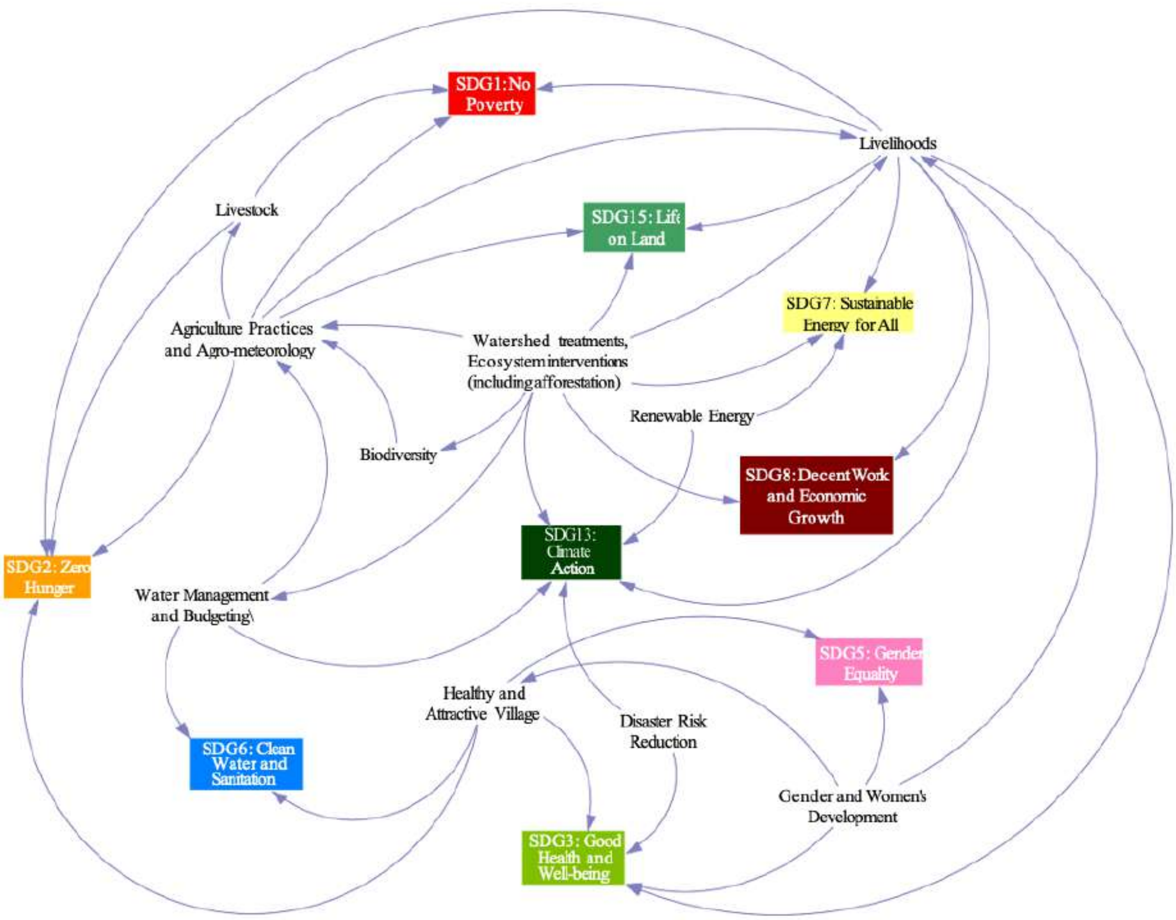

Fig. 1: SDG linkages of CCA interventions

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[2] *It is one of the agro-climatic zones of Maharashtra state of India. https://ataripune.icar.gov.in/PDF/agroclimaticzone.pdf*

Relevance of the Study

The study attempts to assess the following impacts of the CCA project implemented in Western Maharashtra:

i. Status of land degradation
ii. Agriculture
iii. Household water availability
iv. Non-timber forest produce

The study also tries to assess the investment in climate change adaptation projects through a cost-benefit analysis. While there are many benefits of the investment in natural resources, some are intangible. However, these intangible benefits are perceived differently by different beneficiaries. Therefore, the study also attempts to capture the perceptions of people with regard to the benefits of project interventions.

Objectives of the Study

The study aims to assess the impact of the CCA project on the biophysical and socioeconomic aspects of selected villages. The specific objectives of the study are:

1. Analyse the climate profile of the project treated villages;
2. Assess the impact of the climate change adaptation measures on land degradation, agriculture, and household water availability of the project and control villages;
3. Assess the engagement of the villagers in the CCA activities and the perceived benefits, as well as carry out an economic valuation of the benefits and a cost-benefit analysis;
4. Analyse the perspectives of the stakeholders with regard to the coping and adaptation strategies to climate risks.

Methodology

4.1 Analytical Framework

The study assesses the benefits of climate change adaptation interventions in Maharashtra's rainfed areas in terms of biophysical and socioeconomic aspects. The intervention scenario is also weighed against the Business-as-Usual (BaU) scenario, through a comparison with the baseline condition for both project and control villages. The analysis, therefore, includes the actual benefits, participation, and perceived benefits of various activities related to water, agriculture, land management and forests. However, the perceived values (by the villagers) are restricted to the project villages only (Leimona, Noordwijk, Groot, & Leemans, 2015; Gray & Srinidhi, 2013; Tröltzsch, et al., 2016).

In this study, three different topographies are selected: hilly, plateau, and rivulet villages located adjacent to the plateau villages. The analysis includes a comparison of these areas, and the benefits of the CCA activities, both actual and perceived. For the biophysical assessment, four indicators have been used: changes in LULC (Land Use and Land Cover), soil erosion, soil organic carbon (SOC), and land productivity dynamics (LPD). At the socioeconomic level, benefits from agriculture and household water availability are assessed. Comparisons are made in the following way: (a) project village and control village baseline - endline comparison; (b) project village and control village baseline - abnormal rainfall year comparison. The perception of climate change and the actual data of how the climate has varied over the years helps to put into perspective the climatic and agricultural changes and the impacts of adaptation interventions (Gray & Srinidhi, 2013; Samuel, 2007; Palanisami, Kumar, Wani, & Giordano, 2009).

4.2 Study Area

The study area is located in the blocks of Akole and Sangamner in the district of Ahmednagar. The blocks lie in two agro-climatic zones: Transition Zone-II (Akole) and the Water Scarcity Zone (Sangamner). The Akole block is in an assured heavy rainfall zone, while Sangamner is in a rainfall scarce (rain shadow) zone. The topography of these two areas is also starkly different, where the former is a predominantly hilly areas, while the latter includes areas of a plateau with rivulets flowing through. Two villages are selected for each of the three typographies based on the availability of data. One control village is selected for each of the geographies based on the key-informant interview, topographical analysis and field verification. The names of the project and control villages are given in Table 1.

The villages of the hilly area are located in the Transition Zone-II of the Western Ghats, having an average annual rainfall of 1800 mm. These are remote villages with low population density, having problems of connectivity and market accessibility. They mainly cultivate food crops for household consumption. The villages of the Akole block are rich in natural resources,

Block	Type	Project Village Name	Control Village Name
Akole	Hilly Area	Ghoti	Shinde
		Khadki Budruk (Bk)	
Sangamner	Plateau Area	Warudi Pathar	Pimpalgaon Matha
		Mahalwadi	
	Rivulet Area	Kauthe Khurd	Chas
		Kauthe Budruk (Bk)	

Table 1: Study villages according to topography

have good forest cover, with streams flowing near the villages, giving them access to these natural resources. These predominantly tribal households own small parcels of land, hence seasonal migration for wage work to nearby villages is observed here.

In the plateau and rivulet areas, the annual rainfall is 550 mm due to its geographical location in a rain shadow. The location of the plateau and rivulet villages on a plateau in the rain shadow makes these villages more vulnerable to climate change due to low rainfall, rainwater runoff, soil erosion and low water availability from the beginning of the winter season. Small and marginal farmers who don't have water resources seek wage work in neighbouring villages that have better agricultural potential.

In contrast, the rivulet villages are more agriculturally prosperous due to water availability from tributaries of the Mula river. People of the rivulet villages cultivate more cash crops than the villagers of the other two areas. The rivulets villagers have greater market access, and farmers also own livestock and dairy businesses.

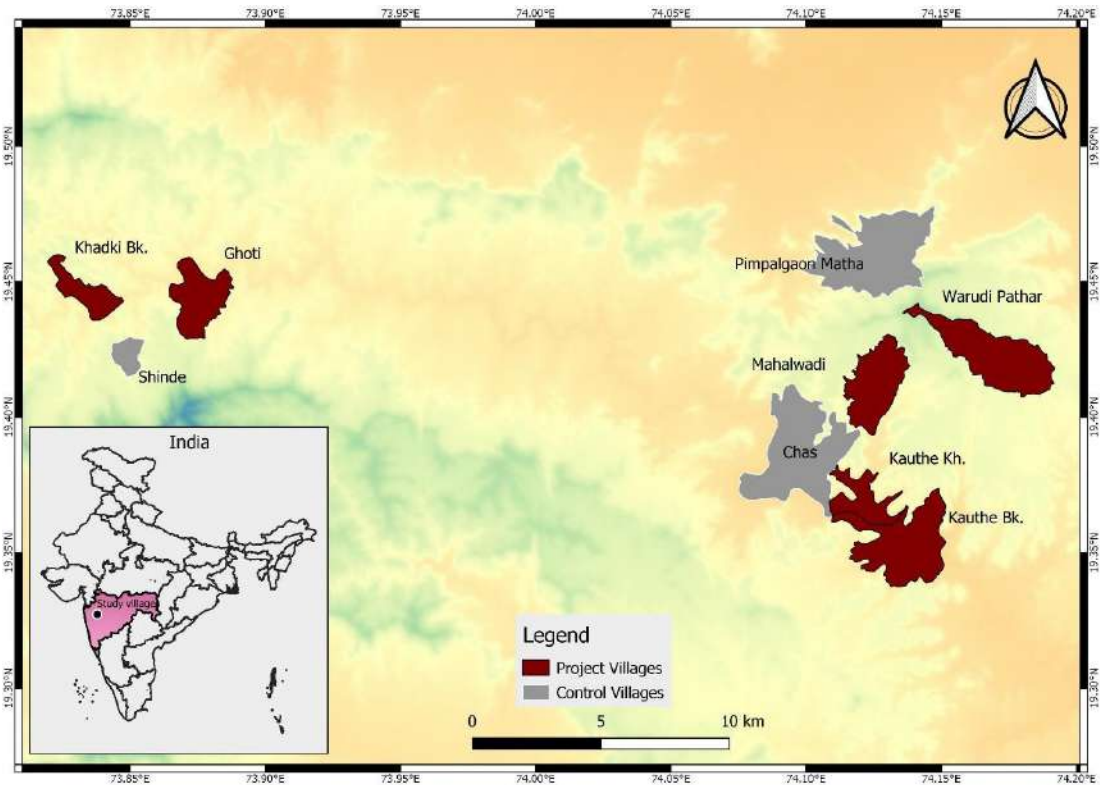

Fig. 2: Location map of study villages

4.3 Data Collection and Analysis

An interdisciplinary approach is adopted for data collection and analysis. The study team comprised of experts from different disciplines—economics, social work, geospatial technology, agriculture, water resource, and climatology. The methodology adopted is given in the table below:

Objectives	Data collection and analysis
Analysis of the climate profile of the project villages to obtain insights for preparedness to climate risk	The last 30 years[1] data is collected from IMD1 and the automated weather stations installed by WOTR in the project villages. Two indicators—temperature and rainfall—are studied to analyse the climate profile of the project villages.
Assess the impacts of the climate change adaptation project on land degradation, agriculture, and household water availability of the project and control villages	LULC change, LPD, Soil Erosion, SOC by RS&GIS; Changes in crop productivity by household interview (419 households sampled by stratified random method), baseline report/data, DPR, KII
Assess the participation of the villagers in the CCA activities and the perceived benefits; economic valuation of the benefits and the cost-benefit analysis	Participation of the villagers in CCA project and the perceived benefits by collecting data on participation by household interview Data on the cost of interventions from the record book of the project implementation agency Data on the cost of cultivation by household interview (419 HHs from project villages and 75 HHs from control villages) Perceived benefits of different CCA interventions is assessed by collecting data by household interview and Contingent Valuation Method (Krause et al., 2017); it has been done only for the project villages The benefit of agriculture by collecting data through household interview and using Market Price Method Benefits of improved household water availability by collecting data through household interview and using the Cost-Avoided Method
Analyse the different perspectives of the stakeholders on the coping and adaptation actions against climate risks	Household interview, focus group discussion (FGD); qualitative and quantitative analysis

Table 2: Objective-wise Methodology

[1] *India Meteorological Department*

The agricultural status in the project villages is assessed based on changes in two aspects—area under agriculture in the different seasons and crop productivity. The baseline assessment was done in the year 2008–09, although project implementation started two years later, i.e. in 2010–11. Therefore, while the baseline year is 2008–09, the cost-benefit analysis is done for the period 2010–11 to 2018–19.

The cost-benefit analysis is carried out using the costs of interventions contributing to the impacts on agriculture and water (cost apportionment in the intervention years for 2010 to 2018, recurring costs of agriculture, etc.). The total agricultural benefit is calculated using the land use data provided by RS-GIS, the productivity collected through surveys, Key-Informant Interviews (KIIs); and interpolation has been done for the missing years. The total water benefit is calculated using the avoided cost of water tankers, and the total benefit is the sum total of agricultural and water benefits. The benefit-cost ratio (BCR), Net Present Value (NPV) and NPV per household are calculated for comparison across villages. The change in the land degradation/restoration is assessed and its economic valuation is carried out.

ELD 6+1[2] step approach developed by the Economics of Land Degradation (ELD) Initiative is followed to guide the assessment of the costs and benefits of sustainable land management due to CCA intervention.

4.4 Assessment of the biophysical conditions

To assess the impact of the CCA interventions in the study villages, the 1) LULC changes, 2) Soil erosion, 3) Changes in Soil Organic Carbon, and 4) Land productivity dynamics are mapped. The methodology adopted for each component is discussed below.

LULC Change

In this study, LANDSAT thematic mapper (TM), LANDSAT optical land imager (OLI) sensors series having a spatial resolution of 30 meters (Table 3) and satellite imagery acquired for respective cropping seasons of the study years are used. The LANDSAT series data is from the United States Geological Survey (USGS) earth explorer (https://earthexplorer.usgs.gov), and the acquired scenes are level-1 terrain- corrected (i.e., the relief displacements are corrected using the ground control points and the digital elevation model), which are most suitable for pixel-level time-series studies. The Universal Transverse Mercator (UTM) – World Geodetic System (WGS) 84 projection system is used. The project and control village boundary is used as an area of interest to perform the sub-setting of satellite images.

The seasonal satellite imagery for the years 2008–09, 2015–16 and 2018–19 is used to map the LULC information for the project and control villages. Based on the initial field observation and existing land distribution, the study area is categorised into six land classes: (i) cropland, (ii) fallow land, (iii) vegetation, (iv) wasteland, (v) built- up and (vi) water bodies. The cropland category is further classified as a single crop (monsoon, winter, and summer), double-crop (monsoon + winter, monsoon + summer, and winter + summer) and triple crop (all seasons or perennial). Image classification and validation training samples for the region of interest are obtained based on the spectral signature of various classes and compared with high-resolution satellite imagery from Google Earth. Initially, the on-screen image

[2] *ELD Initiative (2015): The Value of Land: Prosperous lands & positive rewards through sustainable land management, Report in English: https://www.eld-initiative.org/fileadmin/pdf/ELD-main- report_en_10_web_72dpi.pdf*

classification method is employed to obtain season-wise (monsoon, winter and summer) LULC, and later, all three seasons are combined to generate the annual LULC.

Year	Season	Acquisition date	Satellite sensor	Spatial resolution in meters
2008–2009	Kharif	23 and 27 September 2008	LANDSAT TM	30
	Rabi	02 and 17 January 2009	LANDSAT TM	30
	Summer	23 April 2009	LANDSAT TM	30
2015–2016	Kharif	01 October 2015	LANDSAT OLI	30
	Rabi	21 January 2016	LANDSAT OLI	30
	Summer	26 April 2016	LANDSAT OLI	30
2018–2019	Kharif	09 and 13 October 2018	LANDSAT OLI	30
	Rabi	13 January 2019	LANDSAT OLI	30
	Summer	19 April 2019	LANDSAT OLI	30

Table 3: LULC data and Images details

Soil Erosion and Soil Organic Carbon

Soil erosion conditions are assessed before and after the CCA interventions using the Unit Stream Power Erosion and Deposition (USPED) model (Warren et al., 2005). USPED is an improved version of the well-known Revised Universal Soil Loss Equation (RUSLE) and USLE soil erosion model. The improvements in USPED handles the complex topography and accounts for sedimentation deposition in the watershed. Measurements of in-field sediment deposition via USPED helps to rectify the overestimation errors of previous models. The basic equation for the USLE, RUSLE and USPED models is

$$\mathbf{E} = R * K * L * * P \qquad (1)$$

The USPED model substitutes an LS analogue computed as

$$\mathbf{LS} = A^m (\sin \beta) \qquad (2)$$

Where A is upslope contributing area, β is slope angle, and m, n are constants that depend on the type of flow and soil properties.

Soil erosion assessment is done using equation (1); each parameter is calculated in the GIS environment. The rainfall erosivity factor is calculated using the formula proposed by (Harinarayan et al., 2015) for the Indian region using SM2RAIN-ASCAT (2007–2019) global daily satellite rainfall of 10 km spatial resolution (Brocca et al., 2019). The soil erodibility index (K) of surface soils of each soil type, associated with the mapping units, is computed using the standard formula (Kumar et al., 2013). Slope length (L) and steepness (S) factors are calculated spatially using the 30 m SRTM digital elevation model data by applying equation (2). Cover factor C is computed for each year based on average NDVI values. Management practice factor P is calculated based on land use/land cover classes for each year.

Soil organic carbon assessment

Soil map at 1:250K scale available from the National Bureau of Soil Survey and Land Utilisation Planning (NBSS&LUP) is used to calculate soil erodibility factor. After calculating all these factors, the USPED model is executed to get the predicted values of soil erosion and deposition.

