A REPORT



ECONOMIC VALUATION OF REDUCING LAND DEGRADATION THROUGH WATERSHED DEVELOPMENT IN EAST MADHYA PRADESH UNDER RISKS OF CLIMATE EXTREMES



W-CReS
Building Resilient Futures

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ELD
THE ECONOMICS OF LAND DEGRADATION

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ABOUT WOTR

The Watershed Organisation Trust (WOTR) is a not-for-profit NGO, founded in 1993, operating in eight Indian states – Maharashtra, Telengana, Andhra Pradesh, Madhya Pradesh, Rajasthan, Jharkhand, Orissa, and Bihar. WOTR is recognized widely as a premier institution in the field of participatory Watershed Development and Climate Change Adaptation. Its unique strength lies in its 'on-field' experience and a systemic, participatory approach.

The WOTR Centre for Resilience Studies (W-CreS) aims to provide evidence-based responses to mitigate the impacts of climate change on ecosystems, water resources, agriculture, food and nutrition, health, livelihoods, gender, governance and local institutions. The Centre conducts inter and trans-disciplinary research to contribute grounded insights and learnings towards policy formulation, programme design and implementation, capacity building as well as behavioural change processes.

ABOUT ELD

The Economics of Land Degradation (ELD) Initiative is a global initiative established in 2012 by European Commission, the United Nations Convention to Combat Desertification (UNCCD) and the German Federal Ministry for Economic Cooperation and Development (BMZ). The ELD Initiative works at the science-policy interface, bringing a large global network of scientists, academics, business leaders, politicians, decision-makers and other relevant stakeholders together to identify solutions for land management. It mobilises different kinds of expertise ranging from ecosystem services to economics, stakeholder participation, communications and other topics related to land management and policy. The Initiative provides economic information on the benefits of sustainable land management to interested parties, capitalising on intellectual capital to promote better land management.

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EXECUTIVE SUMMARY

Madhya Pradesh is a centrally located state having the largest forest cover in the country. It is part of four major river basins and overall it receives good rainfall. The problem of land degradation in the state is alarming; it is predominantly due to water erosion and vegetation loss driven by unsustainable agricultural practices and climate variation. Despite the implementation of many watershed development (WSD) projects, the situation has not improved. Agriculture is non-remunerative and distress migration is common in rural areas. The state also lags behind in terms of important indicators of human development - hunger, food security, poverty, education, and health.

Watershed Organisation Trust (WOTR) is implementing WSD with climate change adaptation in eastern Madhya Pradesh since the last two decades. The present study has been conducted in four selected villages where WOTR implemented WSD from 2008 to 2011 and 2012 to 2014. The selected villages are Kareli (Jabalpur district), Katangi, Partala, and Dungairya (Mandala district). In Partala and Dungariya, additionally Integrated Watershed Management Programme was implemented from 2014 to 2017. Each project village had a control village of similar status. The objective of this study was to evaluate the impact of WSD as implemented by WOTR, from the bio-physical and socioeconomic aspects. At the biophysical level, land productivity dynamics, soil erosion, soil carbon, and land use and land cover changes were assessed from 2008 to 2018 with the help of Geographical Information System and Remote Sensing. The socioeconomic impact of WSD was assessed with the help of data collected through focus group discussion, household interview, the economic valuation of the crop and fodder benefit, household water benefit and the intrinsic value of decline in the distress migration.

Soil-carbon detachment in the project villages has decreased significantly over the period as compared to the control villages. The Land Productivity Dynamics (LPD) analysis shows that the project villages in Mandla district have more land that is ‘stable’ and ‘improved’ as compared to the control; however, the control village Sihora (Jabalpur district) fares better than its project village Kareli (project period 2008 – 2011). The forest area of all project villages show improvement in LPD, indicating the impact of afforestation. Expansion of agriculture area is similar in all project and villages; however except in Dungariya, the other three project villages show greater cropping intensity. The productivity of the major crops has increased in all villages, with a greater increase in the project villages. Moreover, crop productivity in the time of extreme events was more in the project villages than their control villages. The household water collection time decreased for all the villages; the improvement was higher than the control villages for Kareli and Dungariya, but lower for Partala and Katangi. Katangi’s control village Paundi Mal benefited from a government household water supply scheme. During the drought, the project villages required less time to collect water, as compared to their control villages. The number of days spent in distress migration decreased for all the villages, with the project villages faring significantly better. The economic valuation and cost-benefit analysis suggests that the project villages are in a better position than their control villages except for Katangi. Its control village Paundi Mal shows greater economic viability due to time saved in water collection. It is also a market place and has good road connectivity. It should be noted that the other values of livestock, NTFP, carbon sequestration, biodiversity were not captured due to the non-availability of data. The climate analysis shows that there is a possibility of more extreme events of deficit rainfall and excessive rainfall in the near future, for which guidance for adaptation measures will be required.

Overall, the results of the study indicate that the impact of sustainable land management through WSD as implemented by NGOs is an economically beneficial developmental intervention for periods of normal rainfall, as well as extreme events. The results of the study suggest that capacitating the local community to systematically implement WSD with climate adaptive measures and to maintain the structures constructed is economically viable. It also protects the ecosystem regenerated.

1. INTRODUCTION

Land degradation today is one of the biggest challenges of our planet. The concern over large scale land degradation has been in the international policy scenario since the Brundtland report in the late 1980s (Imperatives, 1987). Subsequently, the issue gained traction in Agenda 21 (UNSD, 1992), the Millennium Ecosystem Assessment (MEA, 2005), and the Climate Change report (IPCC, 2017). Despite its recognition at the international and national levels, the problem somehow has not been adequately addressed. Land degradation affects different sectors - agriculture, forestry, water resources - which hamper livelihoods and threaten the sustainability of biodiversity and ecosystem services. At present, land degradation affects the livelihood of 3.2 billion people, and the annual global gross product loss due to land degradation is 10 per of the global GDP. Another estimate suggests that the annual economic loss due to land degradation and land use and land cover (LULC) changes, was approximately US$ 231 billion for 2007, i.e. 0.41% of the global GDP of 2007 (Nkonya et al., 2015). Timely investment in land restoration is essential; however, it is far less than the amount of damage that can happen if we do not invest in its restoration (IPBES, 2018).

The climate exerts a strong influence over vegetation type, biomass, and biodiversity. Precipitation and temperature determine the potential distribution of terrestrial vegetation and constitute the principal factors in the genesis and evolution of soil (Sivakumar et al., 2007). Rainfall is the most important climatic factor that determines areas at risk of land degradation and potential desertification (Asfaha, 2015). Rainfall variability in recent years is observed as delayed monsoons, prolonged dry spells between rainy days, reduced precipitation, unseasonal rains, and short duration high-intensity rains. Temperature changes are observed as longer summers with higher temperature and shorter winters with higher temperatures. Studying the climate extremes of historical as well as short and medium-term climate projections provides insights for preparedness for climate risks.

This study assesses the costs and benefits and quantifies the impacts of Watershed Development[1] / Sustainable Land Management (SLM) interventions on the agro-systems of selected villages of Madhya Pradesh, India, where the projects were implemented between the year of 2008 to 2011 and 2012 to 2017. It analyses the efficacy of SLM interventions through the lens of climate change.

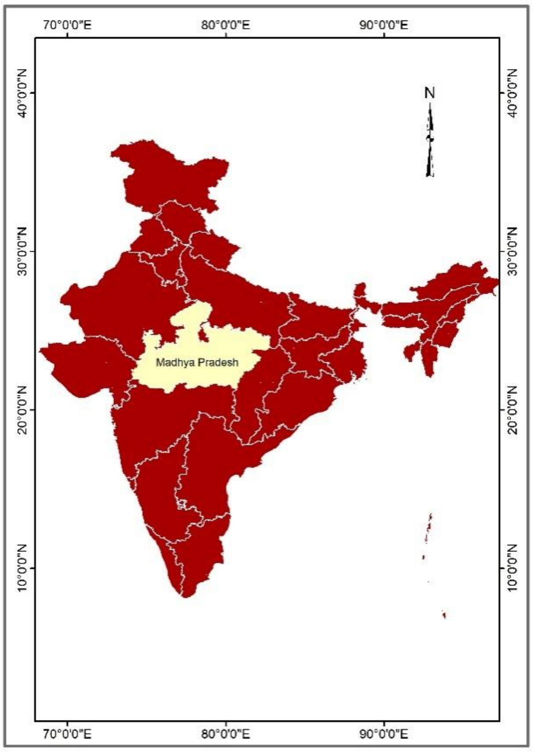
1.1 The Problem of Land Degradation in India

The impact of land degradation is severe for emerging countries like India, that depend heavily on natural resources for the livelihoods of millions of people. Since the last two decades, land degradation has intensified across the country, particularly in semi-arid areas. Climate change, depleting water tables, increased pressure for enhanced yields and return on investments, aggravate land degradation. While land development projects, e.g. Watershed Development (WSD), Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGS) have slowed the pace, recent trends show that land degradation has increased from 81.48 million hectares (mha) in years 2003-05 to 82.64 mha in 2011-13 (Arya et al. 2018). The cost of land degradation for India in 2014-15 was INR 3177.39 billion, i.e. 2.54% of the country's GDP (TERI,

[1] Watershed Development (WSD) refers to the conservation and regeneration of the natural resources of land, water, vegetation and animals across a watershed. In WSD, sustainable land management (SLM) measures are implemented from ridge-to-valley to conserve soil and water in situ and to increase the vegetative cover.

2016). Since India is a signatory of the UN Convention to Combat Desertification (UNCCD), she has set a target of restoring 26 million hectares of degraded land by 2030.

1.2 Land Degradation in Madhya Pradesh, India



Madhya Pradesh is one of the hotspots of land degradation. Despite having several watershed development programmes implemented in this state, there is an accelerated rate of degradation of land resources, especially due to vegetation and water erosion (Le et al., 2014; SAC, 2015; UNDP, undated). With the erratic occurrence of extreme events like precipitation and temperature and precipitation, agriculture has become less rewarding, resulting in outmigration as one of the most favoured coping strategies. Therefore, measures for protection and conservation of soil, water and forest resources are given importance in the State Action Plan on Climate Change (HEDGoMP, 2013). Madhya Pradesh is also one of the most backward states, holding a very low rank in the overall Human Development Index (HDI), hunger and malnourishment, sex ratio and gender empowerment. Having a large number of small and marginal farmer households, the state depends more on agriculture than other states. Therefore, public investment in land development and agriculture is crucial.

1.3 Estimating Land Degradation

Assessing the economic aspects of land degradation is useful to raise awareness of the loss of arable land; it helps to inform policymakers and donor agencies about the economic rationale behind sustainable land management. The ELD 6+1 step approach developed by the Economics of Land Degradation (ELD) Initiative guides to assess costs of ongoing land degradation and benefits of sustainable land management practices. [2]

Economic Approaches for Estimating Land Degradation

Economics of land degradation studies have either been done by calculating the cost of land degradation or by calculating the benefits (actual or potential) from SLM practices or both. Studies on the economics of land degradation mostly use either the direct method or indirect method of valuation (TERI, 2018); either the direct use of simple market price method or the use of complex ecological-economic models (Birch et al., 2016; Hurni et al., 2015). Some studies assessed the cost-benefit of soil and water conservation interventions and found that

[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
Summary in English: https://www.eld-initiative.org/fileadmin/pdf/Quick_guide_-_The_Value_of_Land2015.pdf

the benefits of SLM practices are higher than that of the benefits without SLM practices (Palanisami et al., 2009; Reddy and Behera, 2009).

Hurni et al., 2015 followed the ELD 6+1 step approach to model soil erosion with land management practices. The results suggest that NPV under different types of land management results in positive NPV except for the business as usual scenario (scenario without any land management). Mirzabaev et al., 2016 used the Benefit Transfer method and the Contingent Valuation Method to capture the cost and benefit of land degradation and SLM in Central Asian countries and found that the cost of inaction is as high as five times the cost SLM practices. Similar were the findings in Jordon (Myint and Westerberg, 2015) and four Sub-Saharan African countries: Benin (Westerberg, 2017), Sudan (Aymeric et al., 2014), Namibia (Birch et. a., 2016), and Mali (Sidibé et al., 2014).