Soil maps from NBSS&LUP are used in soil carbon assessment; Soil depth, OC% is converted to raster format for spatial analysis; OC% is then used to calculate total soil organic carbon. The bulk density map is downloaded from the ISRIC world soil grids dataset. The soil erosion and deposition results from the USPED model is used in empirical calculation of the soil organic carbon (SOC) detachment and accumulation in both project and control villages. The SOC value is calculated using equation (4). Soil organic carbon percentage is converted to total soil organic carbon based on the following equation:

$$\textbf{\textit{Total SOC}} = 10000\ m^2 * \textit{Soil Depth (m)} * \textit{Bulk Density } (g/cm^3) * \textit{OC } (\%) \qquad (3)$$

Total SOC is the amount of total soil organic carbon in tons/ha

Land productivity dynamics

The term 'land productivity dynamics' (LPD) reflects the fact that the primary productivity of a stable land system is not a steady state but highly variable between different years and vegetation growth cycles due to natural variation and/or human intervention (UNCCD, 2017). A decline in land productivity is the first indication of ongoing land degradation processes. 'Land productivity' is defined as an expression of the bio-productivity resulting from all land components and their interactions and is not only due to human activities and direct land use. Land productivity is, therefore, not to be confused with agricultural productivity (Cherlet et al., 2013). LULC change detection results of 2008 to 2017 are used to identify the potential trend (positive change, negative change, and no change). Normalised Difference Vegetation Index (NDVI) of the year 2017 is calculated to assess the standing biomass. NDVI is a ratio-based index computed using the linear relationship between the near-infrared and red spectral bands. The NDVI values range

from -1 to +1, where high positive values indicate healthy vegetation whereas those that are closer to 0 or negative indicate the bare or artificial areas and water bodies.

$$\textbf{\textit{NDVI}} = \frac{\textit{Near infrared band - red band}}{\textit{Near infrared band + red band}} \qquad (4)$$

Further, based on the NDVI classes and LULC potential trend, the LPD qualitative classes were assigned as suggested by Retiere et al, 2015.

4.5 Assessment of the socioeconomic condition

Focus Group Discussion

A total of seven focus group discussions (FGDs) were carried out across the three land- types: hilly, plateau, and rivulet areas. These FGDs are conducted as semi-structured interviews, in order to assess the impact of and perceptions about climate change, adaptation strategies, and CCA interventions. This includes people's thoughts and insights on the extreme events they face, the kind of adaptation they need, and relevant institutions in these villages. FGDs are conducted in each of the project villages to capture in-depth information from farmers from each of the geographical areas. Transcription of conducted interviews and the coding of interviews is done using Dedoose qualitative analysis software. Due to the COVID-19 lockdown in 2020, three key-informant's interviews (KII) in each of the control villages were conducted personally or telephonically (where not possible) to understand the cropping practices and the availability of water resources.

Household Survey

A total of 419 households from these six project villages were surveyed, with about 70 households from each village. The sample was determined through a stratified random sampling approach based on landholding categories. In the 3 control villages, a total of 75 households were interviewed, but only regarding the socio-economic aspects of agriculture. The questionnaire was structured and covered the following topics:

- Activity-wise monetary benefits asked through a Contingent Valuation Methodology
- Participation and benefits from CCA activities
- Climate perception and impacts
- Agricultural details, production, productivity and income
- Non-timber forest produce (NTFP) details and other forest benefits
- Water benefits
- Watershed benefits

Results and Discussion

5.1 Climate Profile of the Study Area

Climate Analysis

The study villages although in the same district are located in two different agro- ecological and climatic zones. Within each block the villages are contiguous. Akole being a hilly area is characterized by heavy rainfall. In the future, the region will experience more wet extremes in terms of intensity and duration (Table 4); and at the same time, a decreasing trend in Consecutive Wet Days (CWD) which will have a significant impact on crops and soil erosion. The decreasing trend of CWD implies less consecutive rain in the Kharif season, which is crucial for the growth of crops at different growing stages. More extreme events in the hilly area may cause flood-like conditions in the lower plain area depending on the soil and vegetation conditions. Besides this, rising temperature in the Rabi season could harm the crops that now need to adjust to higher temperatures. All these transformations necessitate a look into the crop management practices, and choice of crops and varieties. Moreover, land management measures and water conservation practices need to be put in place.

Sangamner is a low rainfall region, shows drier and wet extreme conditions for the future (Table 4). The increasing trend of Consecutive Dry Days (CDD) is a severe climate risk identified in the region. The increasing trend of high-intensity short duration rainfall poses challenges to agriculture and land management. Spells of long dry days damage crops. Rainfall runoff during high intensity rainfall results in a heavy soil loss in the region. In the low-rainfall regions, increasing wet indices and increasing CDD would affect the soil moisture condition (Hottenstein et al., 2015) and net primary productivity. Such changes may benefit agricultural production opportunities because of better infiltration and groundwater recharge (Yaduvanshi et al., 2020).

To understand the impact of rainfall extremes, various rainfall indices such as one day highest precipitation (RX1), Simple daily intensity (SDI), Rainy days > 10mm (R10mm), Rainy days > 20 mm (R20mm), etc. were studied. Rainfall extreme indices show an increasing trend in the area except for R20mm. The analysis has been done for the monsoon season from 1989 to 2018.

The Table 4 lists the climate analysis results across the 6 study villages for the parameters observed over the timeframe mentioned above.

The annual rainfall (1989–2018) in the study villages varies from 2229.44 mm to 688.53 mm across the villages of Ghoti, Khadki Bk, Warudi Pathar, Mahalwadi, Kauthe Kh, and Kauthe Bk. In the past 30 years, there is a significant increase in annual and seasonal rainfall. In the last ten years, it has been observed that rainy days have increased in the Kharif (June to September) season. However, minimum and maximum temperatures have markedly risen in the summer months (March to May). The past 30-year maximum temperature trend shows a sharp

Variables (1989–2018)	Ghoti and Khadki Bk	Warudi Pathar and Mahalwadi	Kauthe Kh, Kauthe Bk
Annual Average Rain	2229.44 mm	688.53 mm	688.53 mm
Deficit Rainfall Years (Meteorological Drought Years)	2009, 2015 and 2018	2011, 2012 and 2018	2011, 2012 and 2018
Excess Rainfall Years	2012, 2013 and 2017	2013 and 2017	2013 and 2017
Rainfall Trend Annual	Increasing trend (1989–18)	Increasing trend (1989–18)	Increasing trend (1989–18)
Rainy Years	More years of excess rainfall	More years of excess rainfall	More years of excess rainfall
Trend in Rainfall (months and season)	Increasing trend: July and Sept, Increasing trend: Kharif and No change in trend in Rabi Season	Increasing trend: Aug and Sept, Decreasing trend: June, Increasing trend: Kharif and a decreasing trend in Rabi Season	Increasing trend: Aug and Sept, Decreasing trend: June, Increasing trend: Kharif and a decreasing trend in Rabi Season
Trend in Temperature	Increasing trend: Annual, seasonal, steep rise in Rabi	Increasing trend: Annual, seasonal, steep rise in Rabi	Increasing trend: Annual, seasonal, steep rise in Rabi
Annual Rainy Days (1989–2003 Vs 2004–2018)	Rainy days increased and rainfall increased	Rainy days increased and rainfall increased	Rainy days increased and rainfall increased
Annual Temperature	32.15, 20.34	32.80, 18.49	31.88, 18.70
Temperature Trend	Increasing Trend (Annual, April, May and June, Kharif and Rabi seasons)	Increasing Trend (Annual, April, May and June, Kharif and Rabi seasons)	Increasing Trend (Annual, April, May and June, Kharif and Rabi seasons)
Near Future Rainfall (2015–2040) Trend	Increase in annual rainfall. Increasing trend in rainfall of July; decrease in rainfall in September month Rabi-Decreasing, Kharif-Increasing trend	Increase in annual rainfall. Increasing trend in rainfall in July; decrease in rainfall in September months. Rabi-Decreasing, Kharif- Increasing trend	Increase in annual rainfall. Increasing trend in rainfall of July; decreasing trend in rainfall of September months, Rabi- Decreasing, Kharif- Increasing trend
Excess and Deficit Years	More Deficit years	More Deficit years	More Deficit years

Variables (1989–2018)	Ghoti and Khadki Bk	Warudi Pathar and Mahalwadi	Kauthe Kh, Kauthe Bk
Rainfall Extremes (1989–2018) Consecutive Dry Days (CDD) Consecutive Wet Days (CWD)	7–20 dry spells/ monsoon 22–77 wet spells/monsoon Trend: Decreasing CDD Trend: Increasing CWD	6–37 dry spells/ monsoon 4–24 wet spells/ monsoon Trend: Increasing CDD Trend: No change in trend CWD	6–37 dry spells/ monsoon 4–24 wet spells/monsoon Trend: Increasing CDD Trend: No change in trend CWD
Consecutive Five Dry Days (CDD_5) Consecutive Five Wet Days (CWD_5)	1–3 Dry spells 5–20 Wet spells Trend: Decreasing CDD_5 and CWD_5	1–6 Dry spells 0–4 Dry spells Trend: No change in trend	1–6 Dry spells 0–4 Dry spells Trend: No change in trend
Rainy Days with Rainfall >20mm (R20); Rainy Days with Rainfall >10mm (R10)	17–55 Days 32–73 Days No change in trend	2–13 Days 9–24 Days Increasing trend	2–13 Days 9–24 Days Increasing trend
Simple Daily Intensity (SDI)	12.71 mm to 33.87 mm/day Increasing trend	5.82 to 18.12 mm/ day Increasing trend	5.82 to 18.12 mm/ day Increasing trend
One Day Highest Rainfall (Rx1)	85.21 mm to 241.01 mm/day Decreasing trend	28.36 to 138.47 mm/ day Increasing trend	28.36 to 138.47 mm/ day Increasing trend

Table 4: Summary of Climate Analysis

increase in temperature from 35.4°C to 38.2°C in April. The temperature in the winter months has also increased in the last ten years. The minimum temperature shows a greater rise compared to the maximum temperature in the Kharif and Rabi seasons.

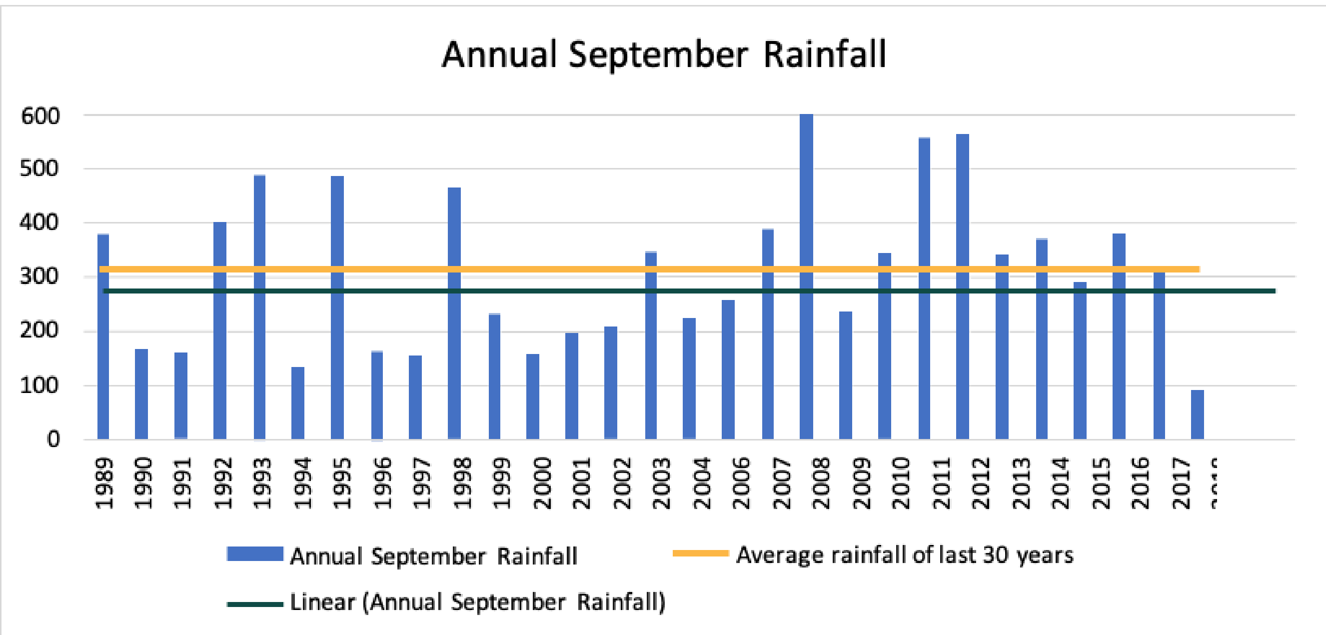

Fig. 3: Increasing trend in the September Rainfall (1989–2018) in Ghoti and Khadki Bk – Hilly Area

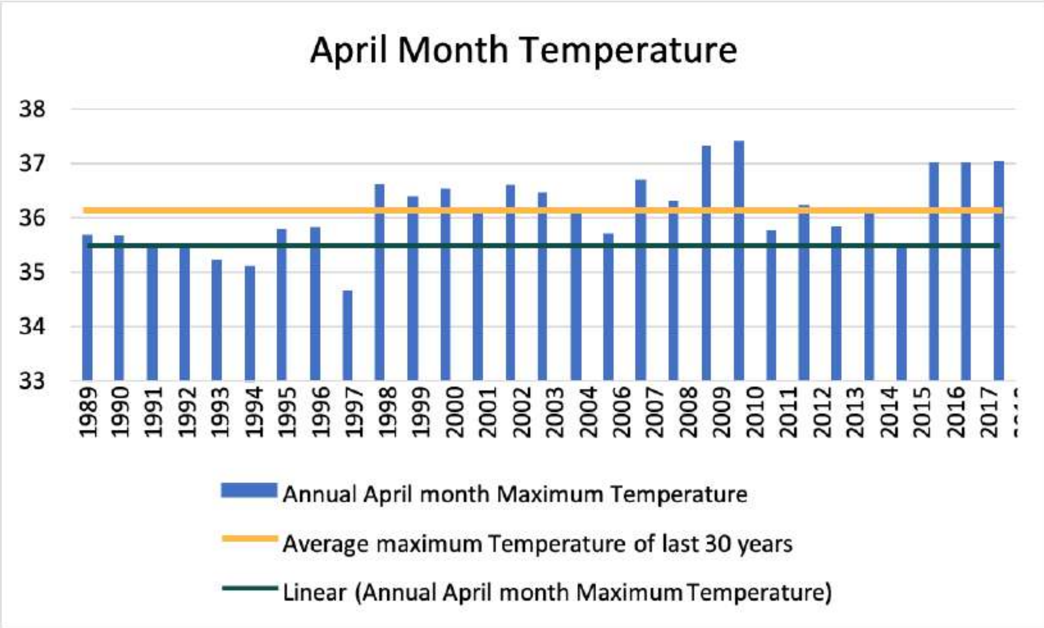

Fig. 4: Increasing trend in maximum temperature of April (1989–2018) in Ghoti and Khadki Kh–Hilly Area

Climate Perception and Extreme Events

The study tools focused on the perceptions of the local community about climate change, in order to understand how they have experienced climate change and extreme events. Their experience of climate change explains the context in which they operate. The severe climate events that local communities face includes droughts, flash floods, unseasonal and intense rainfall, frost, etc.

The village-wise graph below captures how village communities understand the changing weather patterns and their severity. Most of the population has observed the marked changes: About 80% of all the households interviewed in the 6 villages consider that climate change impacts have been severe or very severe.

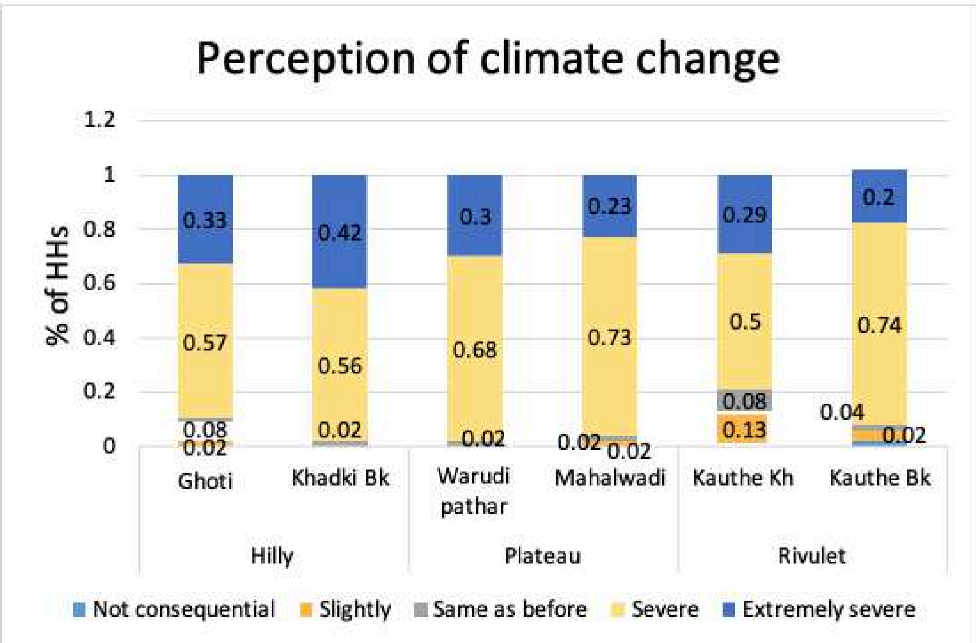

Fig. 5: Perception of climate change by different households of the project villages of the Hilly, Plateau and Rivulet areas

In recent years, climate change in these areas is conspicuous due to the increased intensity and frequency of extreme weather events. In the past ten years, there have been three years of drought, unduly long dry spells and a high number of dry days during the monsoons; high intensity rainfall days; and instances of excessive and unseasonal rainfall. As seen in the graph below (Fig. 6), drought is the most common extreme event, followed by dry spells. Almost all households have experienced droughts and dry spells. In the Sangamner block, which lies in a rain shadow and includes the plateau and rivulet villages, several households have also observed unseasonal rainfalls. The events of frosts are common in higher altitude hilly villages of Khadki Bk.

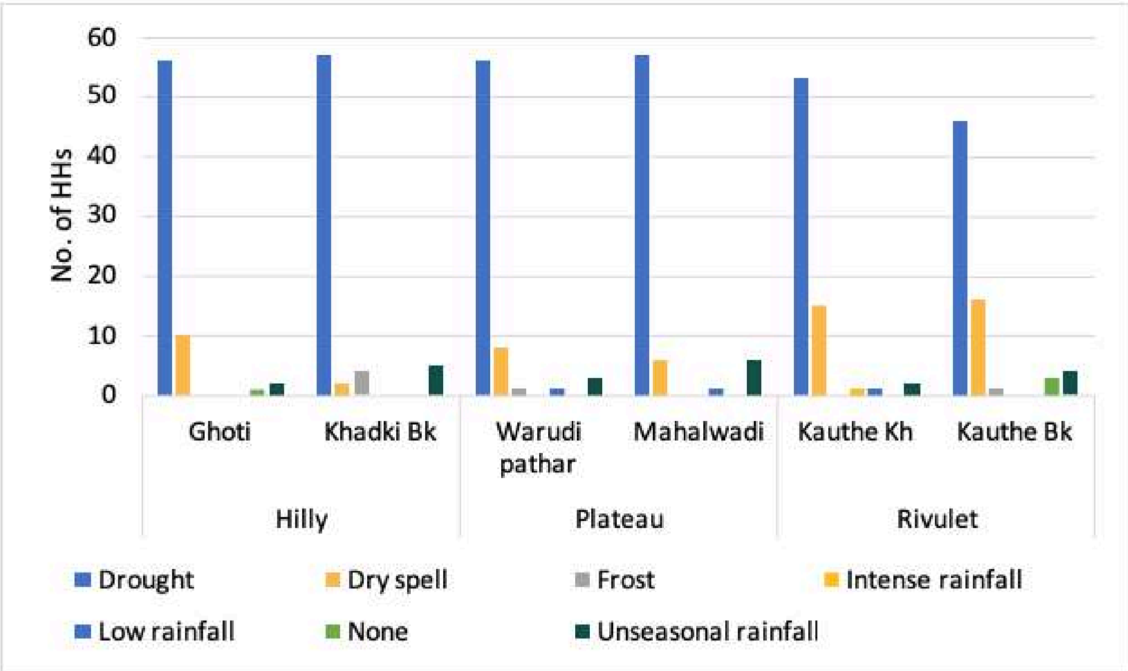

Fig. 6: Experiences of different types of extreme weather events (as mentioned by the community)

The hilly area experienced meteorological drought in 2009, 2015, and 2018; whereas both the plateau and the rivulet area experienced meteorological drought in 2011, 2012, and 2018. However, according to the experience of the villagers, the only drought that was perceived in the hilly area was in 2018–19. The people of the plateau and rivulet areas mentioned that they faced two severe droughts: one in 2012–13 and the other in 2018–19.