Land Degradation Assessment using Remote Sensing and GIS

Mapping and monitoring the land degradation process is imperative to report the effectiveness of SLM practices and to identify the problematic regions that require intervention. There is a wide range of tools and approaches available for assessment and monitoring desertification and land degradation process (Turner et al., 2015; Bunning et al., 2016; Masoudi et al., 2018). However, geospatial technology (i.e. combination of Remote Sensing (RS), Geographical Information System (GIS), and Global Positioning System (GPS) tools and techniques) offers numerous possibilities in the concurrent monitoring of degradation, visualizing the spatial distribution and dispositions of land change, and supports planning/decision making (Dubovyk 2017; Mariano et al. 2018). The synoptic area coverage, regular revisit of the same location makes the RS satellite imagery an important resource in monitoring and evaluation of SLM activities. Geospatial technology also plays a major role in the Land Degradation Neutrality (LDN) target setting. The RS derived proxy biophysical indicators are used to quantify the impacts of human activities on the environment (Bai et al. 2008). In the present study, LDN indicators are measured using geospatial technology including i) land productivity dynamics, ii) land use/ land cover change and iii) carbon stocks above/ below ground (soil organic carbon) that are approved as a general framework by the Parties to the Convention in 2013.

In India, water and wind-induced soil erosion and degradation of vegetative cover are the main processes that contribute to land degradation (SAC, 2016). The biophysical environment, i.e. soil, terrain, ground cover, weather and interactions between them influence the erosion process. This, in turn degrades agricultural land because of the loss of nutrient-rich surface soil, increase in runoff from the sub-soil, and reduction in water availability to plants (Ganasri and Ramesh, 2016). Thus, quantifying soil erosion and identifying critical areas for the implementation of best management practices is central to the success of a soil conservation. Several erosion models are available to predict soil loss and assess soil erosion risk. Widely used empirical models to assess soil erosion include Universal Soil Loss Equation (USLE), an empirical model (Wischmeier and Smith 1978), and the RUSLE model (Renard et al. 1997). USLE based models estimate long-term average annual sheet and rill erosion (E) per year as a product of factors representing rainfall and runoff erosivity (R), soil erodibility (K), the length and steepness of slope (LS), plant cover (C), and conservation support practices (P). These models have a significant drawback in their 1-dimensional approach used to account for the effects of topography, the Unit Stream Power Erosion and Deposition (USPED) model differs from the other USLE-based models, which handles the influence of topography on the erosion process. As a result, the USPED model predicts both erosion and deposition, while most other USLE-based models are limited to predictions of erosion only (Warren et al. 2005). Vegetation degradation is quantified by analysing the trend in normalized difference vegetation index

(NDVI). NDVI acts as a proxy parameter to measure the health of the vegetation (Bai et al. 2008). Various studies report the high correlation of NDVI and field measured sampling of biomass (González-Alonso et al. 2006; Pandey et al. 2019; Tian et al. 2016).

1.4 Interventions of Watershed Organisation Trust WOTR in Madhya Pradesh

Watershed Organisation Trust (WOTR) has implemented watershed development (WSD) projects in these districts since over a decade. From the many villages where WSD was implemented, four were selected for this study. These are Dungariya, Partala, Katangi in Mandla district, and Kareli in Jabalpur district. The villages implemented WSD from 2008-09 to 2010-11 and in Kareli up to 2011-12. In Dungariya and Partala additionally, the Integrated Watershed Management Programme (IWMP) was implemented with WOTR and PRADAN[1] respectively from 2014 to 2018-19. WSD includes the following SLM interventions: area treatment and afforestation on forest lands and private lands, drainage line treatment, capacity enhancement, institutional building, and promotion of agriculture and livelihoods.

1.5. Research Objectives and Deliverables

(i) Assessment of the land degradation status in the project villages and control villages (without project interventions) based on LDN indicators and identification of drivers of land degradation.

(ii) Economic valuation, including cost-benefit analysis of the provisioning ecosystem services of agriculture (food) and water derived from WSD interventions implemented in project villages.

(iii) Analysis of climate extremes in the selected agro-ecological zones to obtain insights for preparedness to climate risk.

2. METHODOLOGY

2.1 Location of the study villages

The study villages are located in Madhya Pradesh where WOTR has intervened. Villages are selected based on data availability for project baseline and its representation of the respective agro-climatic zones in the area. Villages selected for the study are: i) Kareli (Jabalpur district), ii) Katangi, iii) Partala and iii) Dungriya (Mandla district). The chosen study villages represent two agro-climatic zones, namely 1) Northern Hill Region of Chhattisgarh (Jabalpur) 2) Kymore Plateau and Satpura Hills (Mandla) (Fig 1). The major soils are red and yellow, medium black and skeletal (medium/light) with good forest cover. The Kymore Plateau and Satpura hills are a wheat-rice zone; rainfall ranges from 1000 to 1400 mm; the major soil types are mixed red and black soils (medium) (GoMP, undated).

For each project village, one control village nearby was selected, having similar topography and socio-economic conditions in the pre-intervention period. Preliminary GIS analysis was performed to select the control villages based on the similarity of the biophysical characteristics with project villages and field verification to confirm the baseline status of the village. The control village for Kareli is Sihora; for Katangi it is Paudi Mal; for Partala it is Amdara; and for Dungariya it is Kui-Ryt.

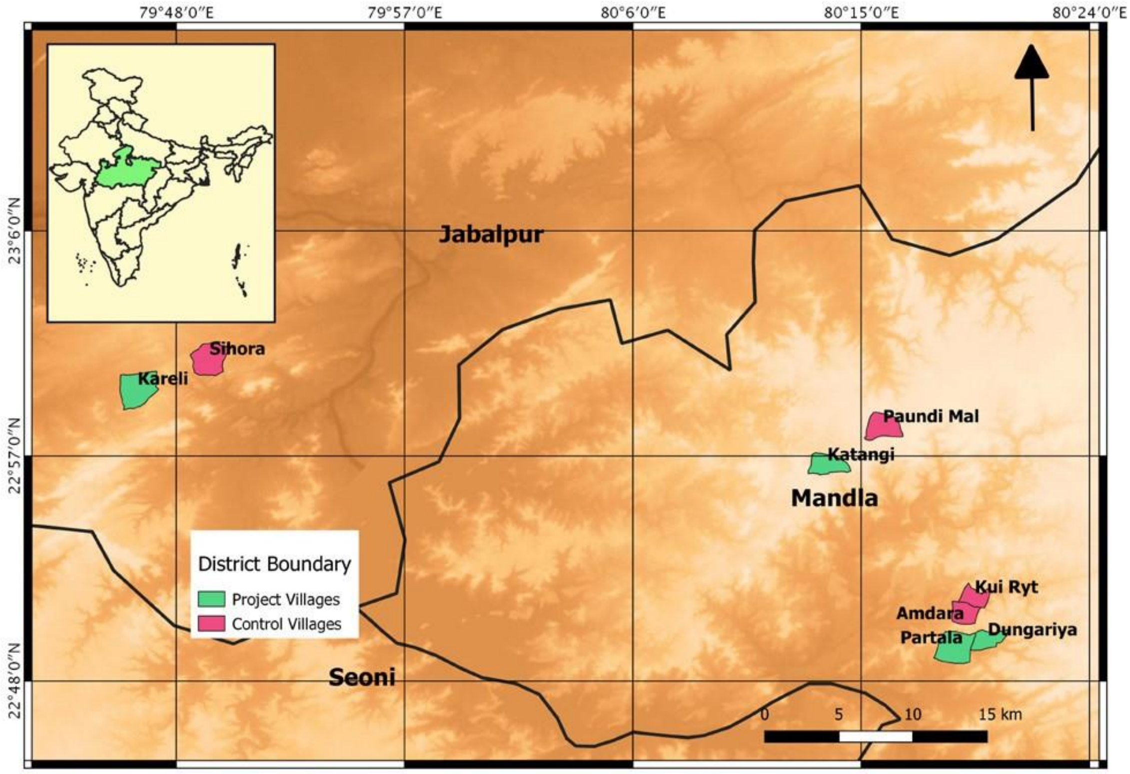


***Figure 1:** Location map of the selected study villages*

Agriculture is the main livelihood activity of the people in these villages; other occupations are farm labour as well as non-farm labour in the nearby towns. The main crops are rice, maize, wheat, and millet and some indigenous crops.

2.2 Assessment on Land Degradation Neutrality in the project and control villages

The understanding of land degradation drivers/ pressures and underlying forces are important to plan, arrest land degradation and achieve LDN. Various watershed development interventions (SLM practices) aid in sustainably enhancing land productivity. To assess the role of the various watershed interventions in achieving LDN, the project villages are compared with control villages (i.e. minimal/no interventions). The amenable indicators of LDN and sub-national indicators used are land use/ land cover (LULC) data, net primary productivity (NPP) and soil organic carbon (SOC) (IUCN 2015). Further, the findings are linked to various drivers/underlying pressures/forces on land degradation in the area.

2.2.1 Satellite data products used in this study

In this study, a combination of open-source LANDSAT thematic mapper (TM) sensor series having a spatial resolution of 30 meters and Indian Remote Sensing (IRS) Resourcesat - linear imaging self-scanner (LISS) – III satellite imagery (23.5 meters) (Table 1) 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 LISS-III data procured from Nation Remote Sensing Centre (NRSC), India. LISS-III data is resampled to 30 meters to achieve uniform spatial resolution.

2.2.2 Land use/ land cover (LULC) mapping

The multi-temporal seasonal satellite imagery of the years 2008 – 2018 is used to prepare the LULC map for the project and control villages. Based on the initial field observation and existing land distribution, the study regions are categorized into seven land classes: (i) cropland, (ii) fallow land, (iii) forest, (iv) open scrub, (v) barren land, (vi) built-up and (vii) water bodies. The cropland category is further classified as a single crop (rainfed, winter or 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. The supervised image classification method is used to obtain annual LULC. The Support Vector Machine (SVM) classification with the polynomial kernel is used for its accurate classification performance (Duraisamy et al. 2018). The classification results are tested using a confusion error matrix, as described by Congalton (1991). The post-classification processing "3*3 majority filter" is applied to the image classification results to remove the isolated pixels. Post-classification comparison change detection is performed to map the "from-to" class transitions.

2.2.3 Land Productivity Dynamics

The term 'land productivity' effectively refers to variations in the rate, quantity, and timing of the standing biomass production of an ecosystem. 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 2018 are used to identify the potential trend (positive change, negative change, and no change). Normalized Difference Vegetation Index (NDVI) of the year 2018 is calculated to assess the standing biomass.

NDVI values range from -1 to +1; it is widely used in vegetation biomass related studies. The NDVI values are stretched from 0 to 255 and classified into four classes, including very weak, weak, moderate, and intensive, as proposed by Dengiz (2017). Further, based on the NDVI classes and LULC potential trend, the LPD qualitative classes were assigned as suggested by Retiere et al. (2015).

2.2.4 Assessment of soil erosion

Pre and post-watershed interventions conditions on soil erosion are assessed using the Unit Stream Power Erosion and Deposition (USPED) model (Warren et al. 2005). It is an improved version of the well-known Revised Universal Soil Loss Equation (RUSLE) and USLE soil erosion model. The economic valuation of soil erosion benefit is assessed by replacement cost method, i.e. the amount of fertilizer needed to replenish the equivalent amount of nutrient loss saved from the agricultural fields (Mythili and Goedecke, 2009). Soil erosion assessment is done using the standard ULSE equation with USPED modifications; each parameter is calculated in the GIS environment. 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 10km resolution (Brocca et al. 2019). Soil erodibility index (K) of surface soils of each soil type, associated with the mapping units, is computed using the standard formula as used by (Kumar et al. 2013). Slope length (L) and steepness (S) factors are calculated spatially using the 30 m SRTM digital elevation model data. 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.

To predict/model soil erosion and deposition seamlessly, an ArcGIS model is developed. Inputs to this model are all the above parameters, plus the watershed boundary; the output is the amount of soil erosion/deposition at the watershed level.

2.2.5 Soil organic carbon assessment

Soil maps are obtained from NBSS&LUP (1:250K), Organic Carbon (OC) % is used to calculate total soil organic carbon. Bulk density map is downloaded from ISRIC world soil grids dataset. The soil erosion and deposition results from USPED model was used in the empirical calculation of the soil organic carbon (SOC) detachment and accumulation in both project and control villages. The SOC value is then calculated using all these parameters.

2.3 Economic valuation including cost-benefit analysis of key ecosystem services and sustainable land management interventions

When watershed development is implemented according to the respective agro-ecological system, it contributes greatly to enhancing the ecosystem services of that particular locale. Through such WSD interventions, the ecosystem services enhanced are provisioning services such as food, fibre and fuel, freshwater. When the forests are given importance, the regulating services, particularly fodder regulation, pollination, seed dispersal, pest and disease regulation, erosion control, flood regulation are improved. It also contributes to climate regulation and supporting services such as soil formation and retention, water cycling and atmospheric oxygen production.

For the purpose of this study, the ecosystem services related to food (agriculture) and water are economically valued. Increase in benefits of the other services are observed and assessed; however, these have not been economically valued.

The Total Economic Valuation (TEV) framework (ELD, 2015[3]) is used for the valuation of the key ecosystem services of the study area. The following specific ecosystem services are selected that are important for the main livelihood of the residents:

- Agriculture for provisioning of (a) food and (b) fodder
- Provisioning of water

The identified key ecosystem services, data requirement, data availability and suitable study methods are given in Table 1.

Table 1: Ecosystem services valuation method, data requirement, and source

Ecosystem Services	Economic Valuation Techniques	Data required	Available sources	Suitable methods
Provisioning Services				
Food - Crop	Market price method	The area under different crops & productivity of crops	Baseline and end-line reports of project villages, village-level yield, satellite imagery, household survey	Household (HH) survey, Focus Group Discussion (FGD), Key Informant Interview (KII)
Fodder - Crop	Market price method	Crop residue, fodder availability	Baseline reports/data, other project reports	House Hold (HH) survey, FGD, KII
Water- for household purposes	Market price/ cost avoided	Data on water availability for domestic needs (surface/groundwater resources) during pre and post-intervention	Rainfall data, water table fluctuations, surface water (extent and availability), etc. (pre and post-intervention) obtained from government & other portals/reports and primary data collected by field staff	Household-level interviews (questionnaire tool) FGDs (Target questions); Direct measurements of water levels of selective resources
Regulating service				
Erosion regulation	The assessment of the soil erosion regulation has been described in the biophysical section. The economic benefit on soil erosion control is observed in the impacts of improved agriculture and is reflected under the provisioning service of agriculture (ref. Section 3.1 A)			

[3] 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
Summary in English: https://www.eld-initiative.org/fileadmin/pdf/Quick_guide_-_The_Value_of_Land2015.pdf

Flood regulation	Economic benefit of flood regulation over the landscape due to the implementation of WSD activities along watershed lines are observed but has not been assessed and quantified. However, the impact of sudden high onset rainfall on the food provisioning service (agriculture) is reflected in the agriculture analysis in the study. It is also observed that these WSD activities have a beneficial impact on agriculture in times of drought, as is observed in the study findings.
Climate regulation	This study has assessed the carbon detachment due to WSD measures undertaken (ref Section 3.1.B), and the beneficial impacts are observed, although not valued.

The cost-benefit analysis is performed for the timeline of 2008-2018 for all project and control villages. The benefits from agriculture is added to the benefit obtained from improved household water collection and the benefit from reduced distressed migration.

2.3.1 The methodology to assess the economic benefits on ecosystem services by the implementation of WSD is described below:

2.3.1.a. Agriculture

One of the main benefits of watershed development is the improvement in agriculture which is reflected by the increase of crop and fodder production. The net benefit of crop and fodder production is calculated with the help of market price method. The data for productivity, cropping pattern, and cost of cultivation were collected from the farmers through household interview and FGD (Palanisami et al., 2009). In this study, the GIS and RS analysis on the crop cover of different years and data from the land revenue department are used to derive the area under different crops in different years.

2.3.1.b Water for household use

A cost-avoided method for estimating the benefit derived from household water availability is used. The amount of time saved for the collection of household water gives an estimate of the opportunity cost of time value in monetary terms. Data regarding the time saved for household water collection over the years was obtained by household interview, FGD, KII.

2.3.1.c The benefit obtained by the reduction of distress migration

The economic valuation of reduction in migration was calculated by assessing the intrinsic value of staying within the village using the “market price method” and the “willingness to accept” method.

Along with the data collected by household interview, FGD, KII the gap-filling for the data of intermediate years was done by KII and interpolation method.

2.3.2 Cost of the project

The project cost was collected from the record book of the implementing agencies, i.e. Watershed Organisation Trust (WOTR) and PRADAN (Professional Assistance for Development Action). The cost for different interventions based on the life-span of each intervention and the period of assessment, i.e. 2008-2018 is apportioned. The wage component in the project was paid directly to the community. Since alternative employment opportunity in these villages is limited, wage employment is a benefit which helped to reduce migration. The expenditure for wage employment, either as the cost or benefit of the project, is not considered. However, community contribution is put under the cost of the project. The other cost considered in all the villages is the cost of cultivation.

2.3.3. Cost-benefit analysis

The total benefit and cost for each of the eight villages are calculated, and the Net-Present Value (NPV) and Benefit-Cost Ratio are calculated with the help of suitable discount rates. Since the value of natural resources is assessed, where the benefits could not be valued economically, such as non-crop fodder, carbon sequestration, soil erosion, availability of fish, NTFP, biodiversity, a very low discount rate has been used. Stakeholder consultations were also conducted in each village before starting the data collection process, to ensure community support during the time of data collection.

2.3.4 Sampling strategy

A purposive stratified-random sampling protocol is used in this study. As a first step, four villages were purposively selected based on the availability of baseline data. In the second step, households (HH) in each village were stratified based on different landholding classes. Using the probability proportionate sample to the size of the land holding, a total of 335 HHs were selected for the HH survey from the four project villages. In each of the control villages based on the stratified random sampling method, approximately 30 HHs were identified; a total of 135 households were surveyed from the control villages.

2.4 Sensitivity Analysis

The sensitivity analysis is done by calculating the BCR and NPV of the project villages and the control villages with the help of three discount rates, i.e. 3%, 5%, and 8%.

2.5 Analysis of historical climate data and climate projections

The climate extremes are analyzed for the selected agro-ecological zones using historical gridded rainfall and temperature data of 30 years obtained from the Indian Meteorological Department (IMD), and the downscaled climate projection data for the period of 2021-2040. This study uses an ensemble of 8 suitable Coupled Model Intercomparison Project 5 (CMIP5) models. The resolution of the model output is 0.25*0.25 degree, statistically downscaled by NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) programme of NASA. It is found that CanESM2, CCSM4 are suitable in replicating the average index value of temperature and ascertained that extreme temperatures are better simulated (Shilid et al.,2014). The right timings of monsoon are suggested by Can-ESM2, CMCC-CMS, CMCC-CM (Hasson et al., 2016). Since the ensemble value reduces uncertainty (i.e., parametric) and has good performance (Palmer *et al.*, 2005; Chaturvedi *et al.*, 2012) as compared to individual models, the ensemble data is used to understand climate risks in future scenarios.

Changes in inter-annual temperature and rainfall variability at seasonal, monthly and annual scales are studied along with the trends in climate extremes. Mann Kendall's tau test is used to analyse the trend in the rainfall and temperature over the period. Climate extremes such as daily intensity (SDI), One-day Highest Precipitation (Rx1), Rainy days >10 mm and 20 >mm, Consecutive wet days (CWD) and Consecutive dry days are calculated.

3. RESULTS

There are a range of benefits from watershed development (WSD) / SLM practices implemented. However, all the benefits are not calculated or economically valued because of the possibility of double counting. Moreover the non-availability of robust baseline data was another reason for not doing the economic valuation of some of the benefits such as, biodiversity conservation, livestock economy, fishery, NTFP, pollination, awareness generation, community engagement in land restoration, besides others.

This section has been organized into three main components: (1) change in the biophysical aspects of the villages; (2) the economic benefits of some ecosystem services and (3) a cost-benefit analysis of the projects. In this section, the efficacy of the SLM practices from the viewpoint of climate change is also discussed.

3.1 Changes in the biophysical aspects of the villages:

Changes observed in the study and discussed are related to (a) Soil erosion; (b) Soil organic carbon; (c) Land use and land cover change and (d) Land productivity dynamics.

A. Soil Erosion

Soil erosion is a serious problem arising from deforestation, intensification of agriculture, land degradation and other anthropogenic activities.

Table 2: Villages selected for this study and location in different topographies

District	Mandla		Jabalpur	
	Project village	Control village	Project Village	Control village
Upper Catchment	Dungariya	Kui-Ryt	Kareli	Sihora
Lower Catchment	Partala	Amdara		
Middle Catchment	Katangi	Paundi Mal		

Project villages Dungariya (upper) and Partala (lower) are located adjacent to each other and fall in the same watershed; while control villages Kui-Ryt (upper) and Amdara (lower) are also similar (Table 2).

Villages in an upper catchment area normally have soil detachment due to erosion, which accumulates in the respective lower catchment area. In Dungariya (upper catchment, project village) soil detachment is less as compared to Kui-Ryt (upper catchment, control village); while in Partala (lower catchment, project village), soil accumulation is also less as compared to Amdara (lower catchment, control village) (Fig. 2). The latter is because of the reduction of erosion in Dungariya the treated upper catchment village.

B. Soil Carbon Assessment

Similar to soil erosion, soil carbon assessment indicates that soil carbon is detached from villages located in the upper catchment of the watershed and gets accumulated in lower line watershed areas. Comparing the first set of treated (Dungariya, Partala) and control (Kui Ryt, Amdara) villages: Dungariya and Kui Ryt are in the upper catchment while Partala and Amdara lie in the lower catchment. Soil carbon detachment is significantly reduced by 64 percent in

Dungariya due to SLM interventions; but in it's the control village Kui Ryt, reduction in soil carbon detachment is about 23%. While in the adjacent lower catchment villages of Partala and Amdara, accumulation is reduced by almost 50%. The second set of upper catchment treated (Katangi) and control (Paundi Mal) villages shows that accumulation in the treated village is reduced by 50%, but there is an 82% of increase in soil carbon detachment in its control village. In the third set treated (Kareli) and control (Sihora) villages fall in the upper catchment area of the watershed. Soil carbon detached in Kareli is reduced by 32% as compared to its control which shows an increase of more than 500% as seen in table 3. Village-wise change in soil carbon is given in Fig. 2.