5.2 Impact of the climate change adaptation project on land degradation, agriculture, and household water availability of the project and control villages

5.2.1 Changes in the land degradation of the villages

The changes in land degradation over the years is assessed by three indicators: changes in the Land Use/Land Cover (LULC), Soil Erosion and Soil Organic Carbon (SOC), and Land Productivity Dynamics (LPD).

LULC Change

Hilly area villages: Project villages Ghoti and Khadki Budruk (Bk) versus control village Shinde

Overall, in 2017, more changes were noticed in the agricultural areas in the hilly project villages than the control, when compared to the corresponding values of the baseline year. The changes that facilitate agriculture in the project villages are observed in terms of both the cropped and fallow areas. The proportional increase (to the total geographical area (TGA) of the corresponding villages) of the area under agriculture in Ghoti, Khadki Bk, and Shinde is 27.7%., 13.7% and 5.5% respectively (Fig. 7). The fallow land is reduced by 93.3%, 48.1% and 49.2%, respectively, signifying the impact on land restoration in all three villages. Reduction in vegetative cover is observed in these otherwise forested Western Ghat villages. Such reduction is seen in all project villages, being slightly more in the control village. However, greater increase in the agricultural area in the project villages highlights the reversal in the degradation. In both project villages, the built-up area is increased slightly by 7.1% and 0.2%, while in the control village (Shinde), the increase is comparatively more, i.e. 75% (0.78 ha). Overall, in the hilly villages, the settlements have not expanded much in both project villages and the control village between 2008 and 2017. In all three villages, the forest area has decreased from the baseline value. Under the Forest Rights Act, forest land is given to tribal households for agricultural purposes.

Fig.7: Hilly Area: Percentage change in land uses of project (Ghoti & Khadki Bk) villages and control village (Shinde) in 2017 in comparison to the baseline value

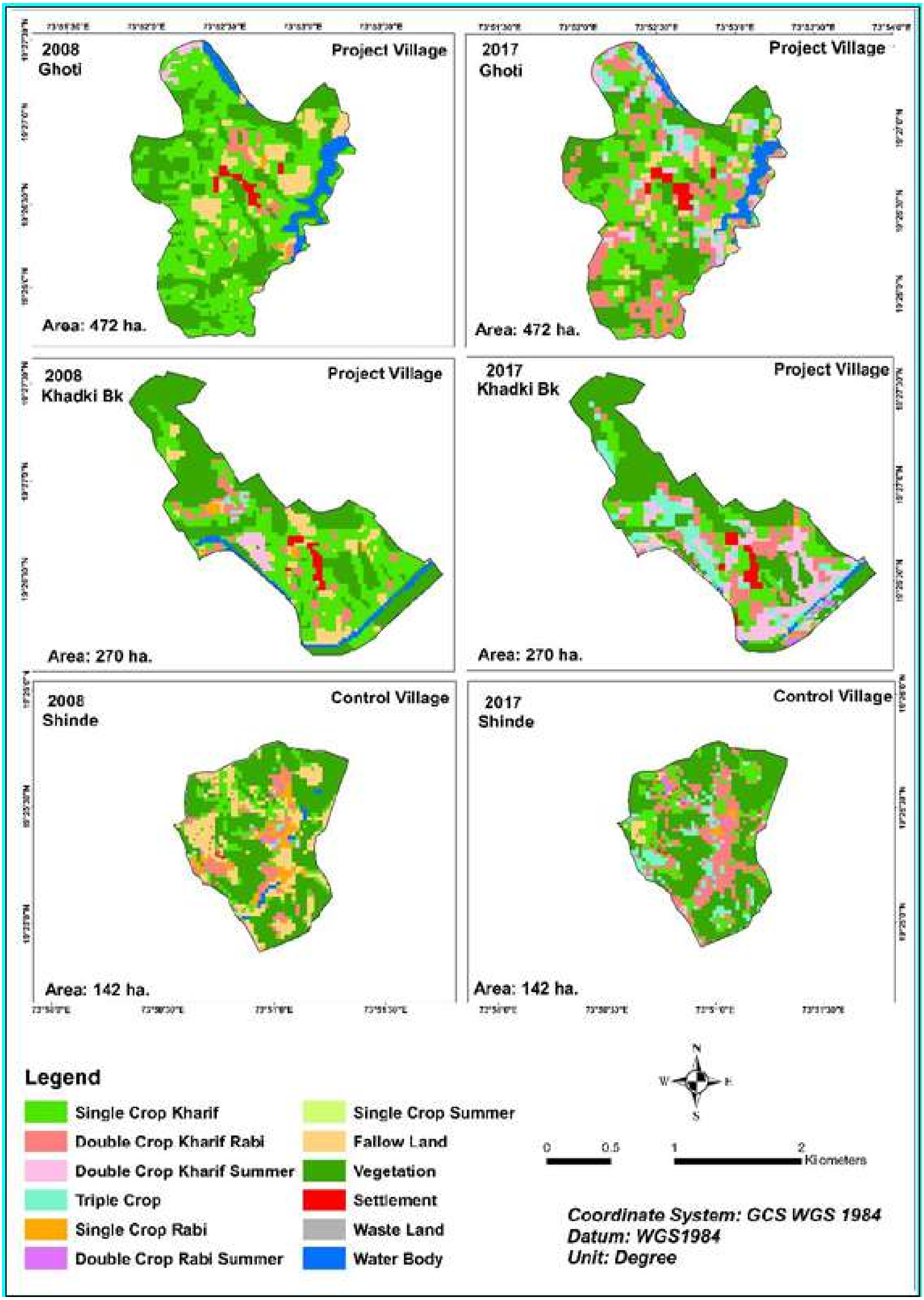

Fig. 8: Hilly Area: Land use/land cover changes in the project (Ghoti & Khadki BK) villages and control village (Shinde) of the hilly area during 2008–2017

The change in the Gross Cropped Area (GCA) in the project villages is much greater than that in the control village (Fig. 9). In the project villages, the GCA shows a more or less increasing trend from 2008 to 2017, whereas the GCA has remained almost unchanged in the control village. The GCA of the three project villages was affected by the drought in 2018–19. For the project villages, the GCAs in 2018–19 were higher than the baseline values, whereas it has decreased from the baseline value in the control village. The GCA improvement over the years bodes well for the project villages, where an increase in the cropping intensity is also observed. It needs to be highlighted that rechargeability of groundwater in hilly areas is low. The impacts on agriculture can only be seen if there are ways to stop and store surface water wherever possible, as well as utilize lift irrigation from flowing water to support agriculture in the Rabi and summer seasons. However, the WSD measures following a ridge to valley approach help to conserve soil and humidity in situ.

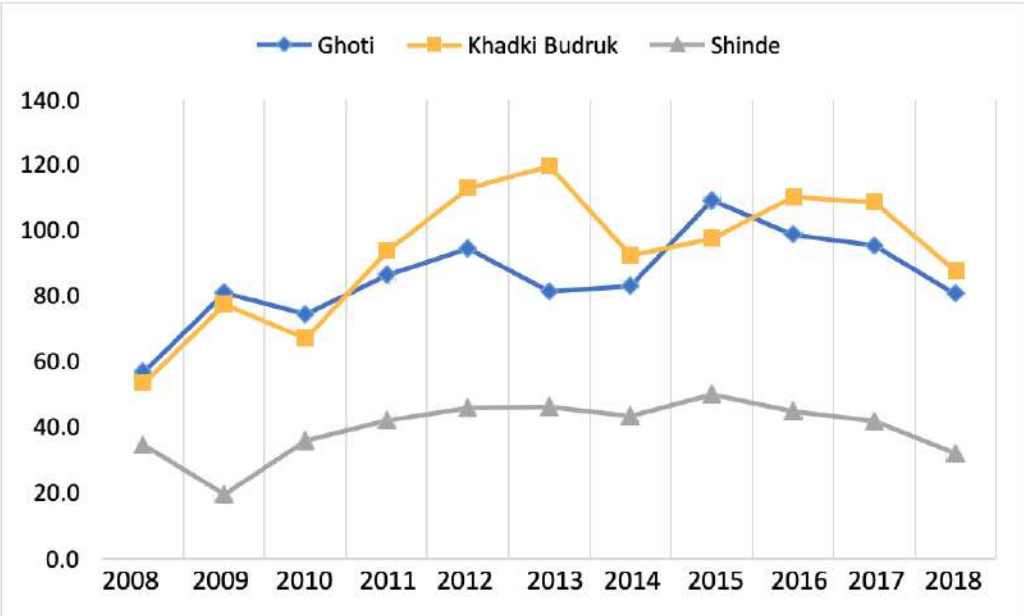

Fig. 9: Hilly Area: Changes in Gross Cropped Area in project (Ghoti & Khadki Bk) villages and control village (Shinde) during 2008–2019

Plateau area villages: Project villages Warudi Pathar and Mahalwadi, versus control village Pimpalgaon Matha

In the plateau area, the overall change in agriculture in the project villages is better than that of the control village in terms of area under agriculture in the different seasons in 2017, in comparison to 2008. The proportional increase (to the TGA of the corresponding villages) of the area under agriculture for Warudi Pathar, Mahalwadi and Pimpalgaon Matha is 65%, 41% and 1%, respectively (Fig. 10). The reduction in fallow land in the three villages is 41%, 44.46% and 3.79% respectively. The low increase of agricultural area in the control village (Pimpalgaon Matha) can be attributed to the little change in fallow land in the village, indicating an inability to cultivate it, and the limited ability to cultivate two or three crops in the year. Greater land restoration in the project villages can be attributed to the CCA interventions, which include WSD / SLM activities and can be said to have contributed to the reversal of land degradation. Although minimal, an increase in the vegetative cover is observed in the project villages, while a decline of 8.5% is observed in the control village. In Warudi Pathar, there is a considerable increase in the built-up areas of 16.21 ha. (76%) and in Mahalwadi the increase is 26.52%, while in Pimpalgaon Matha (control), it is 0.45% which is negligible. This increase in the built-up area indicates that the expansion of

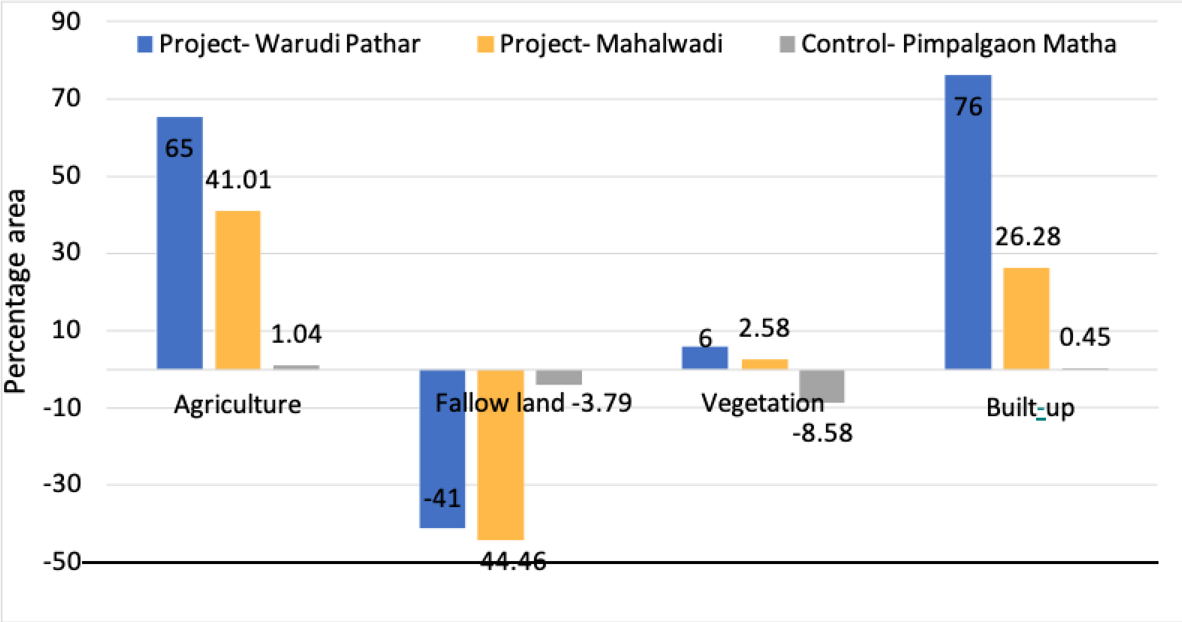

Fig. 10: Plateau Area: Percentage change in land uses of project villages (Warudi Pathar and Mahalwadi) and control village (Pimpalgaon Matha) in 2017 in comparison to the baseline value

settlements is more in project villages than in the control village between 2008 and 2017.

The GCA in the plateau area shows marked changes between 2008 and 2017. The starting point is different in the 3 villages with the control village having far less cropped area. Although there has been an improvement overall, the improvements are much more pronounced in the project villages than in the control. However, the

effect of the first drought (during the assessment year the first drought was in 2012 and the second one in 2018) i.e. the drought in 2012 saw minimal impact in the project villages, whereas the control village suffered a lot in terms of GCA and cropping intensity. The drought of 2018 affected all three villages drastically, reducing the GCA and cropping intensity significantly. The peculiarity of the area is that the plateau villages have slopes and the flow of water can be harvested only by WSD measures, however, rainfall is required. Hence, in the drought years of 2012 and 2018, farming could not be carried out. The villages also have a low natural resource base which does not favour economic growth, unless water is available. The vulnerability of the resident communities to droughts and climate risks is visible in the volatility shown in Fig. 12.

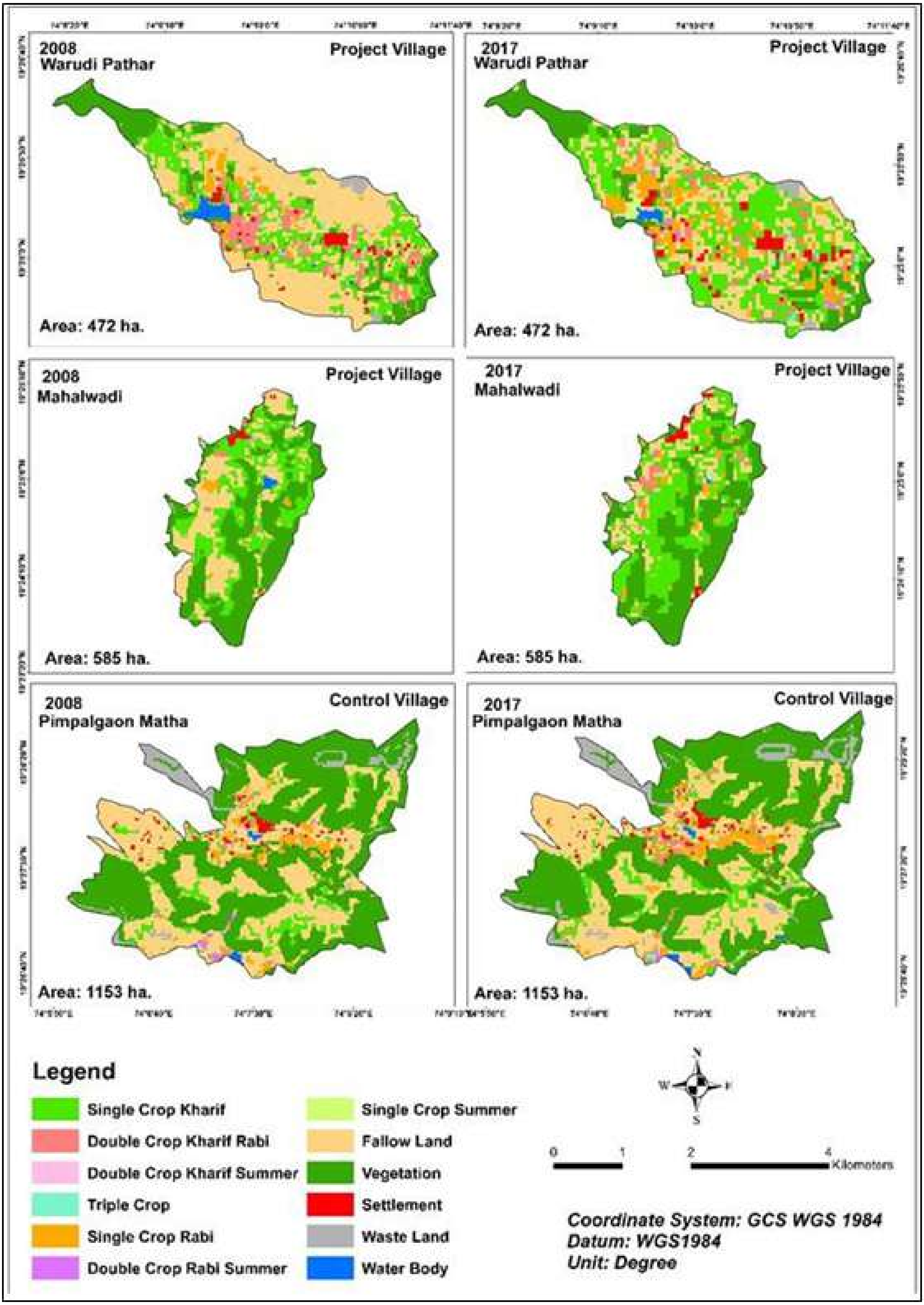

Fig. 11: Plateau Area: Land use/land cover changes in the project (Warudi P. and Mahalwadi) and control village (Pimpalgaon Matha) during 2008–2017

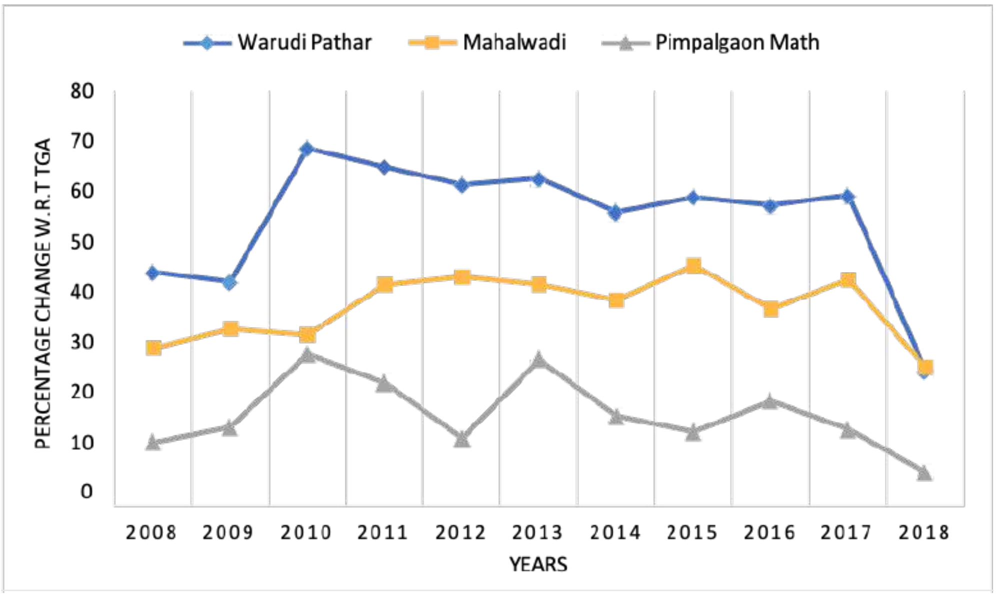

Fig. 12: Plateau Area: Changes in Gross Cropped Area of the project (Warudi Pathar and Mahalwadi) villages and control village (Pimpalgaon Matha) during 2008–2018

Rivulet area villages: Project villages Kauthe Kh and Kauthe Bk versus control village Chas

Overall, the rivulet villages have performed marginally better than the control village in terms of area under agriculture in the different seasons from 2008 to 2017. The proportional increase (to the TGA of the corresponding villages) of the agricultural area for Kauthe Kh, Kauthe Bk, and Chas are 25.3%, 24.8% and 28.4%, with the control village of Chas performing marginally better (Fig. 13). However, the reduction in fallow land for the three villages is 86.6%, 51.1% and 43.9%, which shows that the project villages have seen a much more significant arrest and reversal in land degradation. The higher agricultural impact in the control village might be due to the construction of a minor dam about 5–6 years ago. While vegetation saw a marked difference in the project villages i.e. -0.8% reduction in Kauthe Kh, and 7.3% increase in Kauthe Bk, it has drastically reduced by -8.5% in Chas, despite the construction of the dam. The built-up area has slightly increased in both the project villages by 1.4 ha. (34.2%), 3.97 ha. (17.9%). An increase in built-up area of 1.72 ha. (4.8%) is also noted in the control village, which indicates an expansion of settlements in both project and control villages between 2008 and 2017.