Table 3: Comparative analysis of soil organic carbon between baseline and end-line periods

Set	Village	% Change	Remarks
1-a	Dungariya	64.8	Detachment reduced
	Kui Ryt	23.8	Detachment reduction less
1-b	Partala	53.7	Accumulation reduced
	Amdara	55.5	Accumulation reduced
2	Katangi	51.2	Accumulation reduced
	Paundi Mal	-82.3	Detachment increased
3	Kareli	32.7	Detachment reduced
	Sihora	-567.1	Detachment increased

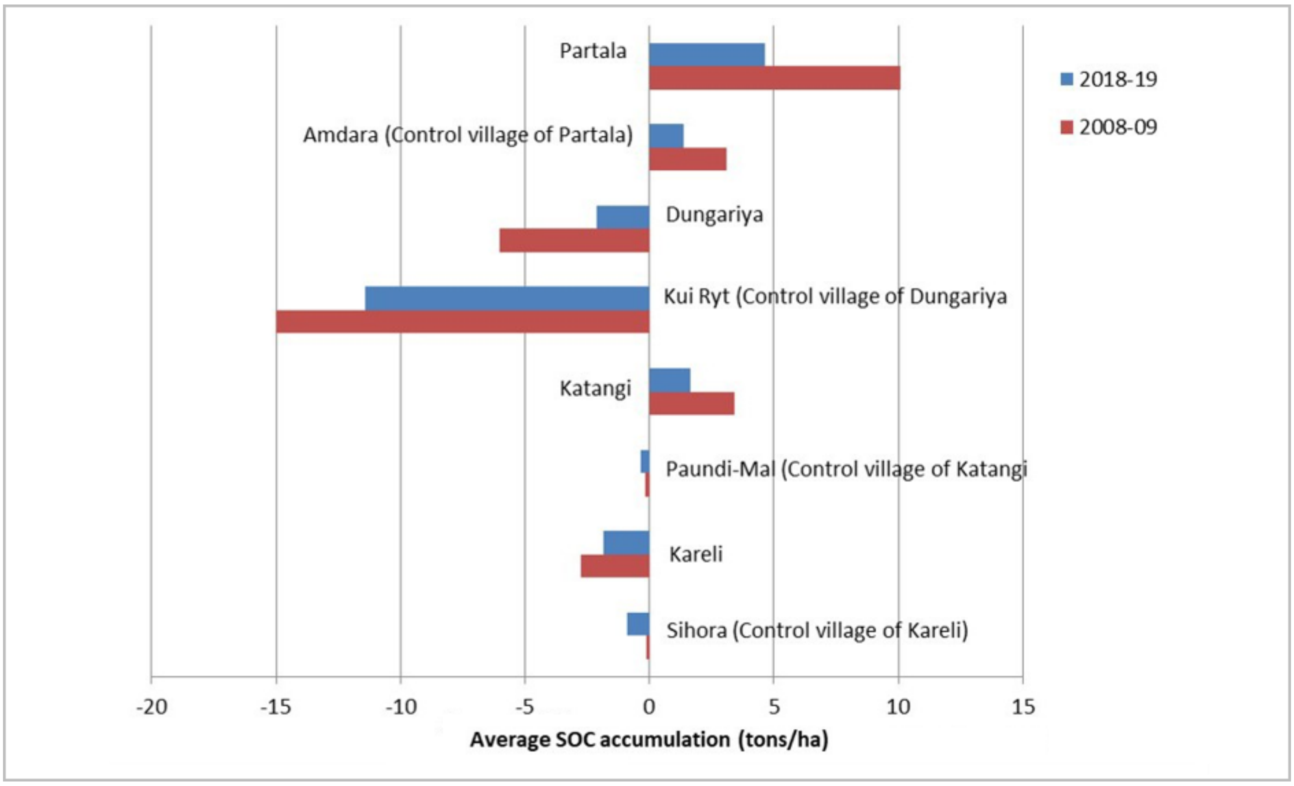


***Figure 2:** Average change in **soil organic** carbon during 2008-2018 in project and control villages*

C. Land use/ Land Cover (LULC) Change

The change detection helps to understand land transitions and trends in the LULC change.

(i) Dungariya (project) and Kui Ryt (control) villages

The TGA of the Dungariya and Kui-Ryt villages are 248 ha and 214 ha respectively. The LULC has significantly changed from the year 2008 to 2018 (Fig.3). In Dungariya, the net cultivable land area (including fallow land) has increased by 45 ha; however, cropping intensity (Fig. 4), i.e. the double-crop area of 4.3 ha remains unchanged. The percentages of change in agriculture and fallow land categories are 32% and 18% respectively.

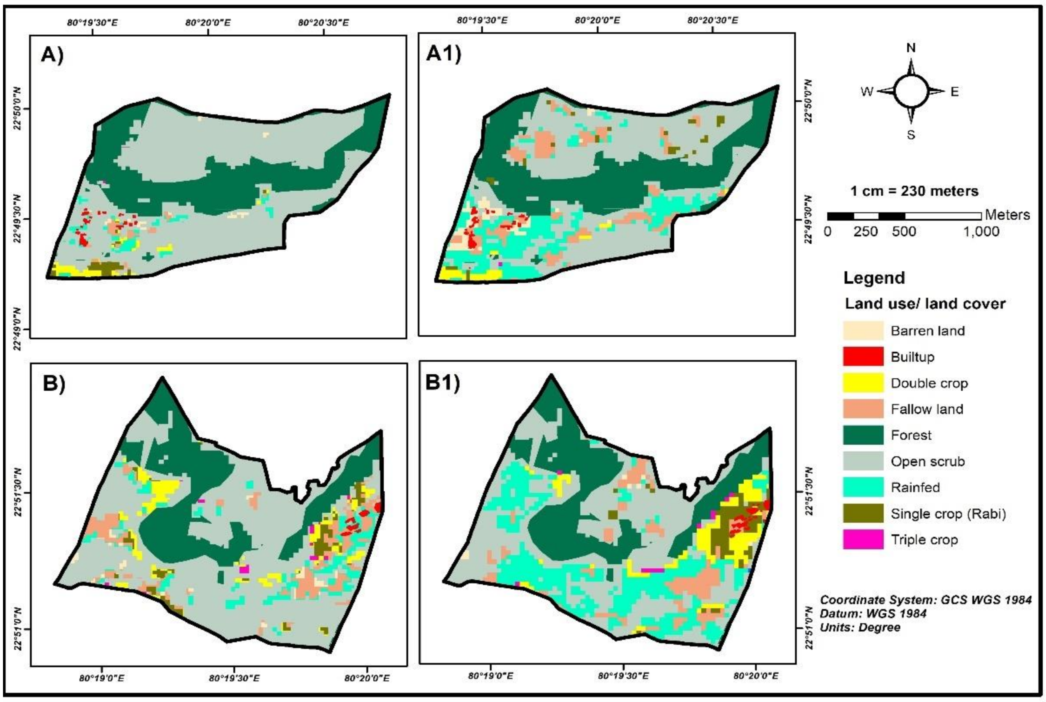


***Figure 3:** LULC map of project village Dungariya in the year 2008 (A) and 2018 (A1) and control village Kui.Ryt, in the year 2008 (B) and 2018 (B1).*

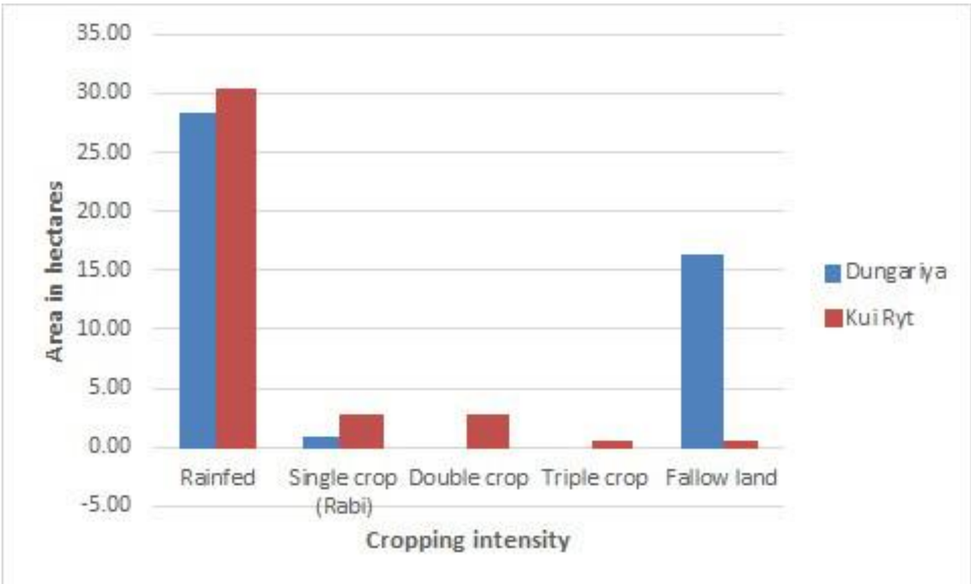


***Figure 4:** Cropping area changes in Dungariya and Kui Ryt during 2008-2018*

In Kui Ryt during the same period, the net cultivable land area (including fallow land) increased by 36 ha. In both the project and control villages, the area under single *Kharif* crop accounts for the major cultivated area (Figure.3 [B & B1]). The cropping intensity slightly increased in Kui Ryt (Fig.4). The double-crop area and single crop (*rabi*) area is increased by 2.5 ha and 2.38 ha respectively.

(ii) <u>Partala (project) and Amdara (control) villages</u>

The spatial disposition of LULC change in *Partala* (project village) and *Amdara* (control village) is given in Figure 5 below.

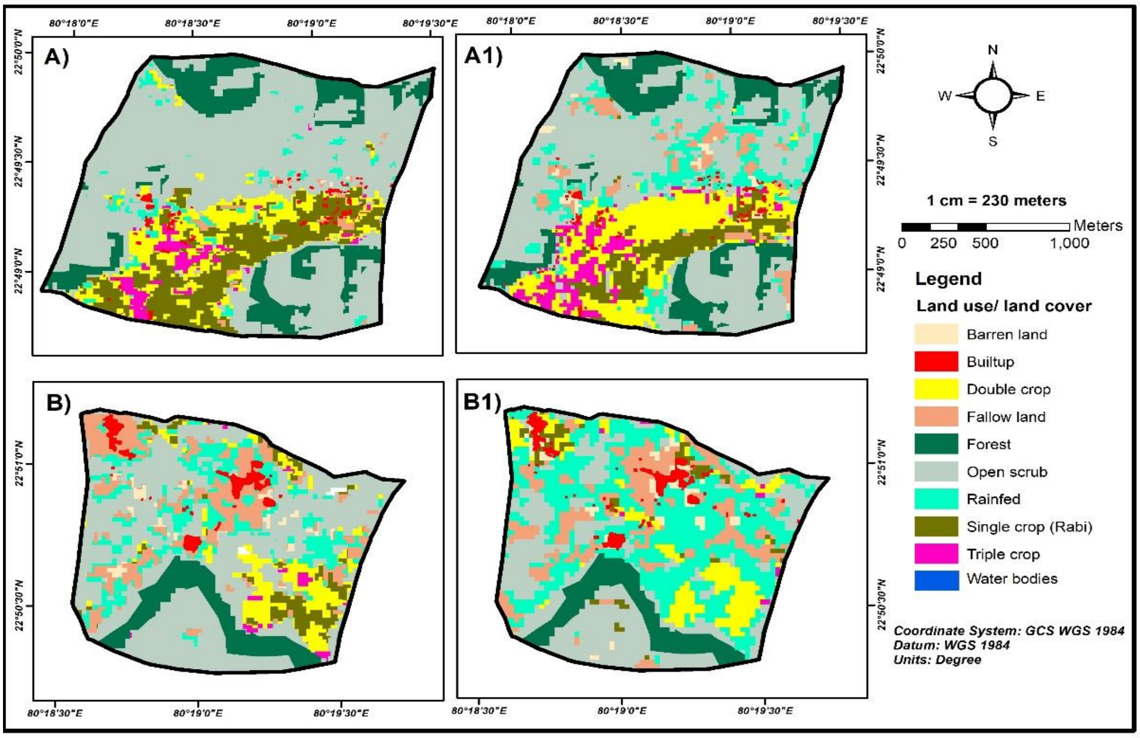


Figure 5. *LULC map of project village Partala in the year 2008 (A) and 2018 (A1) and control village Amdara in the year 2008 (B) and 2018 (B1)*

The total geographical area (TGA) of the *Partala* and *Amdara* villages is 493 ha and 250 ha respectively. The LULC has significantly changed from the year 2008 to 2018 (Fig.5). In *Partala* (project village), an increase in agriculture (45.23 ha) and fallow land of 32% and 17% respectively is observed; the uncultivable land (barren land & open scrub) area has reduced by -50% and built-up area increased by 1%. Change is also observed in the control village *Amdara* (Fig.5 [B & B1]). However, the land kept fallow in *Amdara* (1%) in 2018 is far less than in *Partala*.

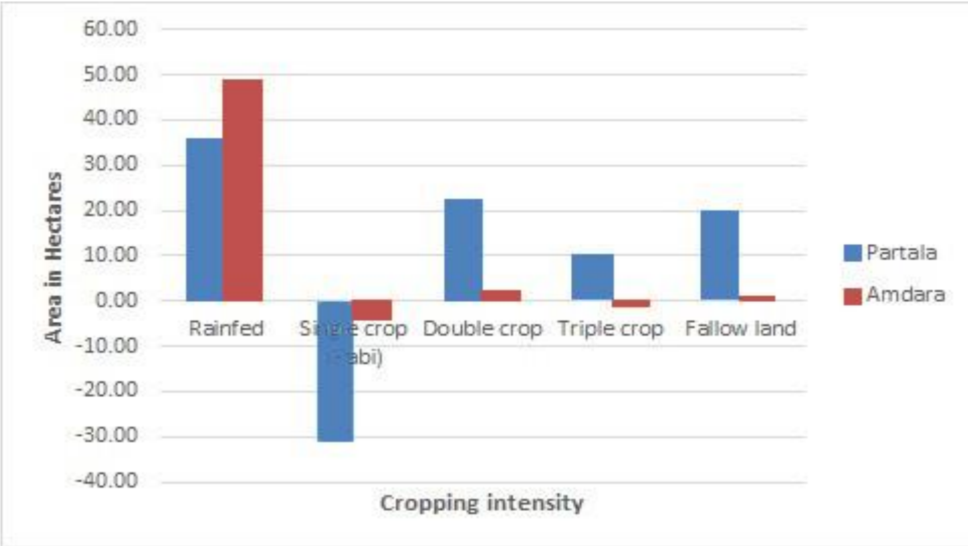


Figure 6: *cropping area changes in Partala and Amdara during 2008-2018*

Multi-seasonal cropping changes (*Kharif, rabi*, and summer) and in cropping intensity (single crop, double-crop, and triple crop area) are seen in both villages; the rainfed area has increased, i.e. in *Amdara* by 48.6 ha (252%) area while in *Partala* by 35.5 ha (153%) (Fig 6). However, in *Partala* an increase in double crop area of 22.2 ha (46%) is observed, while the single crop (*rabi*) area has reduced by -31 ha (-48%); and the triple crop area has increased by nearly 10 ha (74%). In *Amdara*, *a* slight increase is noted in the double-crop area (11%) with the reduction in triple crop area by -56%. The watershed development activities along with the access to irrigation water resources in Partala have helped farmers to cultivate the additional crops. Most of the non-forest area in both villages has been converted into agricultural land, which indicates a focus on agriculture as an income source.

iii) Katangi (project) and Paundi Mal (control) villages

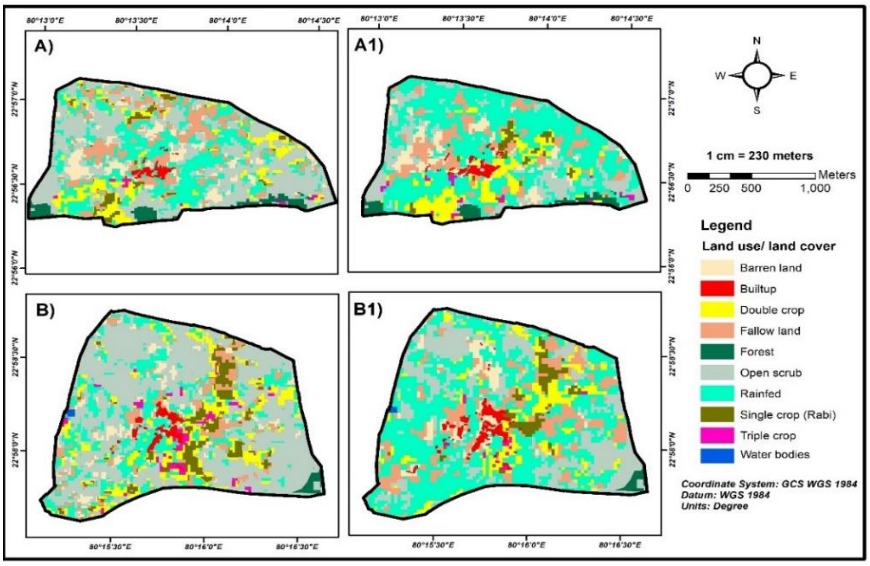


Figure7: *LULC map of project village Katangi in the year 2008 (A) and 2018 (A1) and control village Paundi Mal in the year 2008 (B) and 2018 (B1).*

The TGA of the Katangi and Paundi Mal villages are 318 ha and 367 ha respectively. The LULC has changed significantly from year 2008 to 2018 (Fig. 7).

In Katangi the area under cultivation has increased by 49% during 2008-2018, with the total addition of 74.5 ha. At the same time, fallow land area has reduced by -3% (-5.2 ha). The built-up area shows an increase of 1% area (1.8 ha). The double and triple crop area shows a slight increase of 3.82 ha and 1.74 ha respectively.

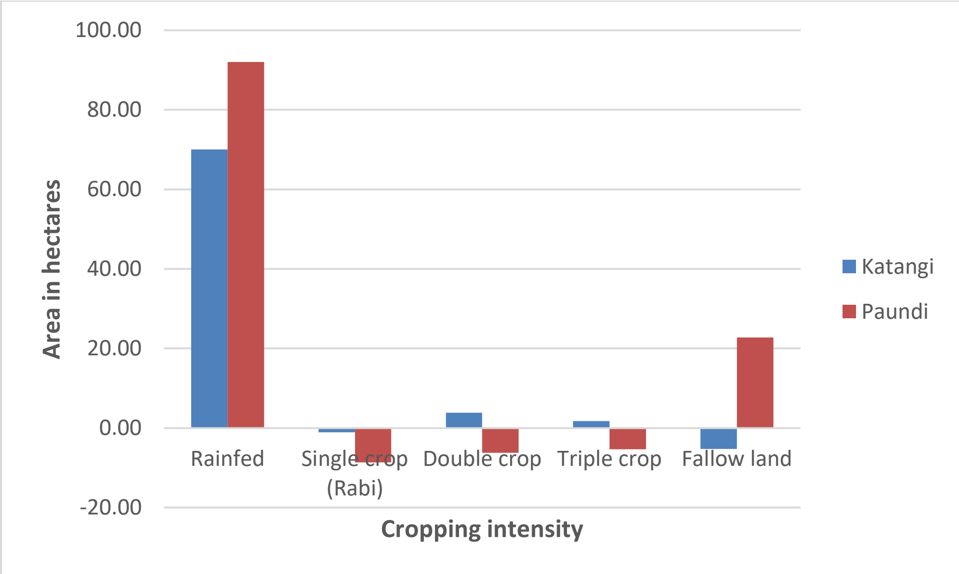


Figure 8: *Cropping area changes in Katangi and Paundi Mal during 2008-2018*

Paundi Mal village also shows a significant increase in the total cultivable area and fallow land by almost 115 ha (Fig. 8). The change is mainly attributed to the rainfed crop area that has increased by 92 ha between the year 2008 and the year 2018. However, the cropping intensity has decreased in the double-crop (-6.2 ha), single crop (*rabi*) (-8.6 ha) and triple crop area (-5.3 ha). The fallow land area has increased by 23 ha. Built-up area in the village has also increased by 2% (3.2ha). Despite not having watershed interventions, the marked increase in area under agriculture. Paundi Mal is a market village having the government offices located within. Hence the village has the opportunity of availing of various government schemes and benefits.

iv) Kareli (project) and Sihora (control) villages

The TGA of the Kareli and Sihora villages are 537 ha and 468 ha respectively. A significant change has been observed in the LULC from the year 2008 to 2018 (Fig.9). In Kareli, the total cultivable area, including fallow land, has increased by 19.8 ha, from 180.5 ha in the year 2008 to 215 ha in the year 2018. Similar to other project villages, uncultivable land was converted to cultivable land. In Sihora, the cultivable land area decreased in 2018 with an increase in the fallow land (1.86 ha) and uncultivable area (2.35 ha).

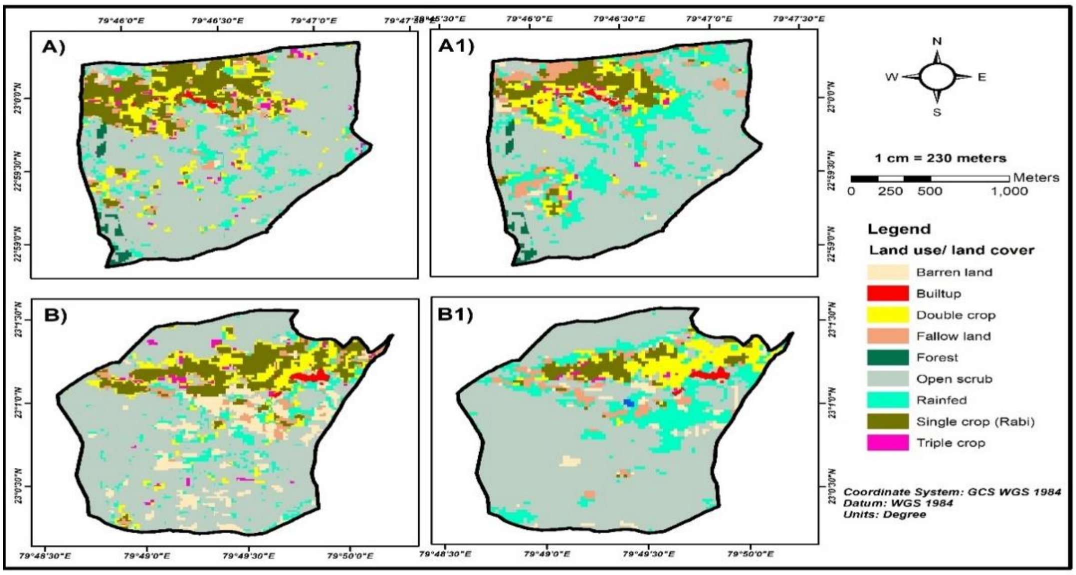


Figure 9: *LULC map of project village Kareli in year 2008 (A) and 2018 (A1) and control village Sihora in year 2008 (B) and 2018 (B1).*

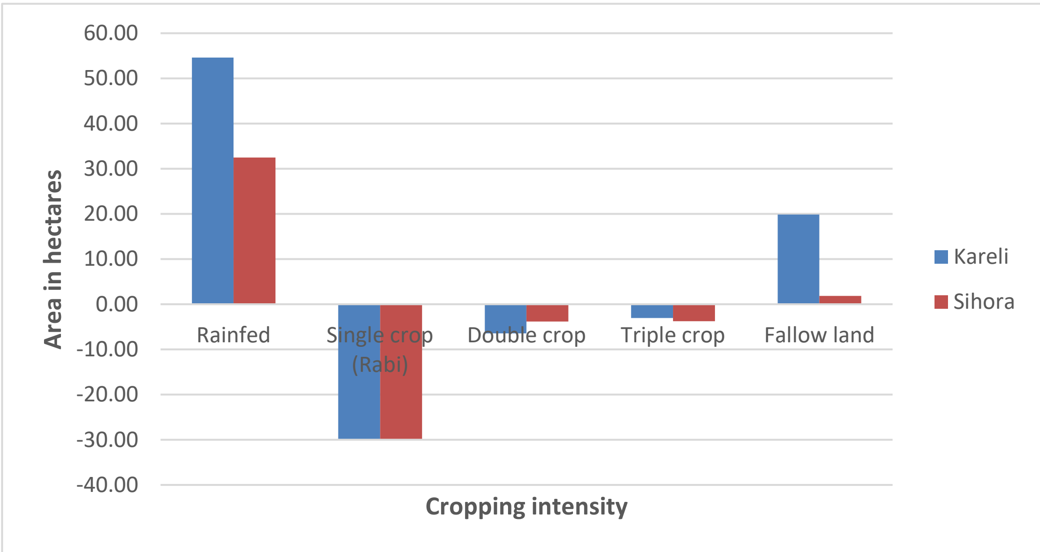


Figure 10: *Cropping area changes in Kareli and Sihora during 2008-2018*

In both the project and control villages, the cropping intensity reduced in 2018 as compared the year 2008 (Fig. 10). The rainfed crop was the major cultivation. In Kareli the rainfed cultivated area increased by 55 ha between 2008-2018, whereas the single crop (*rabi*) and triple crop areas are reduced.