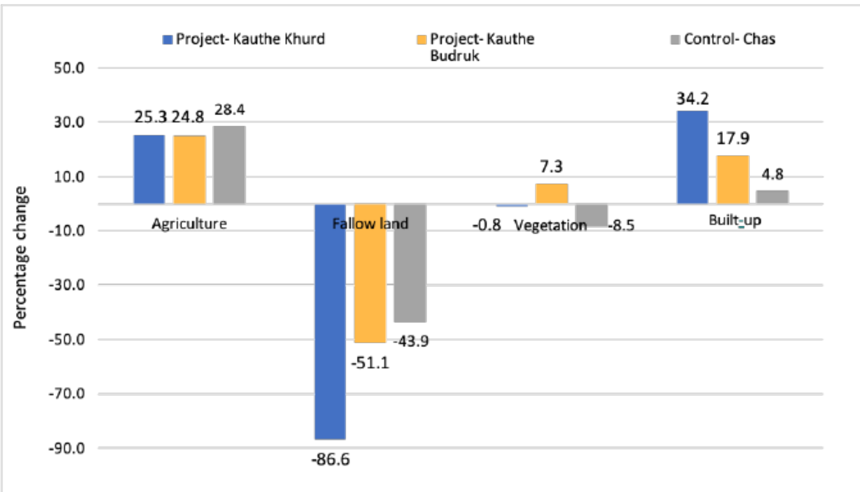

Fig. 13: Rivulet Area: Percentage change in land uses of project villages (Kauthe Kh and Kauthe Bk) and control village (Chas) in 2017 in comparison to the baseline value

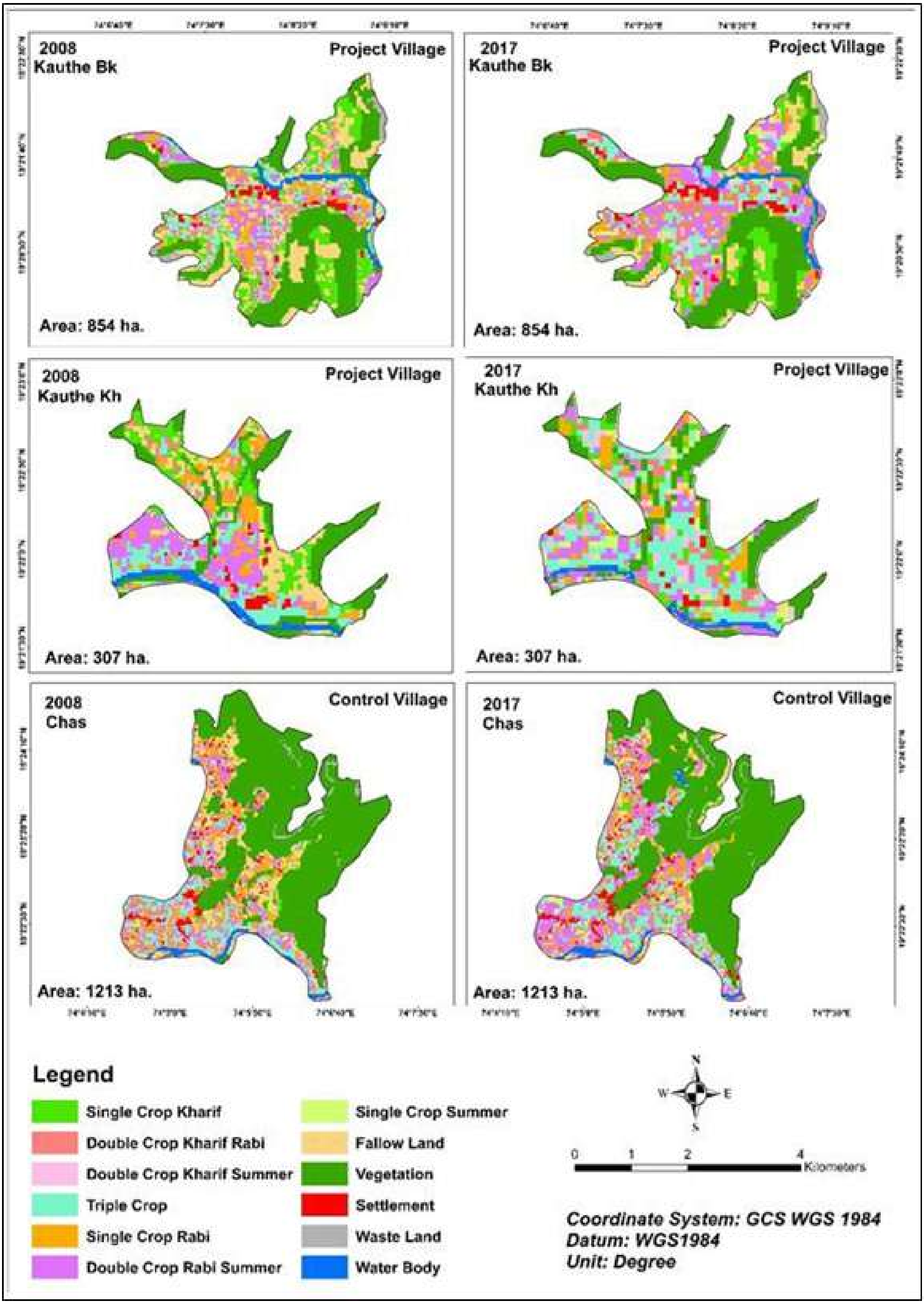

Fig. 14: Rivulet Area: Land use/land cover changes in the project (Kauthe Kh and Kauthe BK) villages and control village (Chas) during 2008–2017

The project villages of the rivulet area have also performed better in terms of the proportional change in the GCA from 2008 to 2017 as seen in Fig. 15. This demonstrates the overall impact on agriculture, the cropping intensity and the differential impacts in abnormal years. The GCA trend shows that the project villages in the rivulet area have performed significantly better than the control village. The overall and gradual increase in GCA over the years shows that cropping has increased in these villages. However, with regard to adaptation, it is seen that the impact of the drought in 2012 was much sharper in the control village as compared to both project villages, although midway into project implementation. This has had a direct bearing on the impact of CCA activities on the adaptive capacity of the villagers. The drought of 2018 was one of the more severe droughts that this area has experienced since the drought of 1972 (based on anecdotal evidence). It has resulted in a steep decline in the GCA of all the villages in this area, however, an increase in GCA in the project villages is seen between 2008 and 2017. Although each of these villages has access to the rivulet that flows into the Mula, better agricultural practices and watershed interventions in the project villages have helped farmers plant multiple crops successfully throughout the year.

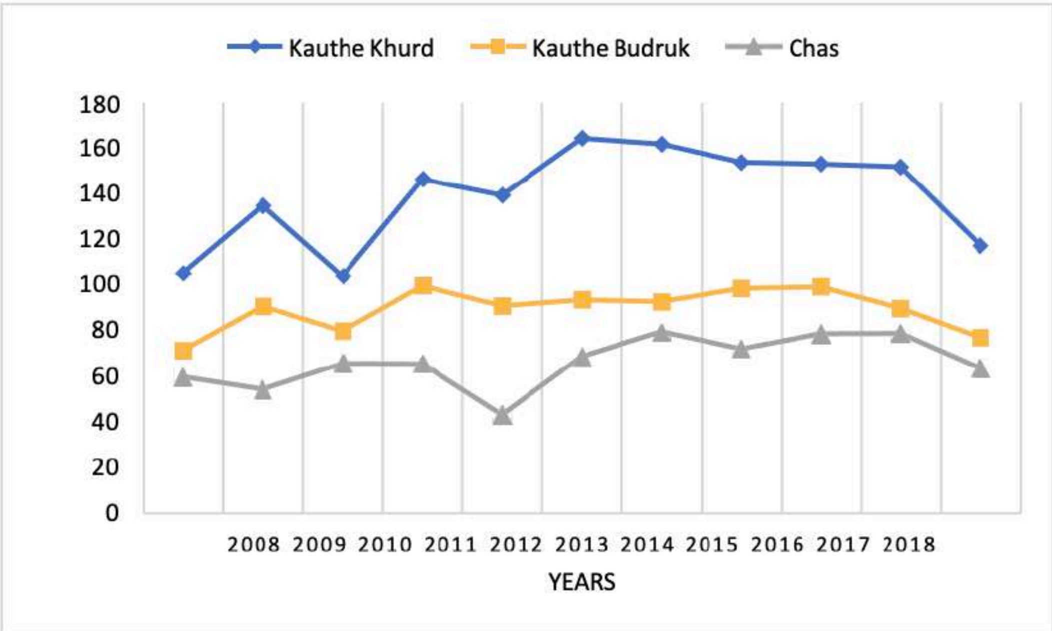

Fig. 15: Rivulet Area: Changes in the Gross Cropped Area of project villages (Kauthe Kh and Kauthe Bk) and control village (Chas) during 2008–2017 (cropped area with respect to the TGA)

Changes in Soil erosion and Soil Organic Carbon

The first set of studied villages lie in the hilly area: Ghoti, Khadki Bk, and Shinde (control); the third set lie in the rivulet area (and in the lower catchment area of the respective watersheds): Kauthe Kh, Kauthe Bk, and Chas (control); while the second set lie in the plateau area (and in the upper catchment): Warudi Pathar, Mahalwadi, and Pimpalgaon Matha (control). As a natural phenomenon, soil erosion is always higher in the upper catchment area, and the soil is deposited in the lower catchment area. However, with project interventions, soil erosion and thereby loss of soil organic carbon is reduced by 24.7% in the Warudi Pathar (project upper catchment village) as compared with the 2.8% increase in erosion in the control village (Pimpalgaon Matha) (Fig. 16).

Since the rivulet villages are in the lower catchment, eroded soil from the upper catchment gets deposited in these villages. It is observed that soil accumulation in the rivulet area project village Kauthe Kh (15.8%) is higher than that of the project village Kauthe Bk (2.6%) and the control village Chas (2.6%), which indicates reduced soil accumulation. The hilly villages are also located in the lower catchment, which has soil deposited in these villages. Soil accumulation in the project village Khadki Bk (14.9%) is comparatively higher than that in the project village Ghoti (8.5%) and the control village Shinde (9%) (Fig. 16). The reduced soil accumulation in the project villages of Ghoti and Kauthe Bk is similar to that in the control village, which needs further investigation. However, this implies that the soil retention rate or accumulation is lesser in the control villages as compared to the project villages. Based on soil erosion and deposition, the soil organic carbon (SOC) detachment and accumulation are calculated. The average SOC detachment and accumulation in project and control villages is shown in Fig. 16.

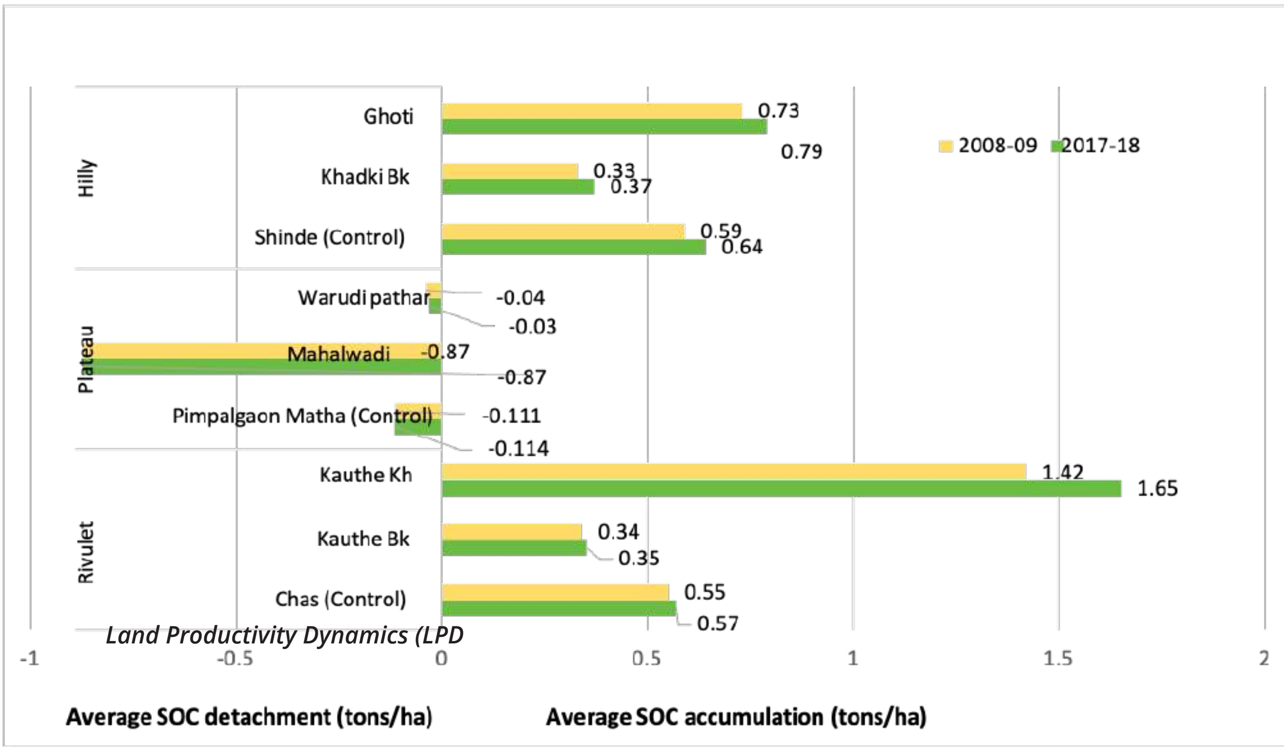

Fig. 16: The average change in soil organic carbon during 2008–2017 in the project and control villages of the three areas

In the LPD analysis, the LULC changes and Normalized Difference Vegetation Index (NDVI) is used for the years 2008 and 2017 to identify the trend (positive change, negative change, and no change) of land-use change. Land Productivity Dynamics (LPD) is presented in terms of declining productivity, early signs of decline, stable but stressed, stable, not stressed, and increasing productivity.

In the hilly villages, most of the total geographic area (TGA) of both project and control villages falls under the stable category followed by the increasing productivity category (Fig.17.a). In the plateau area, a greater percentage of TGA of project and control villages falls under the categories stable and stable but stressed, with the former being more in the control village (Pimpalgaon Matha). In the project villages (Warudi Pathar and Mahalwadi), the area under increasing productivity is higher as compared to their control village, which indicates the positive impacts of SLM (Fig. 17.b). In the rivulet villages, stable and stable but stressed categories occupy most of the TGA. In the project villages (Kauthe Bk and Kauthe Kh), the area under the category of increasing productivity is higher (13.12%, 15.12%) as compared to the control village (Chas—2.56%) (Fig. 17.c). Land productivity dynamics—an early sign of decline, declining productivity and stable but stressed—indicate that in both project and control villages, the croplands and natural vegetation (scrub) are under stress and more so in the control villages. This may be due to the agricultural practices followed and climate change i.e. longer summers and higher annual temperatures, with decreasing rainfall and floods, all of which impact vegetation and erosion.