D. Land Productivity Dynamics

As a first step, the LULC change from the year 2008 to 2018 is classified as positive, negative and no change categories. For example, the forest category in the year 2008 remains forest in the year 2018 classified as no change, the shift from forest to cropland classified as a negative change (i.e. reduction of the forest), and barren land brought under vegetation or forest classified as a positive change. The NDVI values resampled to 8-bit values (0-255) and classified into very weak (46–101), weak (102–159), moderate (160–215) and Intensive (216–255). Higher NDVI value characterizes the higher vegetation health. Further, based on the LULC change pattern and NDVI category the land classes categorized into declining productivity, early signs of decline stable, but stressed, stable, not stressed, and increasing productivity.

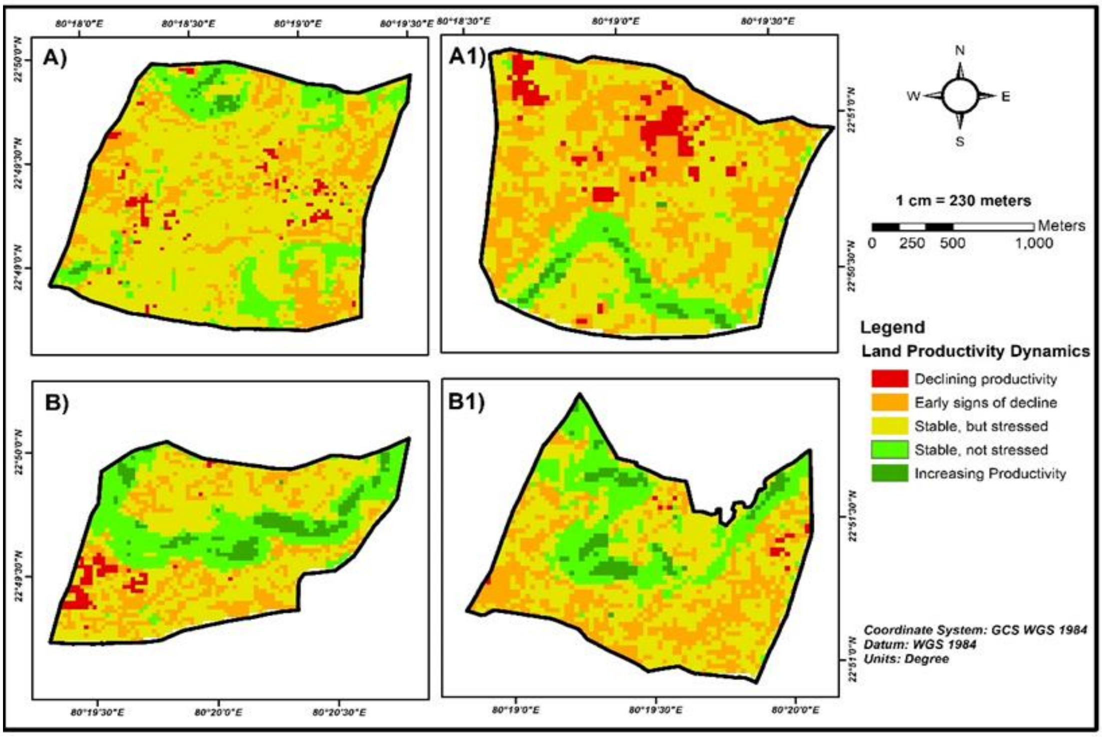


Figure 11: *Land productivity dynamics in project villages Partala (A) and Dungariya (B) and respective control villages Amdara (A1) and Kui-Ryt (B1)*

The LPD distribution maps of *Partala* (project village), its control village *Amdara*, and *Dungariya* (project village) and its control village *Kui Ryt* are shown in Fig.11.

i) Partala (project village) and Amdara (control village)

The LULC change between the years 2008 - 2018 are similar in project and control villages (Fig. 13 A). In *Partala,* of the total geographical area (TGA) the LPD category are *stable but stressed* in 60% of the land area. Cropland, open scrub and forest categories account for 31%, 27% and 2% respectively. The 10% *stable* and 1.2% *improvement* LPD class is observed in the forest category. *Early signs of decline* account for 13.3% in open scrub and 7.3% in cropland. The *declining* productivity accounts for 2.4% in total. In Amdara, the *declining* productivity observed is 5.4%; within the cropland, it is 2%, artificial surface 2.2% and barren land 1.2%. *Early signs of decline* in the cropland category is 25.7% and in the open scrub category, 9.6%. The *stable but stressed* category within cropland is 30% and in open scrub 15.1%. The overall assessment of the LPD in *Partala* is comparatively better as compared to *Amdara* village (Fig 13 A).

ii) Dungariya (project village) and Kui-Ryt (control village)

In *Dungariya*, the *stable but stressed* LPD is the major category accounting for 44% (Fig. 11 B), of which open scrub is 29.2% and cropland 14.8% of the total TGA. Nearly 25% area is *stable* category, falling within the forest (22.8%) and open scrub (2.2%). *Improvement* in land productivity is 7% and is in the forest area. *Early signs of decline* account for 20% area of which open scrub is 10.6% and cropland 9% (Fig 13 B).

In *Kui Ryt* the *stable but stressed* LPD accounts for 42.6%, with open scrub 22.3% and cropland 20.2% (Fig 11 B1). The *early signs of decline* category are 26.7% of the TGA, within cropland (14.7%) and open scrub (11.9%). The *stable, not stressed* area accounts for 20% area. The forest area under *stable* category is 16% and 4% in open scrub. The 4.3% TGA showed *productivity improvement* noticed in the forest (Fig 13 B).

iii) Katangi (project village) and Paundi Mal (control village)

The percentage area share of LPD classes within LULC category of *Katangi* (project) and *Paundi Mal* (control) villages are seen in Fig. 12 (A & A1). In both the project and control villages, declining productivity noticed, with *Katangi* having the declining productivity of 8.5% within barren land (6.89%) and artificial land (1.38%); and cropland (0.23%); and in Paundi Mal the declining productivity (7%) is within the LULC categories of cropland (2%), artificial land (2.3%), open scrub (0.6%) and barren land (2.1%). The *stable, but stressed* (cropland and open scrub) category accounts for 46% and 50% in *Katangi* and *Paundi Mal* respectively. The cropland category in both villages has>35% in the stable category (Fig. 13 C).

In the cropland category, the *early signs of decline* in land productivity account for 34% and 30% in *Katangi* and *Paundi Mal* respectively. The 3% *stable not stressed* category is within the forest area. Both the villages show no improvement in land productivity.

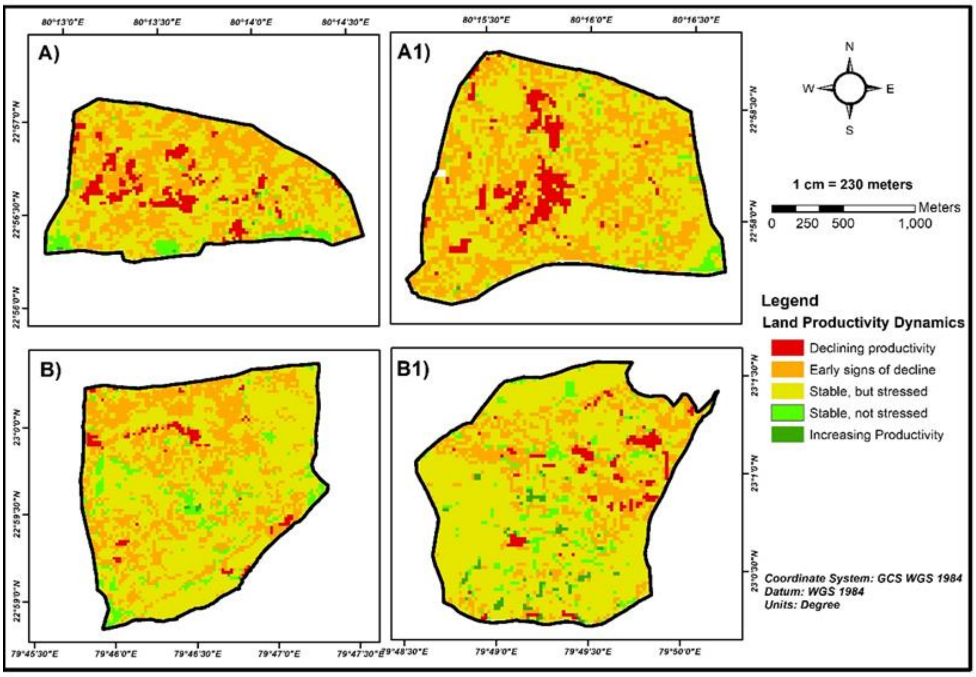


Figure 12. *Land productivity dynamics in project villages Katangi (A) and Paundi Mal (A1) and Kareli (B) and Sihora (B1)*

iv) Kareli (project village) and Sihora (control village)

The percentage area share of LPD classes within the LULC categories of *Kareli* (project) and *Sihora* (control) villages are seen in Fig. 12 (B & B1). The LDP of 61% of *Kareli* village shows *stable* productivity with some stress and chances of *early signs of decline* in productivity. Within the *stable but stressed* category, open scrub and cropland account for 41% and 20% respectively. The *early signs of decline* category are seen in 29% of TGA within cropland (18.8%), and open scrub (10%) and *stable not stressed* category is 5% of the TGA. In the control village *Sihora,* nearly 69% of LDP is in the *stable but stressed* category within open scrub (52.1%), cropland (16.3%) and barren land (1%). The *early signs of decline* account for 19%; the 2% *land productivity improvement* is seen in the open scrub category, and *declining productivity* is noticed in 3.6% TGA within barren land (1.5%), cropland (0.8%) and open scrub (0.62) (Fig 13 D).

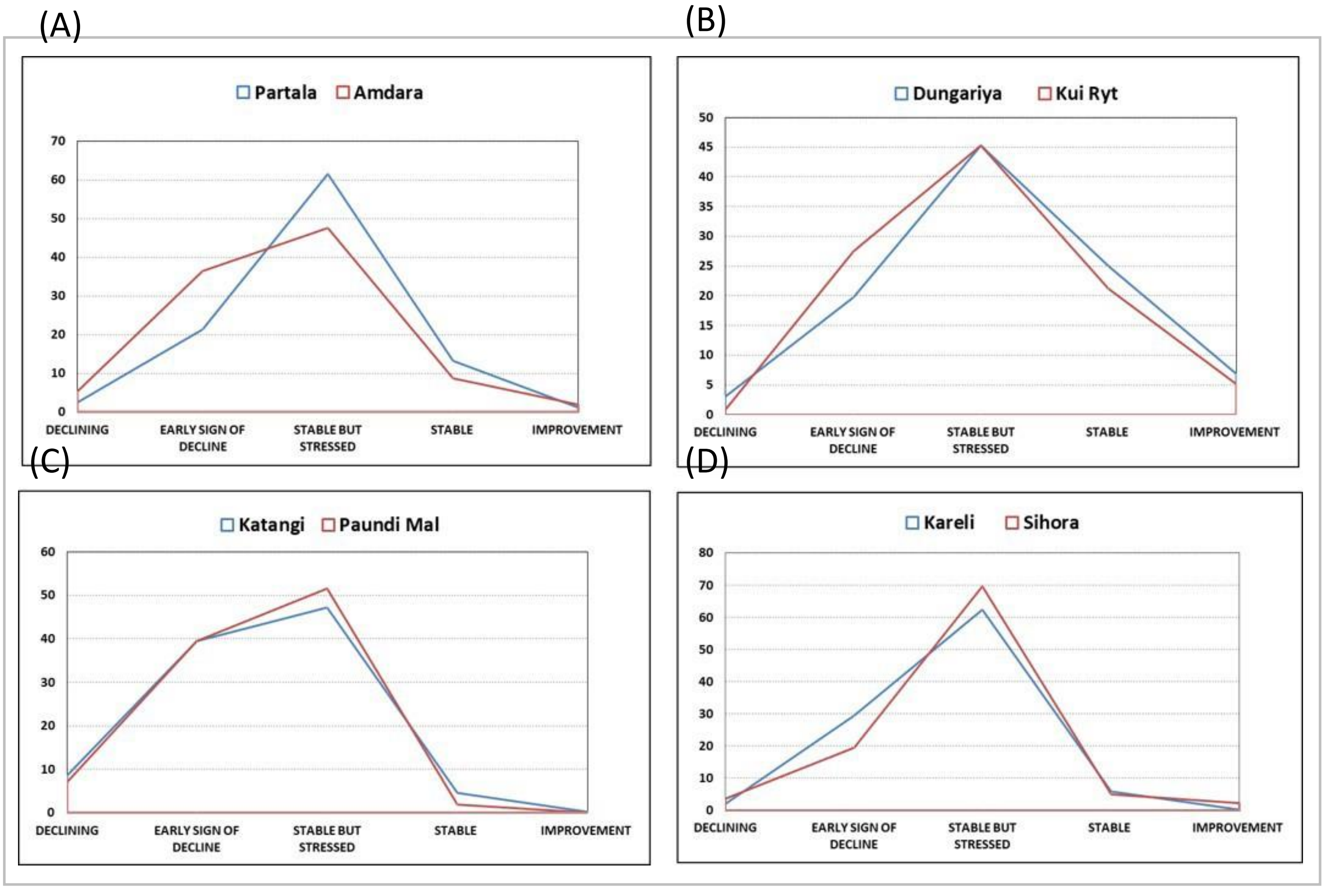


Figure 13. *Percentage area of the land productivity dynamics in project and control villages*

3.2. Assessment and Economic Valuation of Ecosystem Services

The ecosystem services assessed in this study are (a) Crop and fodder, (b) water for household

purposes as also some intermediate ecosystem services such as soil conservation (already described) and hydrological services which improve crop productivity. Besides these, the intrinsic value of the decrease in migration was assessed and monetized.

A. Changes in the ecosystems related to crop production

Agriculture is the main occupation of the residents of the selected villages. Therefore, interventions done were to improve the condition of the agro-ecosystem, i.e. reduction of erosion, enhancement of soil moisture content, improvement of agricultural practices, development of irrigation infrastructure, and the choice of crops. Given that the physical measurement of all indicators (soil moisture, well water table levels, surface follow, etc.) for the improvement of the agro-ecosystems were not available, FGDs, KIIs were used to explore the knowledge of the people to assess the change.

The WSD interventions contributed to the conservation of soil both on agriculture and non-agriculture lands. Farmers in both control and treated villages are aware of the erosion of the topsoil and its relation to soil fertility and crop productivity. Rakesh[i4ii], a farmer from Kui-Ryt one of the control villages said, when asked about the condition of soil erosion, *"You can see the condition. A huge area of farmland has been eroded. This (erosion) is not at all helpful for the fertility of the soil."* However, the farmers of the control villages also recognised the fact that there was some improvement in the soil conservation due to some of the initiatives taken by the government.

On the other hand, respondents of the project villages emphasised the decrease in soil erosion and land improvement through WSD practices. Most of the villagers of project villages voiced a similar opinion. However, few farmers said that the impact of WSD measures is declining as most of the trenches have been filled with sediments.

Improvement in the hydrological parameters in project villages is another observation as the stream flow, rise in groundwater table and in soil moisture. A common finding talked about in all FGDs was, "*there is lot of improvement in the softness (namipan) and moisture content (gilapan) in the soil"*.

B. Change in the production of Crop and fodder

Crop production depends on several factors such as soil fertility, crop management, water availability, and area under agriculture. In the previous section, it has already described how the WSD intervention has contributed to the increase in the gross cropped area (GCA) and net cropped area (NCA) more that of the control villages. Improvement in soil conservation, water availability and crop management also contributed to increase in crop productivity. It has been found that crop productivity was higher in the project villages than that in the control villages in the years of normal rainfall (Fig. 14). The overall productivity of the crops was also higher in the project villages in the abnormal years (Fig. 15). Ramkumar stated, *"Before the intervention production was very low. It only increased due to the efforts made by your organisation."* Dipak, a villager from of Kui-Ryt (control village for Dungariya) said, *"In Dungariya, the improvement is much higher than that of our village which is due to activities on soil and water. However, we have also made some improvement, mostly individual efforts and with some support from the government."*

[4] The actual names of all the respondents have been changed as per the request of the villagers

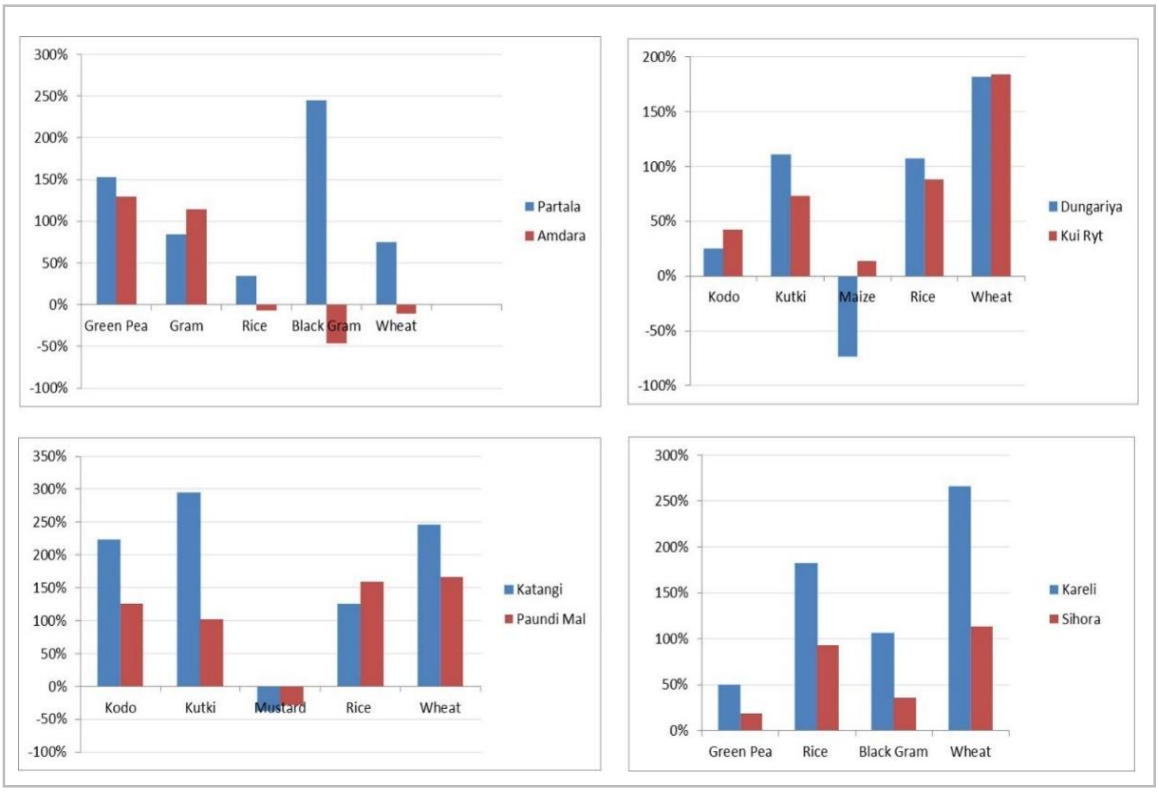


Figure 14. *Percentage change in the crop productivity in 2018-19 (in comparison to the baseline value)*

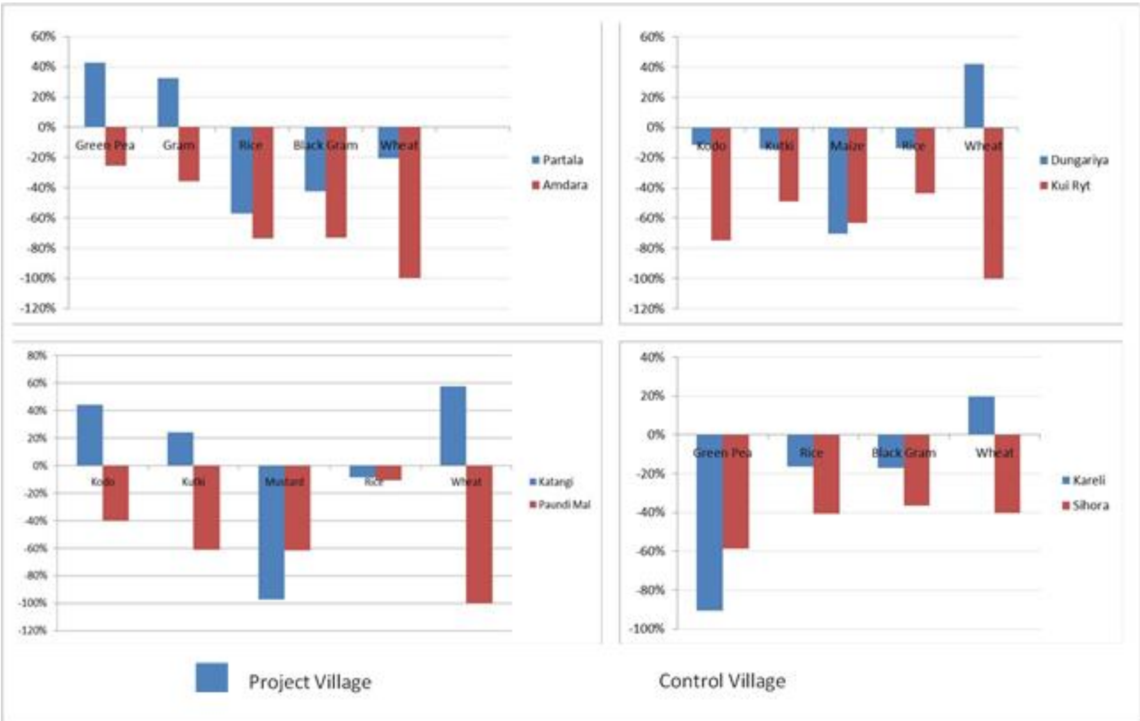


Figure 15. *Percentage change in the crop productivity during the drought of 2012-13 (in comparison to the baseline value)*

C. Water for Household Purposes

Another reason for watershed development besides agriculture, is the access to water for domestic needs. In all the project villages, water for domestic purposes was earlier collected from a distant source. The sources of water varied according to the season and in summer people spent several hours fetching water. Water resources became even scarcer in drought years. Villagers shared privately owned sources with other users or had to limit its use.

The main water sources used for domestic purpose are public wells, public taps and hand-pumps in all villages. Through watershed development, groundwater recharge and the flow in streams improved. Besides this, communities were provided with infrastructures like storage tanks and pipes for effective water distribution which ultimately led to the improvement of the water availability for household purposes. The results show that the time required for household water collection improved for all the eight villages. Government schemes also contributed to make water accessible through drinking water systems. Except for Partala and Katangi, the other two project villages showed better access to water as compared to their respective control villages.

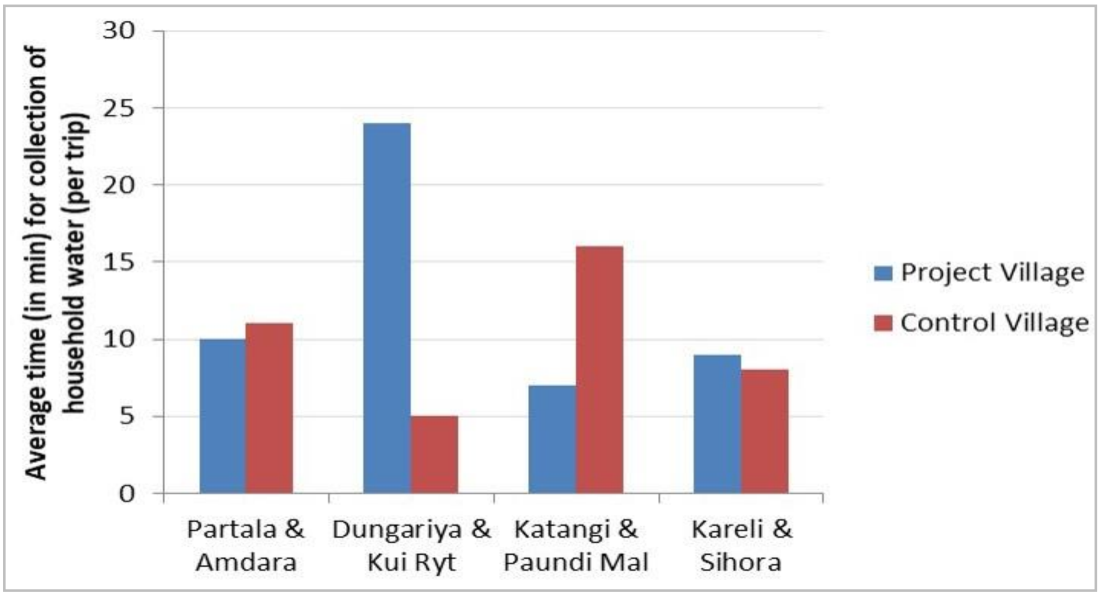


Figure 16. *The average reduction of time (per trip) for fetching water per household*

As seen in Fig 16, Dungariya has the greatest improvement in time saved (ie 24 mins / trip) in water collection. The other project villages on an average saved 8 to 13 minutes per trip. Lata, one of the respondents of Dungariya said, *"Earlier we would go to the water source in the morning, (wash clothes) spend time there and after a bath we would return with water in the afternoon. Now water is within the village."*

The control villages also show the improvement in water collection time over the years. A limited number of water conservation activities have been implemented in the control villages in Mandla under MGNREGS, as also installation of hand-pumps through government-funded projects. The improvement in the Paundi Mal is significant. Villagers attribute the improvement to the initiative of the gram panchayat in implementing some SWC activities through MGNREGS supported by an NGO and the implementation of government schemes by gram panchayat for household water supply. Paundi Mal is a market place hence the awareness regarding government schemes is greater than in other villages.