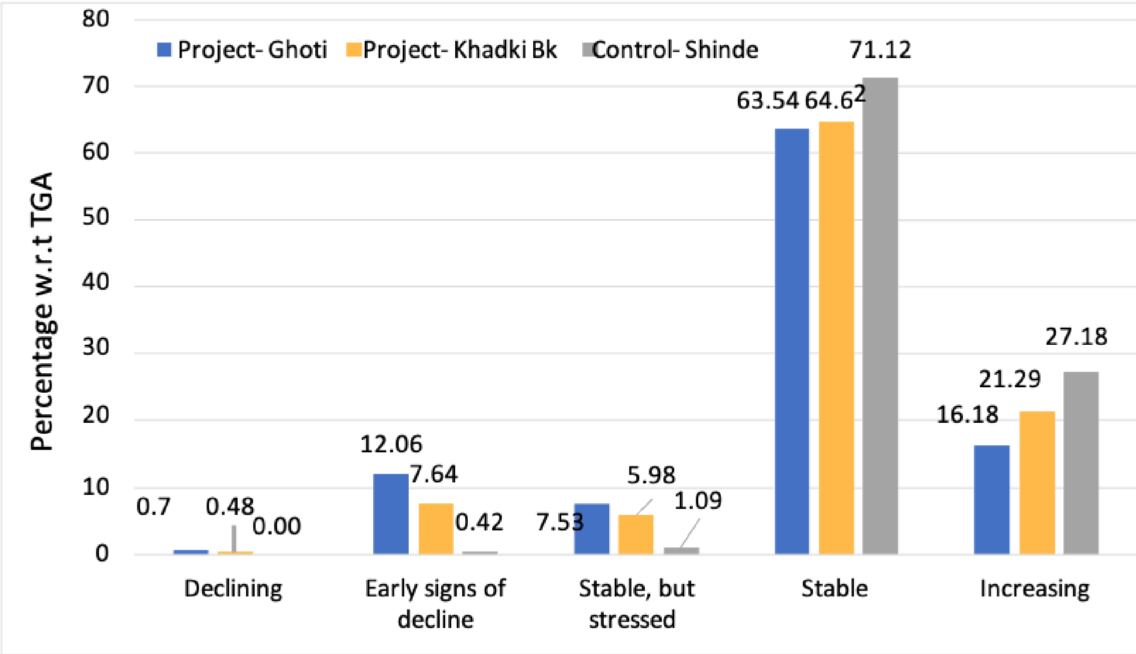

Fig. 17.a: Hilly Area: Percentage area of the land productivity dynamics in project and control villages

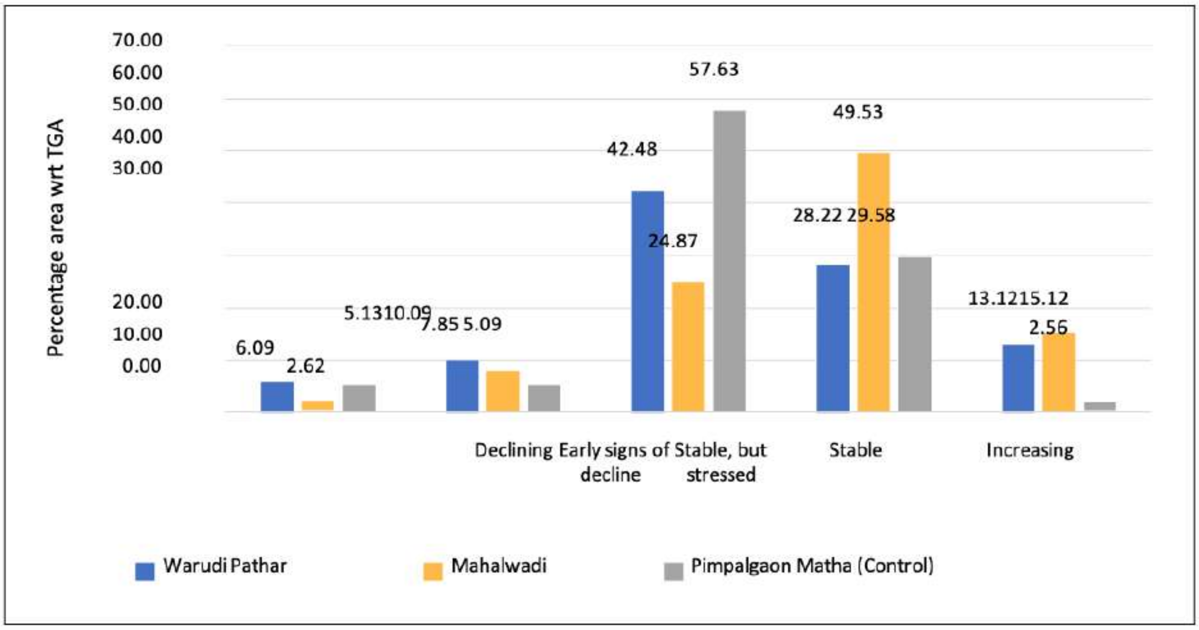

Fig. 17.b: Plateau Area: Percentage area of the land productivity dynamics in project and control villages

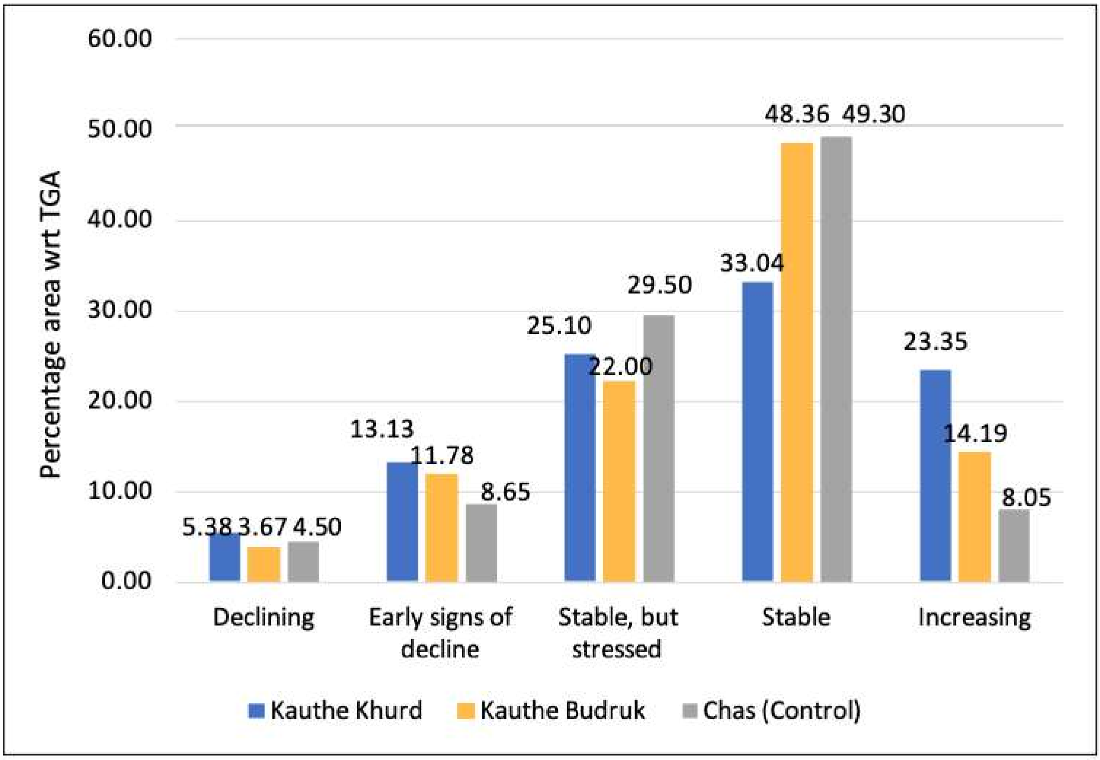

Fig. 17.c: Rivulet Area: Percentage area of the land productivity dynamics in project and control villages

5.2.2 Changes in the crop productivity

The Kharif season is crucial for the agriculture sector, and is the main cropping season. However, it is rain dependent. The crops grown in the Rabi season largely depend on the rainfall during the Kharif season and the following months. With the passage of time, farmers have shifted from food crops to cash crops which are now a priority for most farmers. However, the major crops have remained almost the same in all the villages.

Hilly area villages: Project villages Ghoti and Khadki Budruk (Bk) versus control village Shinde

Paddy is considered as the main kharif crop in the hilly areas. The other crops are nachni (finger millet), wheat, and chickpea. In both the project villages and the control village, there is an increase in the productivity of these crops from 2008 to 2017, but the increase is greater in the project villages (Fig. 18), with Ghoti having the highest productivity for all crops. Due to the availability of water in the summer, many farmers cultivate groundnut in the project villages. No summer crop is cultivated in the control village.

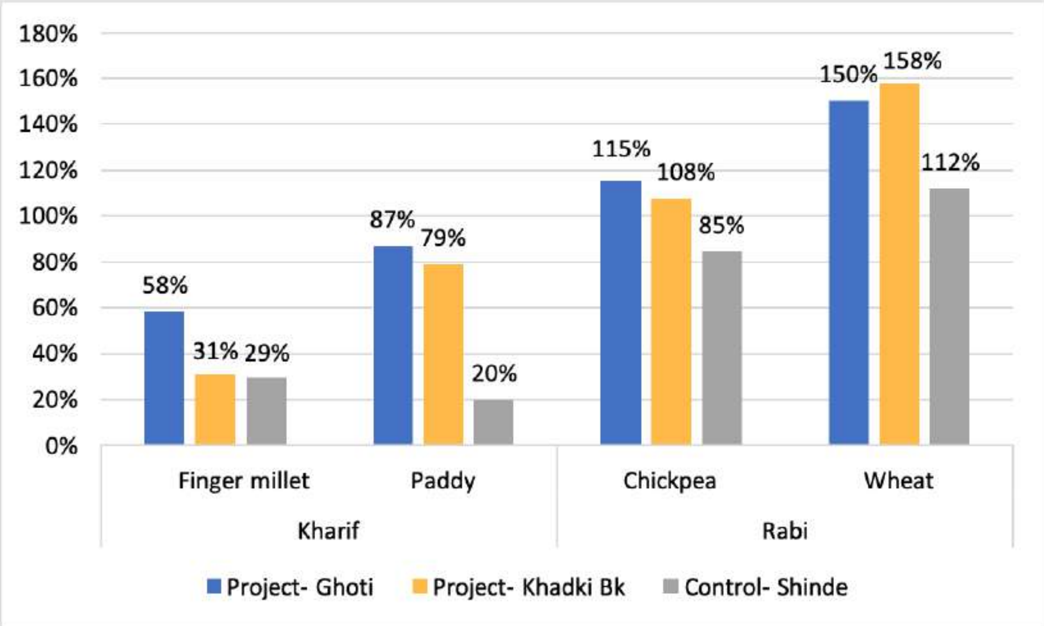

Fig. 18: Hilly area: Percentage change in the crop productivity in 2017–18 (normal rainfall) in comparison to the baseline value

The residents of the hilly area reported that they faced only one drought in the last ten years, in 2018–19, and the productivity of all the crops in the three villages suffered. However, it was found that overall, the productivity of all crops was higher in that drought year as compared to the baseline value (Fig. 18), and the productivity of all the crops in the project villages are higher than that of the control village in 2018–19. This indicates that the CCA intervention has helped to develop some resilience in the project villages.

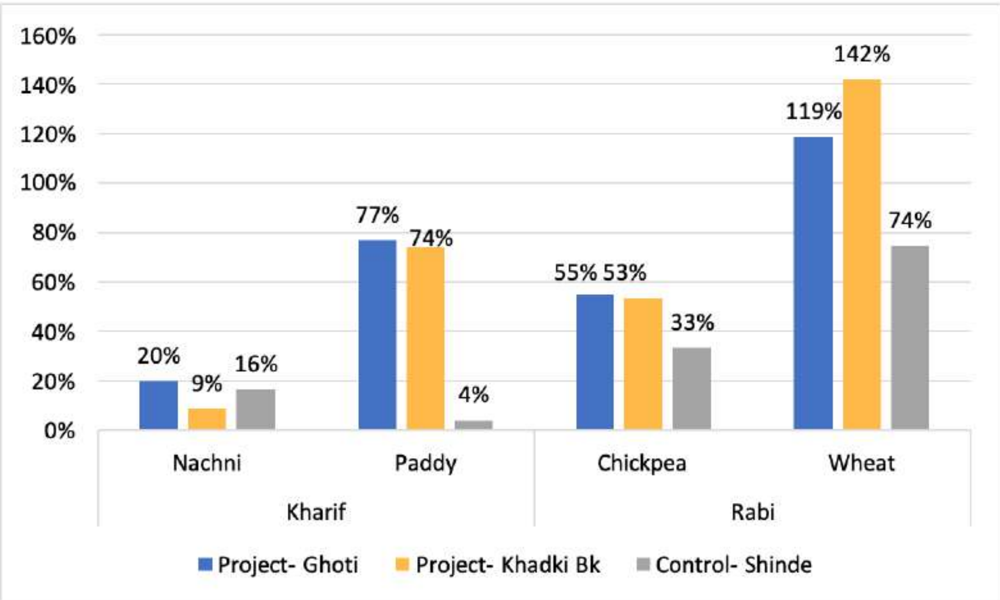

Fig. 19: Hilly Area: Percentage change in the crop productivity in 2018–19 in comparison to the baseline value

An interesting fact found during the community interaction is that in drought years people cultivated a smaller area, but concentrated all their resources into the limited area cultivated. Therefore, the slash in crop productivity may not be that pronounced for some of the crops, especially the Rabi crops.

The hilly area of Akole is in the agro-climatic Transition Zone II which lies in the high rainfall region of the Western Ghats. The main challenge that farmers face here is that of access to knowledge, market, and infrastructure. In addition to the hilly topography, owning small parcels of land makes farming somewhat challenging. Besides, it is an area where water recharge is possible only to a limited extent.

Plateau area villages: Project villages Warudi Pathar and Mahalwadi versus control village Pimpalgaon Matha

In the plateau villages, the main crops are groundnut, soybean, onion, tomato, chickpea, and wheat. Like the hilly area, the productivity of all the crops has increased from 2008 to 2017 and the increase is greater for the project villages than that of the control village (Fig. 20).

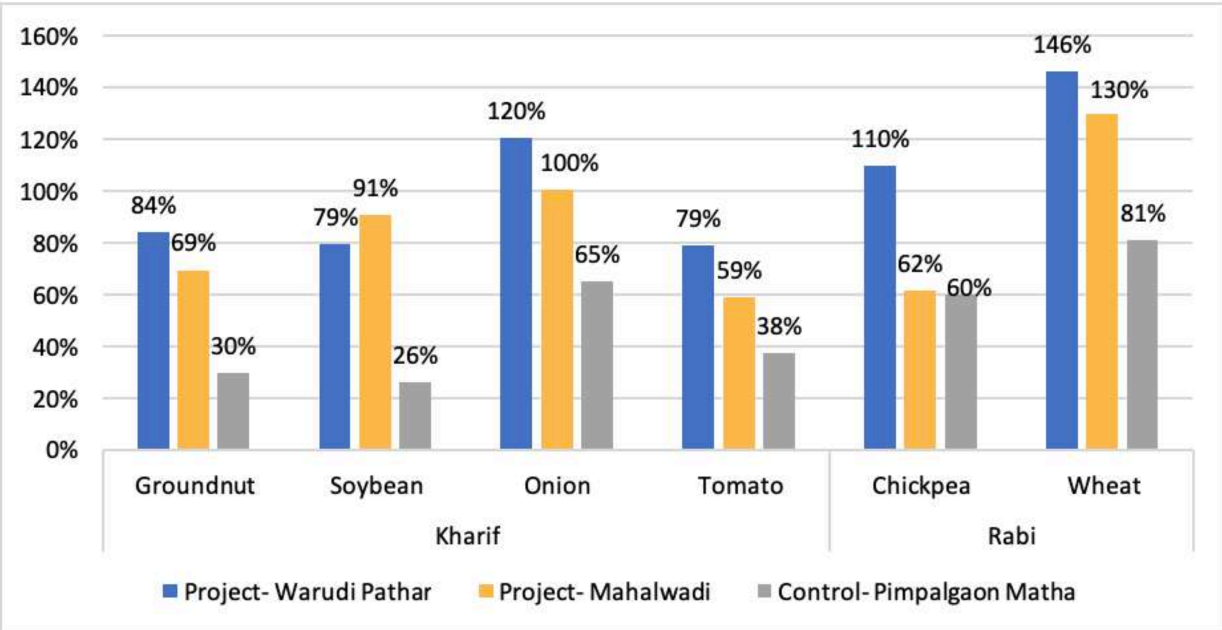

Fig. 20: Plateau Area: Percentage change in the crop productivity in normal rainfall year 2017–18 as compared to the baseline value

It is found that overall, the productivity of all the crops suffered in both droughts i.e. 2012–13 and 2018–19. In 2012–13, a year mid-way in the CCA implementation, the productivity of crops suffered and was less than that of the baseline value. The crop productivity of Mahalwadi is worse than that of the control village. However, the crop productivity in 2018-19 improved and it is found to be better than that in 2012-13. The productivity values are better than that of the control village in 2018-19, one of the worst droughts in that region since the drought of 1972 (as perceived by the people).

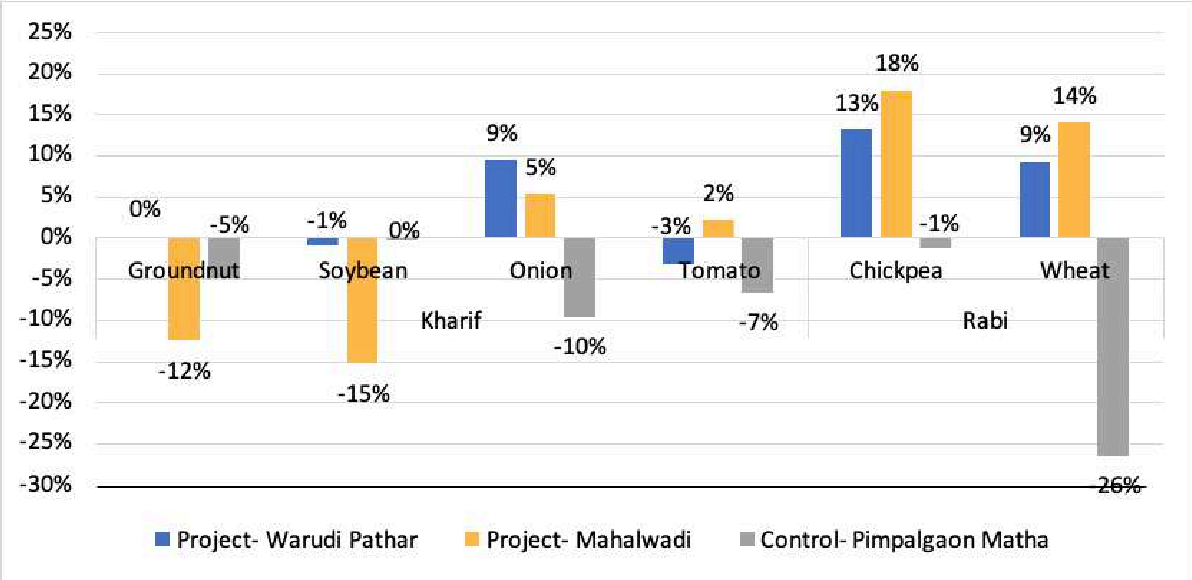

Fig. 21: Plateau Area: Percentage change in the crop productivity in drought year 2012–13 as compared to the baseline value

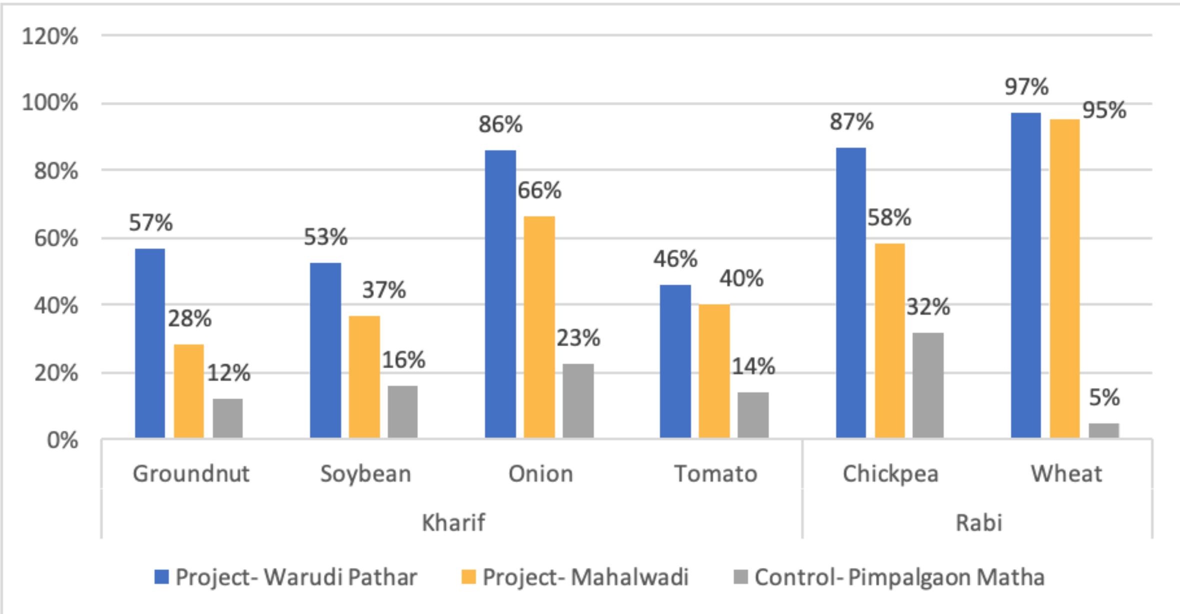

Fig. 22: Plateau Area: Percentage change in the crop productivity in drought year 2018–19 as compared to the baseline value

Rivulet area villages: Project villages Kauthe Kh and Kauthe Bk versus control village Chas

In the rivulet area, the main crops are groundnut, chickpea, onion, tomato, pearl millet, and wheat. Farmers in this area have access to the water of the tributary of the Mula River. Therefore, they barely face water scarcity during the lean period. Like the hilly and the plateau areas, the productivity of the crops is greater than that of the baseline value. The overall productivity of major crops of Kauthe Kh and Kauthe Bk is higher than that in the control village Chas (Fig. 23).

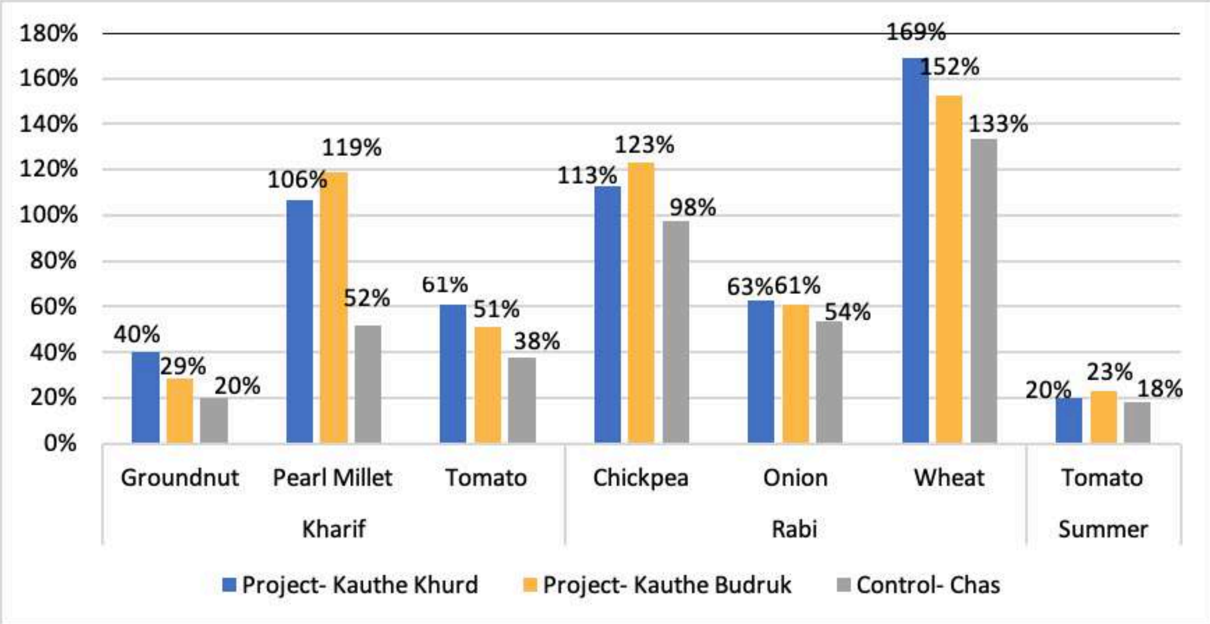

Fig. 23: Rivulet Area: Percentage change in the crop productivity in the normal rainfall year 2017–18 in comparison to the baseline value

A comparison of the data in Fig. 24 and 25 shows that the rivulet villages performed much better in 2018 than in 2012, even when, as perceived by the people, the drought of 2018 was "one of the worst since the 1972 drought". The increase in crop productivity of the project villages from 2012 to 2018 shows that the interventions have helped to improve the adaptive capacities of the people. Importantly, the rivulet villages did maintain high productivity for most of the crops during the 2018 drought, due to the geographical location of the villages and the impact of the CCA intervention.

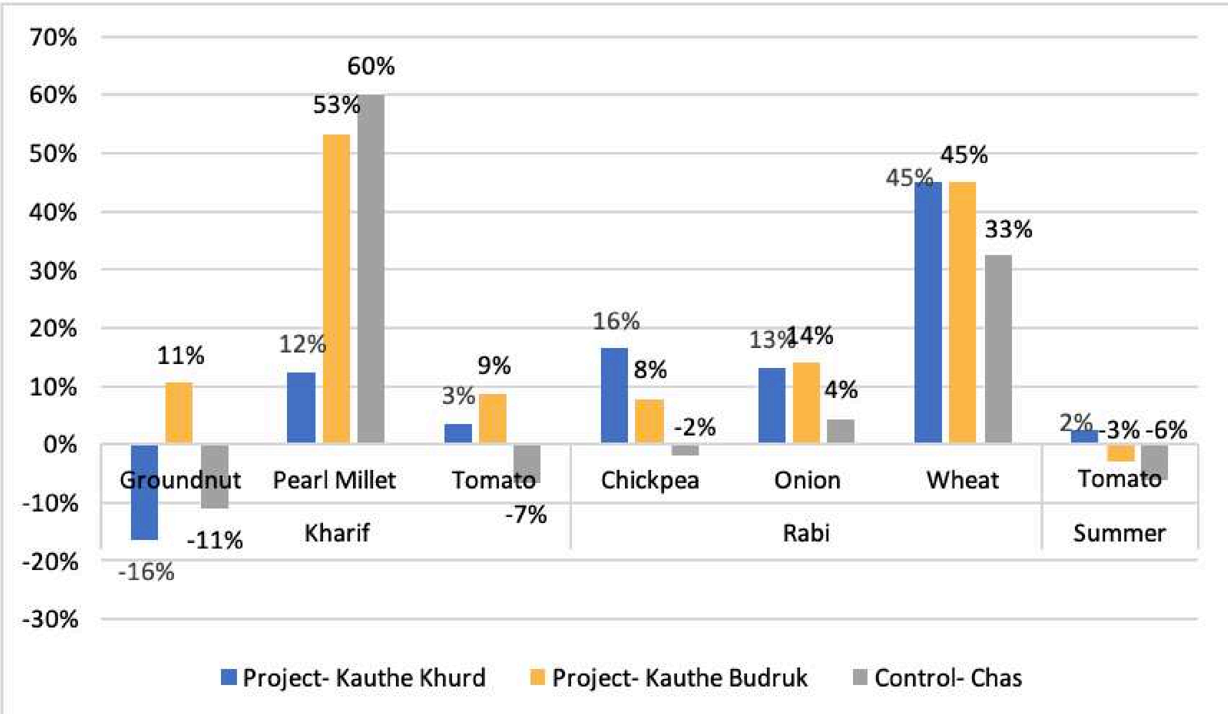

Fig. 24: Rivulet Area: Percentage change in the crop productivity in drought 2012–13 in comparison to the baseline value

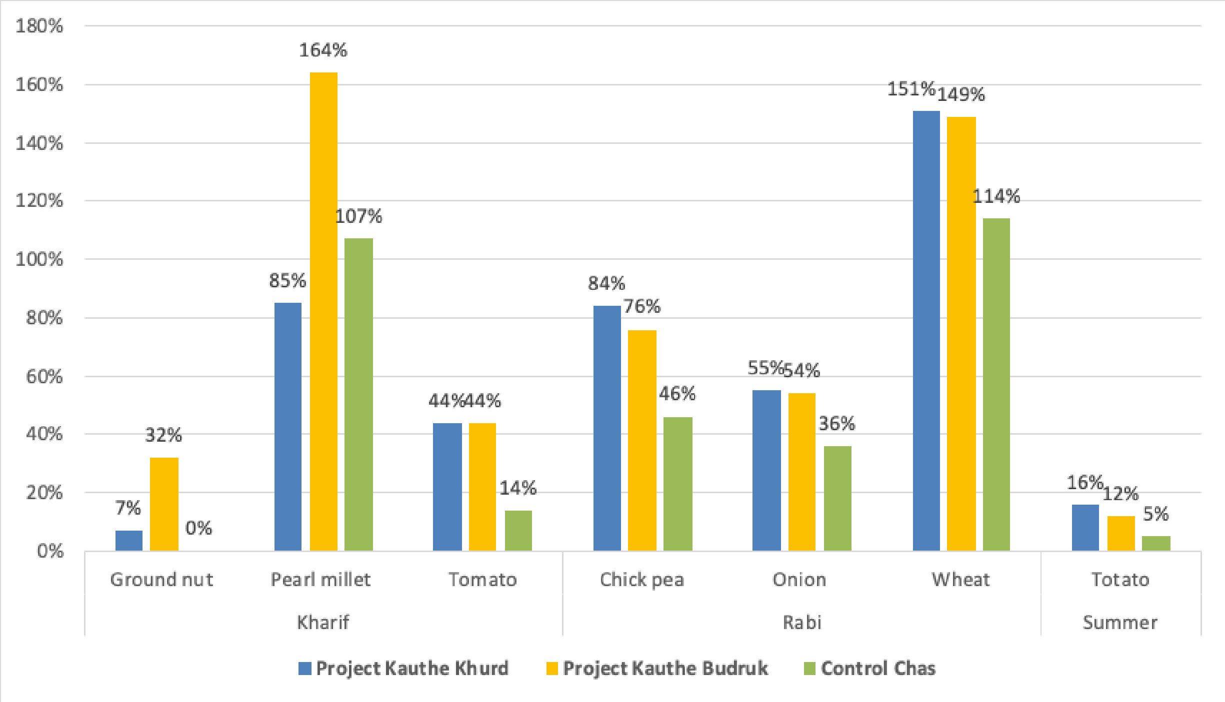

Fig. 25: Rivulet Area: Percentage change in the crop productivity during the drought year 2018–19 in comparison to the baseline value

The impact of the CCA interventions has been reflected in all three topographies. As watershed development is the basic component of the CCA intervention, the impact of WSD measures has been observed in terms of the productivity of different crops during the years after the implementation of CCA. This is in line with the impact of other CCA intervention that are similar in nature (Gray & Srinidhi, 2013). The graphs represented above also show that the project villages have performed much better than the control villages in their respective areas. This is consistent with studies from other semi-arid regions of the country (Palanisami, Kumar, Wani, & Giordano, 2009).

5.2.3 Benefit for household water availability

One of the main benefits of climate change adaptation interventions is the improvement in household water availability. The three plateau villages and the hilly area control village Shinde were dependent on water tankers in 2008–09. The rivulet villages and the project villages of the hilly area have always had sufficient water for domestic needs including in 2019. It is the three plateau villages, both project and control, that have needed water tankers in the pre-project period. However, in the project villages, people have not needed water tankers at all during the year of normal rainfall. For the control village as well, the need for water tankers has reduced. The need for water tankers for project villages is greatly reduced in the drought years, while the control village suffered greatly during both droughts, i.e. during 2012–13 and 2018—19 (Fig. 26).

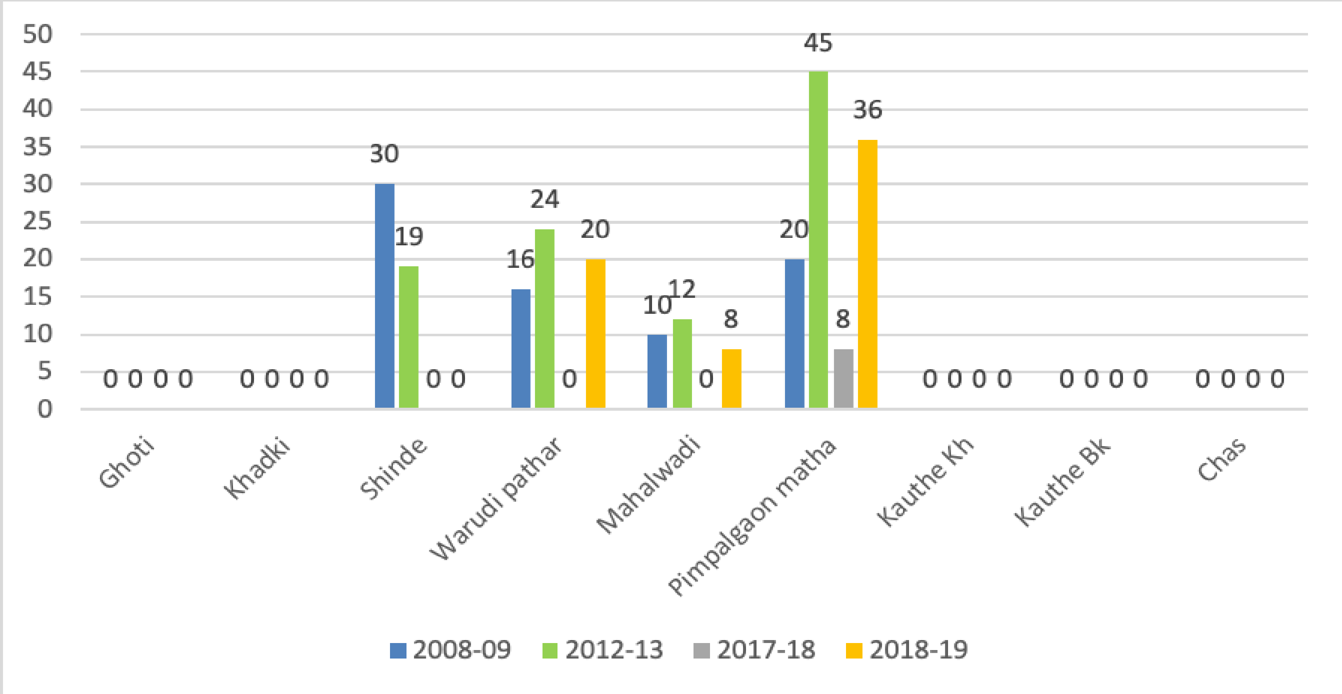

Fig. 26: Requirement of water from tankers during the years 2008–09, 2012–13, 2017–18, and 2018–19

The complete economic valuation of the increased availability of water for domestic use has not been calculated due to the paucity of data (only the money saved for water tanker has been calculated). However, the following section (Section 5.3, Fig. 29 and Table 6) captures the benefits experienced by people such as improved domestic water availability in all the project villages.

5.3 Participation of the villagers in the CCA activities, and their perception of the project benefits, the economic valuation of the benefits, and the cost-benefit analysis

This section analyses the participation of the villagers in the different activities of the CCA intervention and the perception of villagers about the benefits as well as the monetary gains resulting from the intervention. In this section, the cost-benefit analysis for the CCA project villages and the control villages in terms of agriculture and household water availability including a comparative analysis of SLM-CCA with the business-as–usual scenario is addressed.

5.3.1 People's participation and their perceptions of benefits

The CCA project included mobilisation at the village level, raising awareness for WSD interventions, sustainable agriculture, receipt of local crop specific agro-met advisories, and training for water budgeting. This section discusses the participation of the local communities in the CCA activities and the benefits accrued due to these activities.

The WSD interventions included constructing SLM structures such as Continuous Contour Trenches (CCT) along the slopes, loose boulder structures, gully plugs, gabions, percolation tanks, and check dams (Fig. 27), along with afforestation. Of the 419 households in the study sample, 98% participated in at least one of the activities mentioned above. The types of benefits accrued from WSD activities have, according to the village communities, contributed to soil conservation, improved availability of surface water and groundwater, increase in agricultural productivity, increase in income, and decrease in tanker dependency (Fig. 27). These benefits can directly be linked with WSD activities. While these benefits are directly observed, they are also mainly observed through the arrest of soil erosion, increase in groundwater levels and increase in agricultural productivity.

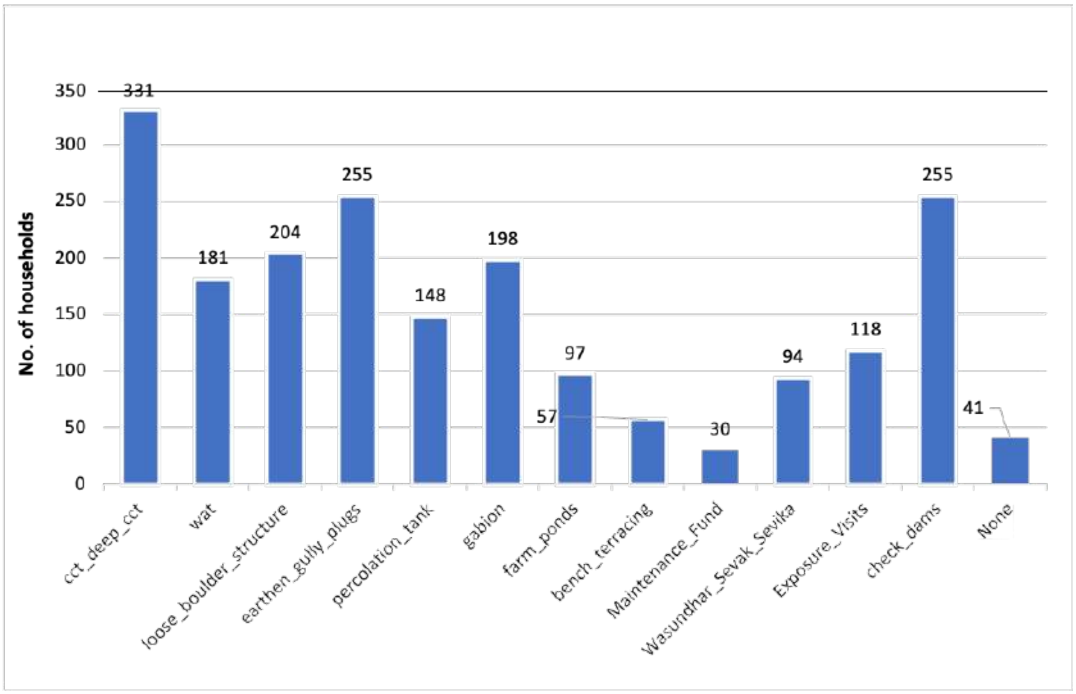

Fig. 27: Participation of villagers in different types of watershed development measures

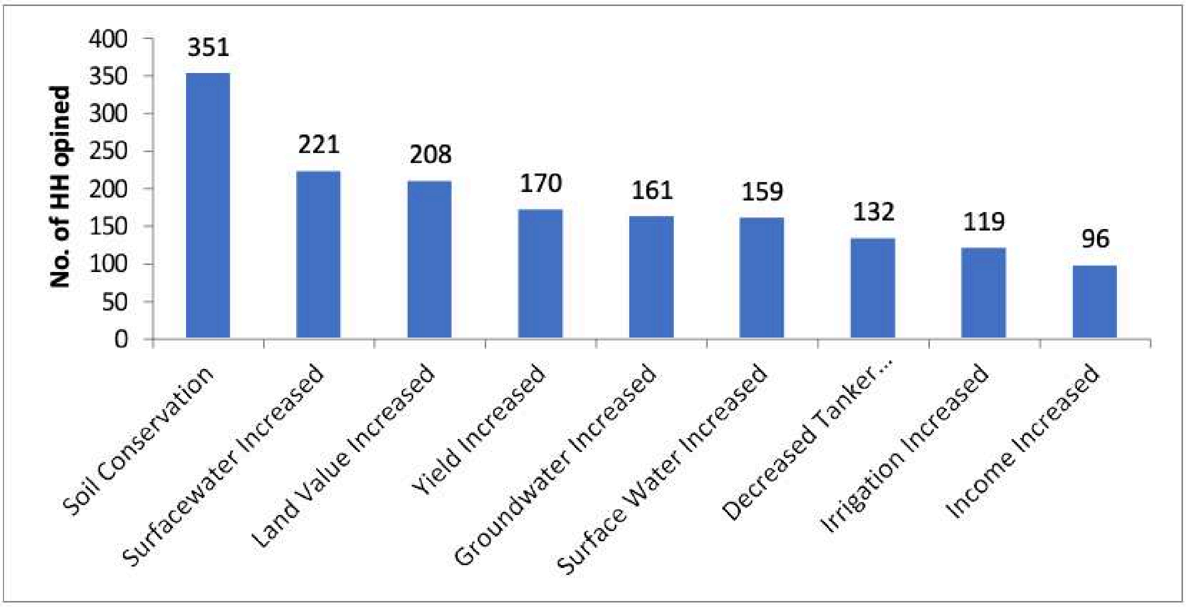

Fig. 28: Types of benefits observed due to WSD as opined by number of households surveyed

Watershed structures contribute to restoration of the natural resources, including soil, water, and forests. WSD structures are the base on which ecosystem services can be improved and climate change adaptation can be addressed. With the systematic regeneration of natural resources and people's participation as well as governance through the Village Development Committees, the community became aware that maintaining the watershed yielded mutual benefits shared between the ecosystem, ecosystem services and the people themselves. This helped them to understand the linkages between the interventions and the natural resources of land, water, agriculture and forests (Gray & Srinidhi, 2013; Ministry of Rural Development, 2015).

Different activities related to water use management, water budgeting and water storage tanks are seen in Fig. 29. Although water-related interventions have an impact on agriculture (captured above on productivity) and domestic needs, the two benefits are separated to better capture the impact on domestic water requirements. This includes water availability of drinking water and domestic needs with a reduced dependence on tankers, as seen in Fig. 29. These impacts are supported by evidence from other Indian and international studies (AFD, 2011).

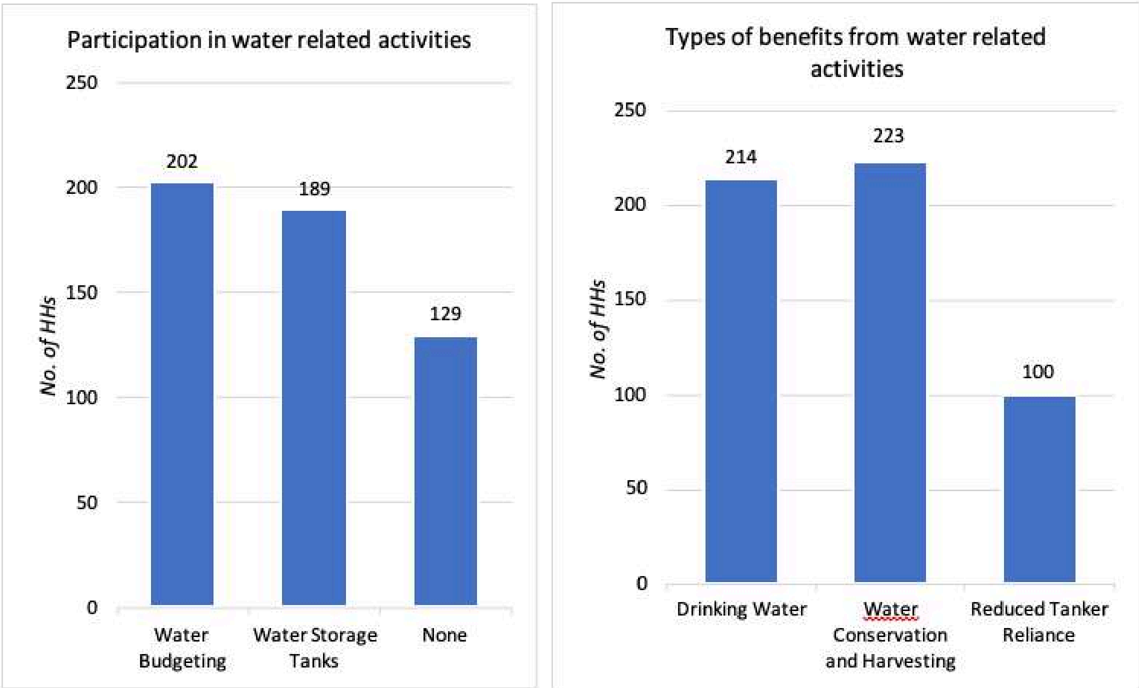

Fig. 29: Participation and perceived benefits of water related interventions in the project villages

The interventions include agricultural practices, demonstrations and capacity building for organic inputs, installation of irrigation sets, etc. These practices are aimed at helping farmers adapt to the changing climate through the introduction of a package of good agricultural practices for different crops. Early Warning Systems help reduce and avoid loss and damage due to weather events, implemented by setting up Automated Weather Stations (AWS) in villages to record the village level rainfall, temperature, and other weather parameters to generate locale specific crop weather advisories. The establishment of early warning systems is important for adaptation to assist farmers in the reduction of crop damage due to extreme weather events.

People's participation in the activities in the study villages includes their involvement in agriculture and water management, as seen in Fig. 30. Almost all the 419 households surveyed in the project villages participated by receiving the agro-met advisories, and close to 90% of the population in these villages have participated in agricultural interventions. The kind of benefits associated with these interventions is also listed in Fig. 30. The benefits of the agricultural interventions are seen in terms of increased production, income, irrigation, food security, etc. The benefits of the AWS early warning systems are seen as avoided loss or damage through weather information and better preparedness. Various agencies across the world have proposed the agricultural interventions mentioned here as measures in adaptation plans (FAO, 2018).

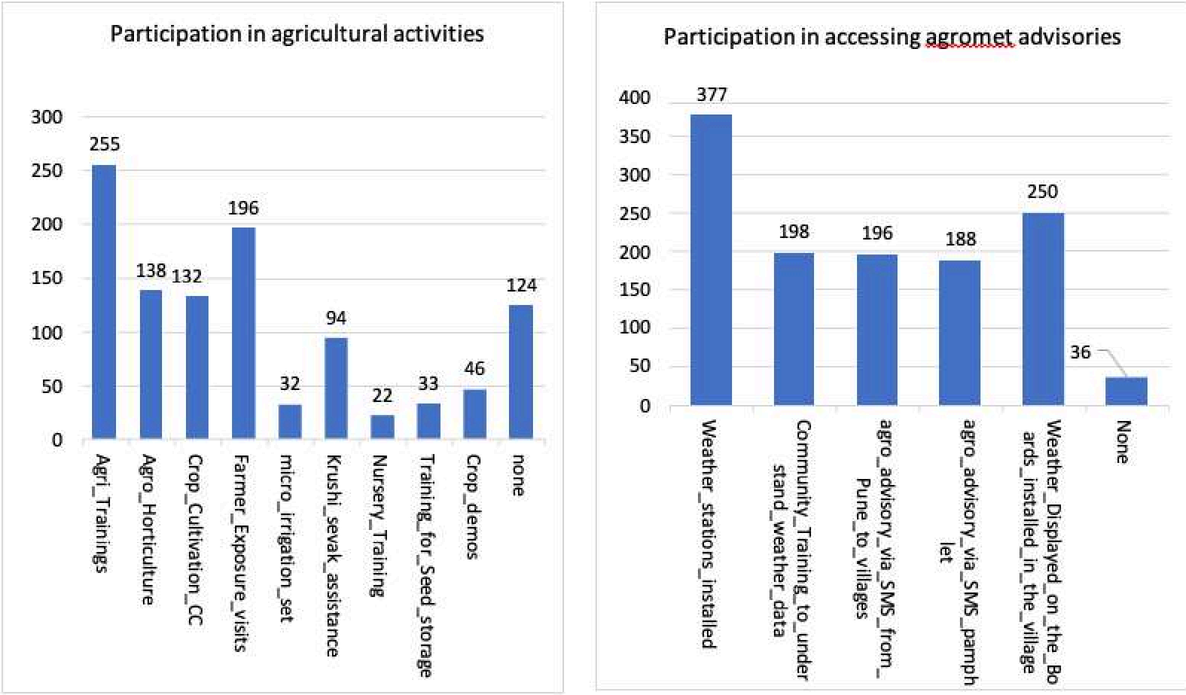

Fig. 30: Participation in agricultural activities and accessing agro-met advisories

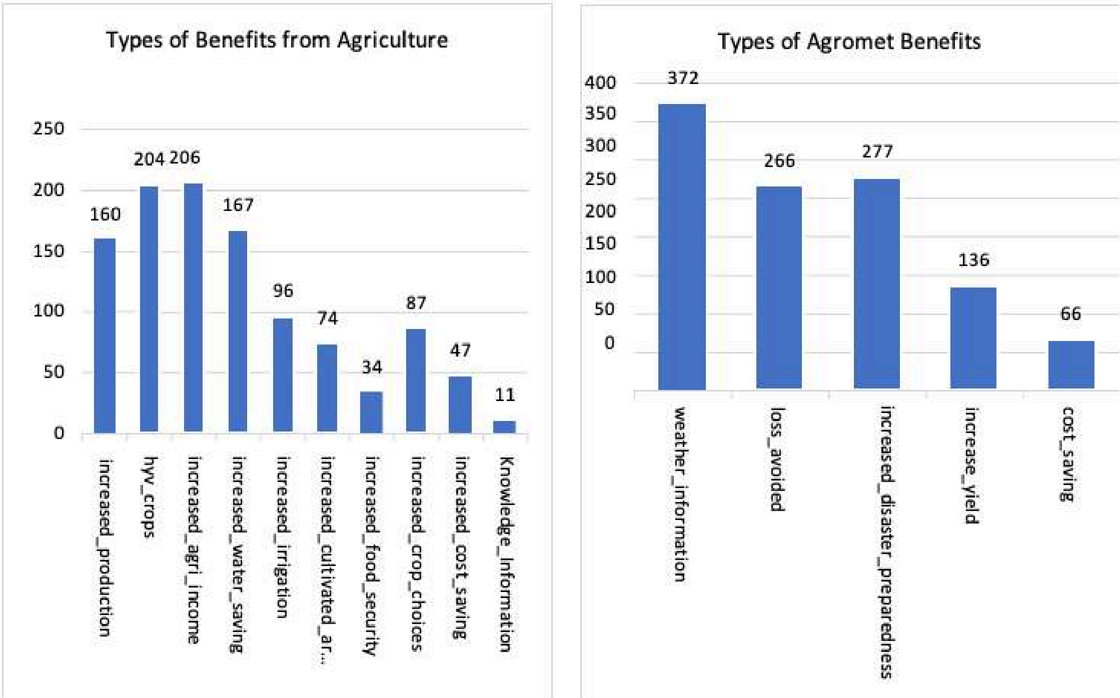

Fig. 31: Participation in agriculture activities and the perceived benefits of interventions related to agriculture

Afforestation was the main intervention related to forests. The forest areas are regulated quite strictly by the forest department, and the interaction of the village communities with the forests is therefore, limited. However, several village communities rely on forests for their food security and income. In Fig. 32 below, the benefits that households derive from neighbouring forests are listed, which include timber, medicinal plants, fodder, fruits, and vegetables. The additional benefits are also seen in terms of soil conservation and income from forests.

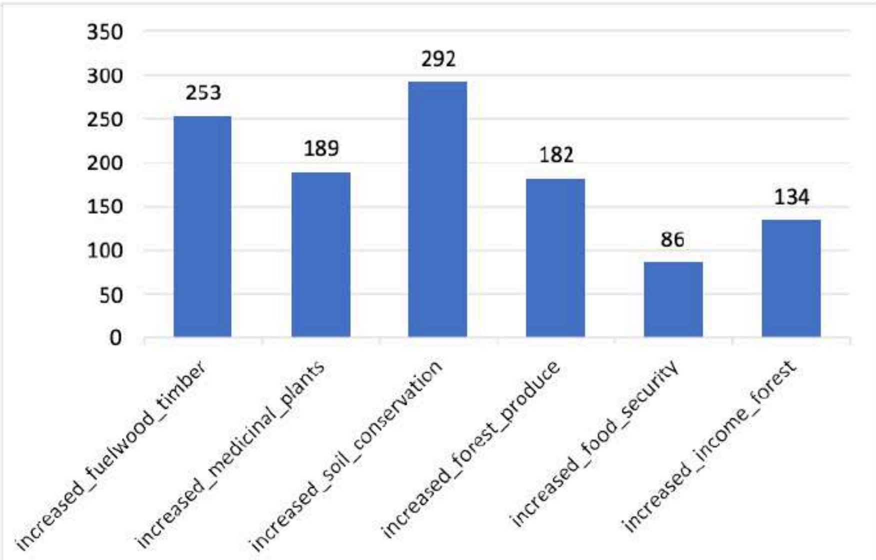

Fig. 32: Opinion of the villagers about the benefits from forests

5.3.2 Actual and Perceived Benefits and Their Economic Valuation

In the previous section, the benefits of the CCA interventions and the local communities' participation are described. In this section, the monetised benefits as perceived by the respondents and the actual monetary values recorded during interviews are noted. The perceived value depends on the views of various households in the study villages about the total benefit or loss associated with these interventions. The actual benefit-cost ratio (BCR) and Net Present Value (NPV) are calculated using the monetised values of agriculture and water-related costs and benefits, project costs and recurring costs if any.

Fig. 33 and Table 5 below show the BCR and the NPV calculated for period 2010–11 to 2018–19. In all the cases, the BCR is found greater than 1 for three types of discount rates: 3%, 5%, and 8%. The project villages of each area have a greater NPV per household (HH) than that for their respective control villages. For all the project and control villages in this study, the BCR is greater than 1, which demonstrates that the total benefit is greater than the total cost incurred. According to the 2nd evaluation criteria, the NPV/HH values of villages of all three areas are found to be higher than that of the corresponding control villages (Table 5). However, the NPV/HH is highest for the rivulet villages, followed by the plateau villages and then the hilly area. The differences are mainly due to water security which is highest in the rivulet area. Though situated in high rainfall areas, the low rechargeable hilly area villages store less water, hence have limited water for agriculture for the second and third crops. Moreover, these villages have poor connectivity to the market. The tribal households that are predominant in this area own small parcels of land. It is to be noted that all of the BCRs have been calculated to include only the benefits from agriculture and water. The benefits from biophysical components such as forests and NTFP and the socioeconomic factors like biomass increase and migration benefits have not been

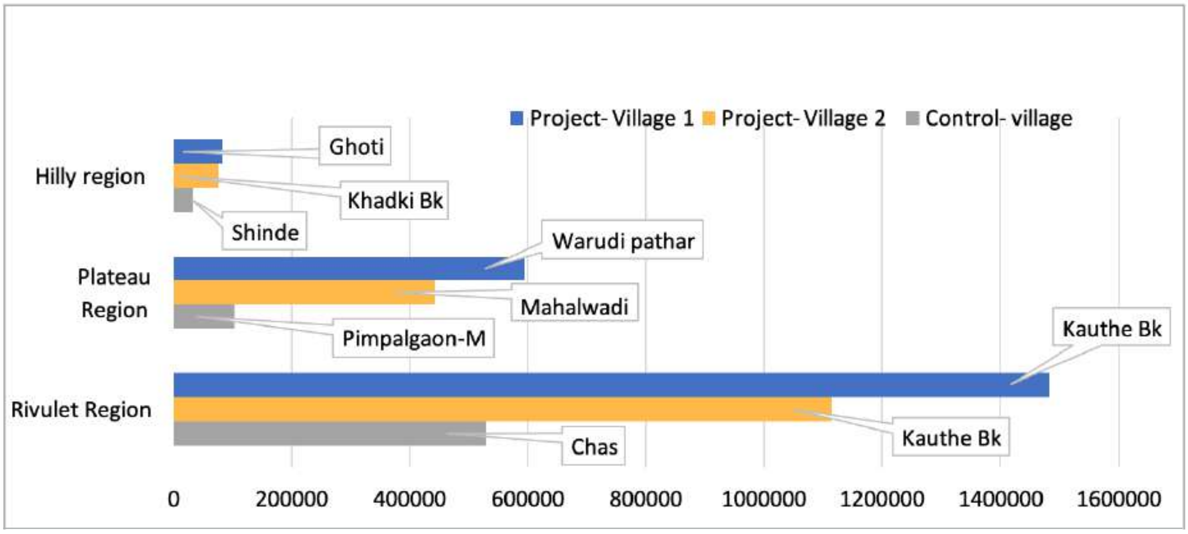

Fig. 33: NPV/HH for project and control villages at 8% discount rate for the three study areas

estimated and economically valued.

Table 5 gives details of the absolute NPV values, the NPV/HH values and the BCRs calculated and adjusted for sensitivities reflecting three discount rates of 8%, 5% and 3%. Even when 8% is taken as the discount rate, which is quite high for a developmental intervention, the NPV/HH values for the treatment villages are greater than that of the control. This shows that it is indeed viable to undertake these interventions. Various studies also support this result, indicating that such methods and results help to evaluate interventions like CCA (Prabhakar & Shaw, 2007; Tröltzsch, et al., 2016).

		Project Village 1: Ghoti			Project village 2: Khadki Bk			Control Village: Shinde		
		NPV	BCR	NPV/HH	NPV	BCR	NPV/HH	NPV	BCR	NPV/HH
Hilly Area	At 8% DR	14652829	1.14	83730	11244549	1.16	77549	1648583	1.16	32371
	At 5% DR	18233797	1.15	104193	14874668	1.18	102584	1905057	1.18	37363
	At 3% DR	21123456	1.15	120705	17886274	1.20	123354	2105606	1.20	41262
		Project Village 2: Warudi Pathar			Project Village 1: Mahalwadi			Control village: Pimpalgaon Matha		
		NPV	BCR	NPV/HH	NPV	BCR	NPV/HH	NPV	BCR	NPV/HH
Plateau Area	At 8% DR	153242813	1.79	596276	57481742	1.66	445595	18923824	1.21	103977
	At 5% DR	180783882	1.81	703439	67551940	1.67	523658	21839989	1.22	120000
	At 3% DR	202750703	1.83	788913	75515933	1.68		24098928	1.22	132412
		Project Village 1: Kauthe Kh			Project Village 2: Kauthe Bk			Control village: Chas		
		NPV	BCR	NPV/HH	NPV	BCR	NPV/HH	NPV	BCR	NPV/HH
Rivulet Area	At 8% DR	259856562	1.88	1484895	362206081	1.64	1114480	277808237	1.37	529159
	At 5% DR	307290188	1.90	1755944	427465552	1.65	1315279	327633659	1.38	624064
	At 3% DR	345137350	1.91	1972213	479389846	1.66	1475046	367217551	1.38	699462

DR- Discount Rate

Table 5: Summary table of the Cost-benefit Analysis Results

A comparison of the perceived monetary value of benefits from agricultural and agro-met interventions is reflected in Fig. 34. It is found that the avoided loss is valued much higher than a gradual improvement of agriculture. This is because the avoided loss is a much more measurable and noticeable quantity than the agriculture sector's gradual changes during the past few years. This also establishes the importance of Early Warning Systems in terms of an adaptation strategy. It is a testament to the fact that early warning systems detect and report instances of extreme events that have grown much more frequent and intense in recent years.

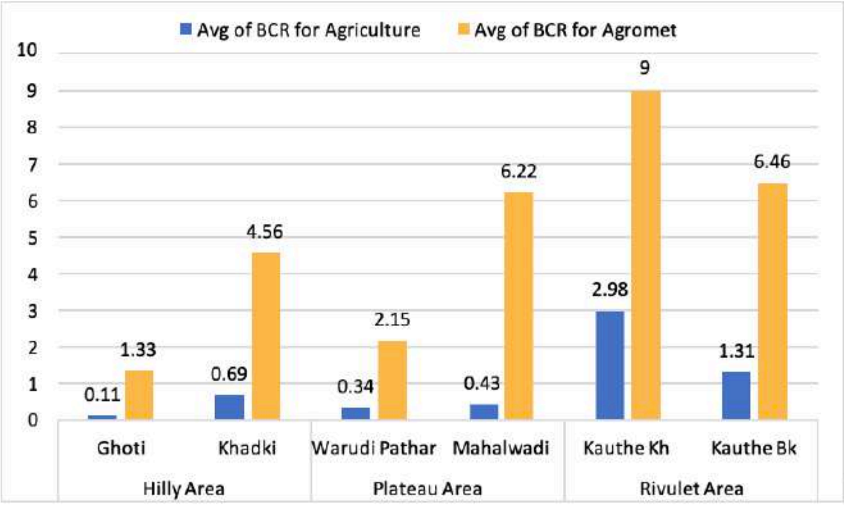

Fig. 34: The perceived BCR for agriculture and agro-met advisory interventions in the 3 study areas

The benefits of water-related interventions have also been assessed based on the monetary benefit perceived by the community (Table 6). Villagers of the plateau area express that the water benefit could have been better if structures had been well maintained.

Geography	Village	Perceived Total Benefit (in INR)	Average Perceived Benefit per HH (in INR)
Hilly	Ghoti	59450.00	340.00
	Khadki Bk	37700.00	260.00
Plateau	Warudi Pathar	62950.00	481.00
	Mahalwadi	47400.00	376.00
Rivulet	Kauthe Kh	123550.00	271.00
	Kauthe Bk	48500.00	194.00

Table 6: Perceived monetary benefits of water related interventions in the project villages

The perceived values of the benefits for the aforementioned ecosystem services have been felt since the implementation of WSD. The impacts of these structures benefit almost all related ecosystems. The individual impacts of WSD activities are subsumed in the impacts we see in agricultural production and water availability. Given below is the graph that reflects the village-wise perceived BCRs for WSD activities (Fig. 35). In Fig. 34 it is observed that most villages in the three areas put a high value on the SLM activities. The two villages that perceived that the BCRs were less than 1 are Ghoti and Warudi Pathar. The possible reasons could include a want of measurable impacts or the lack of understanding in the former village and a lack of resources in the latter (Reddy & Behera, 2009; Leimona, Noordwijk, Groot, & Leemans, 2015). It is also possible that

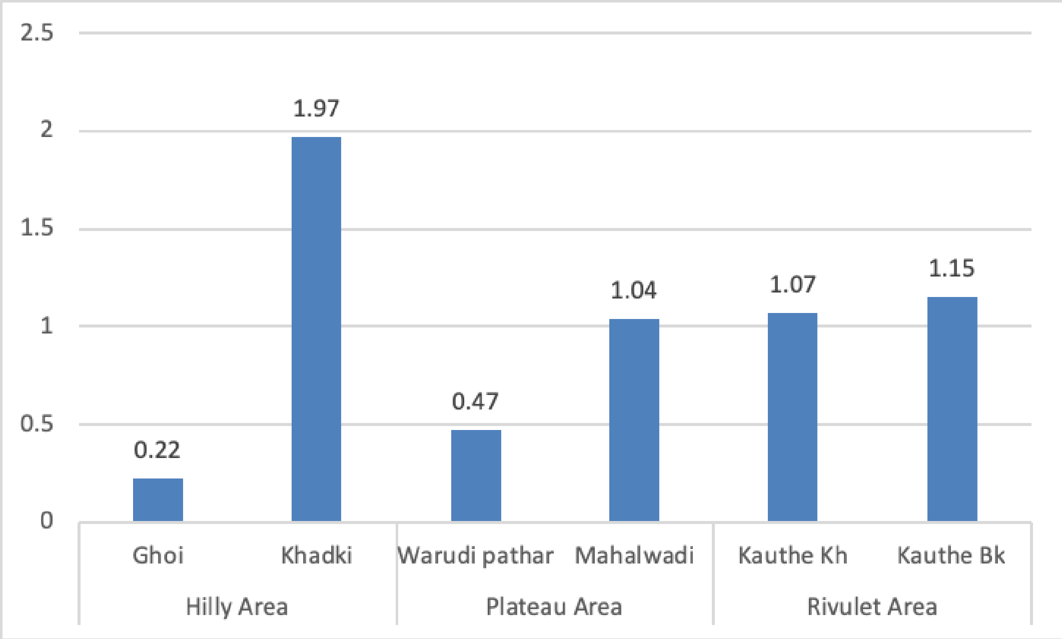

Fig. 35: Perceived BCR of watershed development interventions in the project village

people in these villages expected more from the interventions.

Fig. 36 below enumerates the number of households who benefit from forest produce—fodder, wild fruits and vegetables. A majority of the monetary benefits come from fodder. However, forest areas are very heavily regulated through the Joint Forest Management (JFM) mechanisms. The graph below suggests that very few households actually reveal that they obtain any benefits from the surrounding forests. However, the households who do depend on forests confess to having better food security and income from NTFP

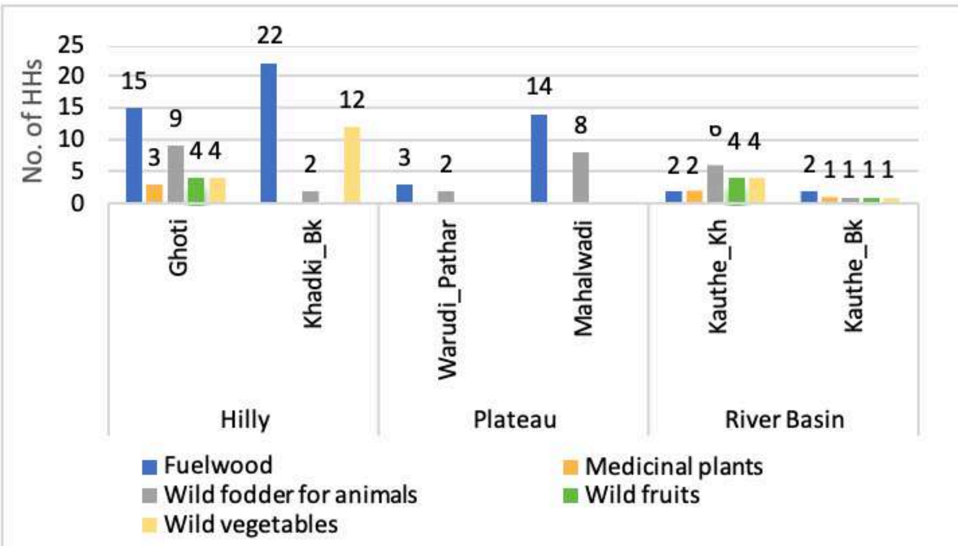

Fig.36: Households of the project villages that benefit from NTFP

5.4 Farmers' Perceptions on Climate Change Adaptation

In the context of adaptation to climate change in the face of extreme events, it is important to examine the coping mechanisms and adaptation strategies employed by the local communities. This process helps us to understand the level of awareness regarding adaptation measures amongst the village population. Most people in the study villages believe that changes in the cropping patterns will help them adapt, and at the same time maintain food security. Besides this, several households rely on ex-post compensation[3] mechanisms like crop insurance and some ex-ante measures[4] like water conservation and water-use efficiency through micro-irrigation. However, a moderate number of households are aware of or opt for Climate Resilient Crops, especially in the hilly and the plateau areas (Fig. 37).

Overall, it is found that the villagers value the CCA intervention very highly as these improve their resilience to climate change.

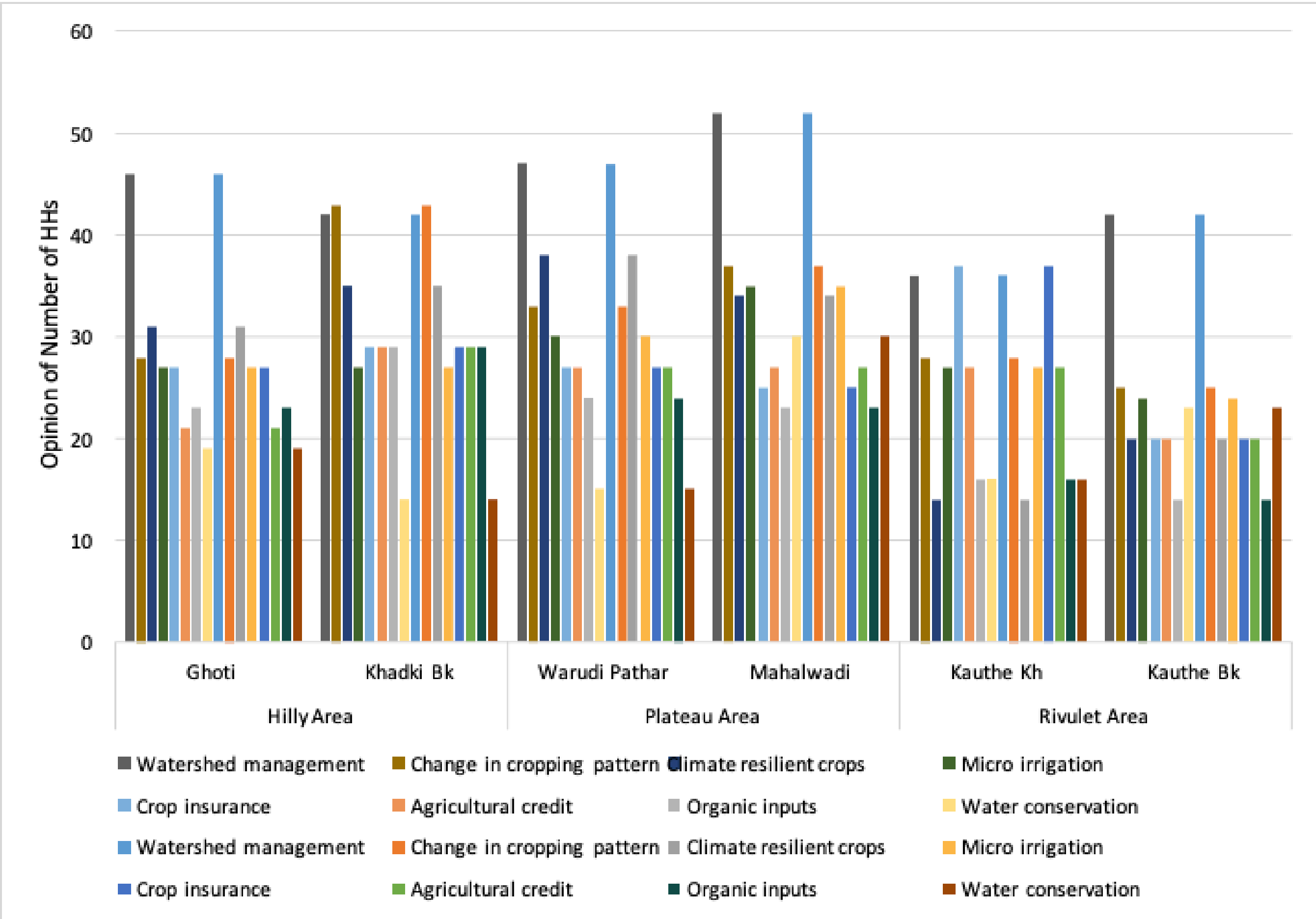

Fig. 37: Coping Mechanisms and Adaptation Strategies for Extreme Events

[3] *Measures taken to tide over the situation after the incident (disaster) has occurred.*

[4] *Precautionary measures taken to avoid the losses that may resulted from the incident (disaster).*

Findings

This interdisciplinary study on the impact of climate change adaptation measures in Western Maharashtra contributes crucial findings that have important policy and practice implications. These are as follows:

• It is observed that the rainfall and temperature in the Akole and Sangamner blocks have increased during the last decade. The rainfall pattern has also changed, which can have adverse impacts on the soil and agriculture. People of the study villages experience the following incidences of climate risks: drought, prolonged dry spell, flash flood, unseasonal rain, and intense rainfall. In most cases, people qualify these events as extreme to very extreme.

• This CCA project aimed to restore land degradation through WSD measures, besides the attempt to improve resilience of rural communities to climate change through associated interventions. It is evident from the biophysical assessment that the investment in land resources is beneficial for the project villages, in terms of increased area under agriculture, reduced soil erosion, conserved soil organic carbon, and restored lands under different types of uses. The restoration of the ecosystems is likely to have a positive impact on ecosystem services, such as groundwater, surface flow, soil moisture, and improvement of the soil fertility. The cumulative impact of these measures is observed in the increase of area under agriculture, improvement of crop productivity, and improved availability of household water. These benefits have not only improved for the years of normal rainfall, but even in the drought years. While people experienced losses in drought years, overall the project villages fared better than the control villages where the project was not implemented. Hence, it is very important to invest in the restoration of the ecosystem so that it functions effectively. However, the loss of vegetation in the hilly Western Ghats area, even though minimal, needs investigation so as to protect the continued enhancement of the benefits of land resource restoration and the ecosystem services.

• It is also found that the conditions of ecosystem services were better during the drought year 2018 than in 2012. While the project was completed in 2014–15, the holistic treatment of the landscape and quality of structures constructed provide benefits beyond the project period. However, as indicated by some interviewee villagers, there is a need to develop a mechanism to maintain the structures developed after the completion of the project, so as to sustain the climate change adaptation process.

• People acknowledge the importance of measures like crop planning, early warning systems, livelihood activities, alternative energy, awareness generation, and women's empowerment. These measures play an important role in adaptation and can easily be incorporated into ecosystem restoration projects to build resilience to climate change.

• There is a need to review the WSD structures in order to manage high intensity rainfall, flash floods, and drought. Besides structural improvements, promotion of a community-based flood management system is required to avoid and reduce crop losses during heavy rainfall.

• Monetisation of other benefits like the availability of NTFP, livestock development, improvement of other employment generation within the villages, improvement of changes in the household consumption, carbon sequestration, and change in biodiversity has not been investigated in this study. Incorporating these benefits in the cost-benefit model may show even greater economic benefits and will further encourage investment in CCA projects.

• Capacity building and institutional strengthening play an important role during project implementation. However, with the uncertainty of weather patterns and other externalities, there is a need for guidance to support the villages after the completion of the project.

• The impact of CCA is greater in the project villages of all three topographies- the hilly, plateau, and rivulet areas of Western Maharashtra. But the monetary benefit to the community is highest in the rivulet area due to its topography and other advantages, particularly water availability and market linkages.

Conclusion

This study is an ex-post evaluation of adaptation interventions to assess the impacts of the CCA project on the biophysical and socioeconomic aspects in three geographies. It is found that the restoration of degraded lands, measures to manage the water resources and adapt the agricultural practices to the changing climate help to build resilience of the communities in all three areas. The management of the restored ecosystem services by the local communities also enables them to enhance their wellbeing during years of normal rainfall, as well as face the years of abnormal rainfall. Such management of the ecosystem also equips people to deal with adverse situations that may emerge after the completion of the project. However, attention must be paid to the protection of the forest cover which in turn reduces soil erosion and protects the hilly ecosystem. In addition, regular maintenance of the structures by the community is essential. It is the people's active involvement—as individuals and as a collective—that contributes substantially to the achievements of the intervention. Therefore, investment in institution development and capacity building of the communities at the grassroots are crucial to facilitate sustained benefits.

India is a signatory of several international agreements like the United Nations Convention to Combat Desertification (UNCCD), the Convention on Biological Diversity (CBD), the Paris Agreement, and the Ramsar Convention, and endeavours to bring about positive changes in its land and the lives of its people through economic developments programmes. Meeting environmental and economic goals together is indeed a challenge. This study highlights the benefits of adopting a holistic approach to the development of natural resources to aid people's livelihoods and bolster their resilience to climate change. A holistic approach to climate change with the active engagement of the community yields substantial economic returns together with protecting the ecosystem.

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Annexure: Village-wise and activity-wise project costs

Components	Khadki Bk	Ghoti	Mahalwadi	Warudi Pathar	Kauthe Kh	Kauthe Bk
1. Social Mobilization	3,32,520	3,32,520	3,32,520	3,32,520	3,32,520	3,32,520
2. Gender and Women's Development	4,63,560	4,63,560	4,63,560	4,63,560	4,63,560	4,63,560
3. Watershed	39,43,470	71,81,392	61,85,484	88,84,291	34,45,637	18,82,122
4. Ecosystems	10,62,919	28,22,963	10,89,408	17,73,820	7,65,726	3,77,055
5. Agriculture	1,68,400	1,68,400	1,68,400	1,68,400	1,68,400	1,68,400
6. Agro-meteorology	96,900	96,900	96,900	96,900	96,900	96,900
7. Water Budgeting	2,01,800	2,01,800	2,01,800	2,01,800	2,01,800	2,01,800
8. Community for Disaster Risk Reduction	1,02,600	1,02,600	1,02,600	1,02,600	1,02,600	1,02,600
9. Livestock	44,160	44,160	44,160	44,160	44,160	44,160
10. Bio Diversity	39,600	39,600	39,600	39,600	39,600	39,600
11. Renewable Energy	3,96,060	4,70,460	4,35,660	5,47,260	3,09,660	3,67,260
12. Healthy and Attractive Village	26,900	26,900	26,900	26,900	26,900	26,900
13. Livelihoods	54,000	54,000	54,000	54,000	54,000	54,000
14. Innovations and Livelihood interventions	3,00,000	3,00,000	3,00,000	3,00,000	3,00,000	3,00,000
15. Program Management Cost	14,25,135	14,25,135	14,25,135	14,25,135	14,25,135	14,25,135

Watershed Organisation Trust (WOTR)
2nd Floor, The Forum, Padmavati Corner, Pune Satara Road, Pune - 411009

Ph.: +91 20 24226211; Fax: +91 20 24213530; Email: info@wotr.org

www.wotr.org