The year 2012-13 was a year of severe drought when villagers faced water scarcity. Extra-time was required per household per day for water collection in the project and control villages during a severe drought. The findings indicate that project villages fared better with regard to household water security during drought years, although Katangi was similar to its control village, for the reasons stated above.

D. Impact of WSD on Migration

In all the eight villages, seasonal migration has declined (Fig 17) as the area under agriculture expanded as well as the outreach of government schemes. Access to schemes is greater in Paundi Mal, while the outreach of the schemes was far less in the remote villages. In the project villages, the increase in area under double and triple cropping provides work opportunities for a longer period within the village. Except for Partala, the other three treated villages show a greater reduction in migration as compared to the control villages, including Paundi Mal. However on an average, households in Partala migrated for only 22 days in 2018 whereas, in Amdara (control), they migrated for 47 days (114% more days).

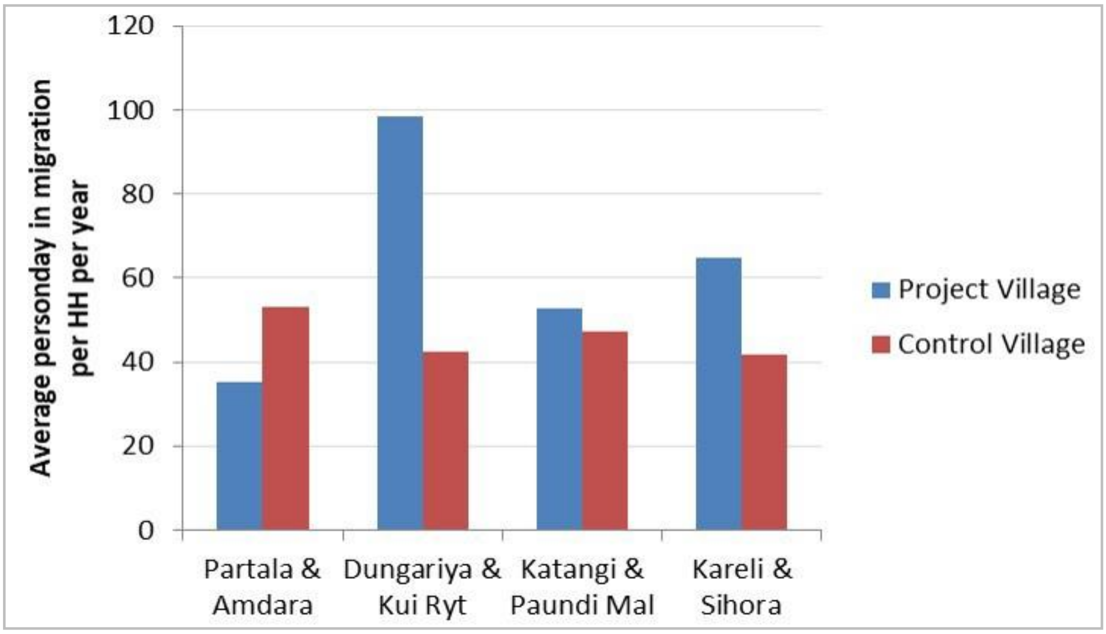


Figure 17. *The average reduction in migration days per household per annum*

3.3 Cost-Benefit Analysis

The cost-benefit analysis of the project and control villages is performed to understand the economic viability of WSD interventions, especially in comparison to the "Business-As-Usual (BAU)" scenario, i.e. the scenario in the control villages. For the project villages on the cost-side, the sum of the cost of the project apportioned for 2008-18 and the cost of cultivation is taken. For control villages, it is only the cost of cultivation. On the benefit side, benefits from agriculture (crop and fodder), time saved for water collection, and the benefit due to reduced migration are summed. The Benefit-cost ratio and the NPV/ per household values are calculated for all villages and are analyzed with an 8% discount rate, followed by analysis using 5% and 3% discount rates to check the B-C Ratio and NPV per household (Table 4). Kareli shows improved values both in terms of B-C Ratio (greater than 1) and NPV per household as compared to Sihora village. The B-C Ratio for Dungariya and Partala are greater than 1, which is also found in their respective control villages. Though the B-C Ratio for the project villages is lesser than their respective control villages, the NPV per household is higher in the project villages. It can be concluded that Partala and Dungariya show better economic viability than the BAU scenario. This is true for all three discount rates. The B-C Ratio of Katangi and Paundi-Mal are both greater than 1, but the value of B-C Ratio and the NPV per household of Paundi-Mal is higher than that of Katangi (Fig 18) as it shows a high value for the benefit for household water only. Katangi performs better in agriculture and migration benefits (NPV of 68646) as compared to Paundi Mal (NPV of 59102). Paundi Mal was able to access government funding for household water supply since the last 10 years. This is also visible in all three types of discount rates.

Table 4. Cost-Benefit Analysis and Sensitivity Analysis for WSD (project) villages and BAU (control) villages

Project Village	Discount Rate	BCR	NPV	NPV/HH	Control Village	Discount Rate	BCR	NPV	NPV/HH
Partala	8%	2.2	26947031	107788	Amdara	8%	3.2	14738046	87207
	5%	2.2	33328669	133315		5%	3.3	18277932	108153
	3%	2.3	38609854	154439		3%	3.4	21241636	125690
Dungariya	8%	2.8	5838731	110165	Kui-Ryt.	8%	3.1	6849835	72871
	5%	3	7508712	141674		5%	3.3	8701253	92567
	3%	3.2	8918437	168272		3%	3.4	10264614	109198
Katangi	8%	2.4	13581722	75454	PaundiMal	8%	4.3	25200581	92649
	5%	2.5	17306448	96147		5%	4.4	31691668	116513
	3%	2.5	20452667	113626		3%	4.5	37165991	136640
Kareli	8%	2.1	14699769	116665	Sihora	8%	2.00	9949647	77129
	5%	2.2	18923624	150187		5%	2.09	12803213	99250
	3%	2.2	22497437	178551		3%	2.15	15224628	118020

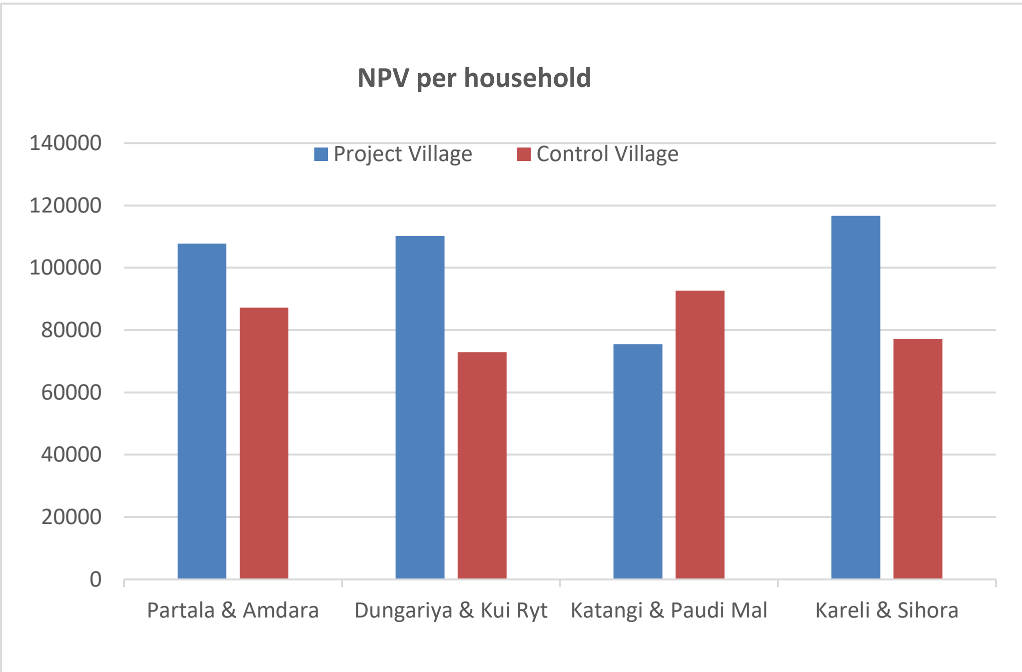


Figure 18. *Pair-wise Comparison of NPV (in INR) per household for the project and control villages calculated at 8% discount rate*

3.4 Climate change analysis and climate risk assessment

The annual rainfall (1989-2018) varied from 1236 mm to 1371 mm across all study villages In the past 30 years, there is a significant decrease in rainfall during August and September (monsoon months) (Fig 20). In the last ten years, the number of rainy days during June to September has decreased. Besides this, the minimum and maximum temperature in summer (March to May) shows a marked increase. The past thirty years trend of maximum temperature in April shows an increase from 38°C to 40°C. The winter temperature has also increased over the last ten years. The minimum temperature shows a greater rise as compared to the maximum temperature in *kharif* and *rabi* seasons. The example of the variation is given for Katangi village below (Fig 19, Fig. 20 and Fig. 21)

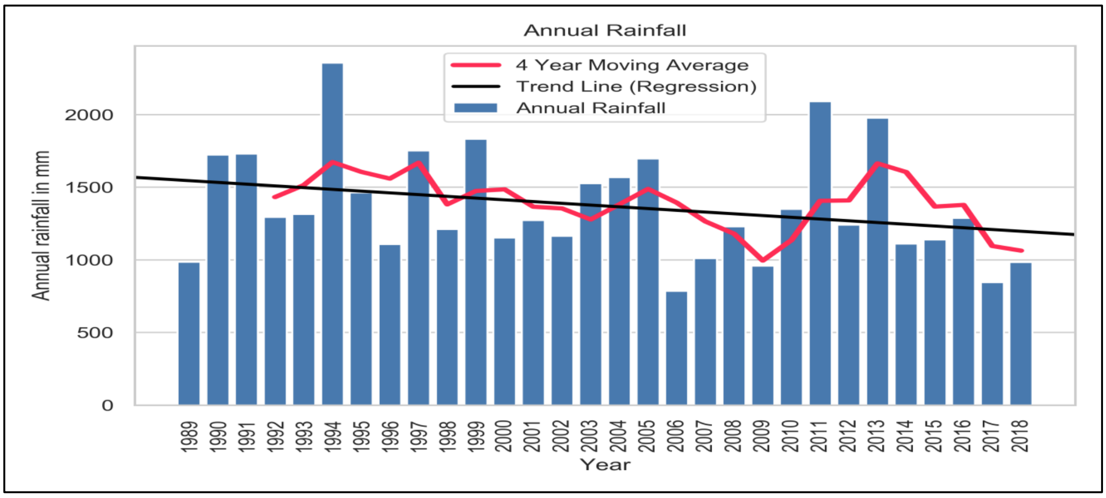


Figure 19. *Mean annual rainfall Katangi village (1989-2018) (IMD data)*

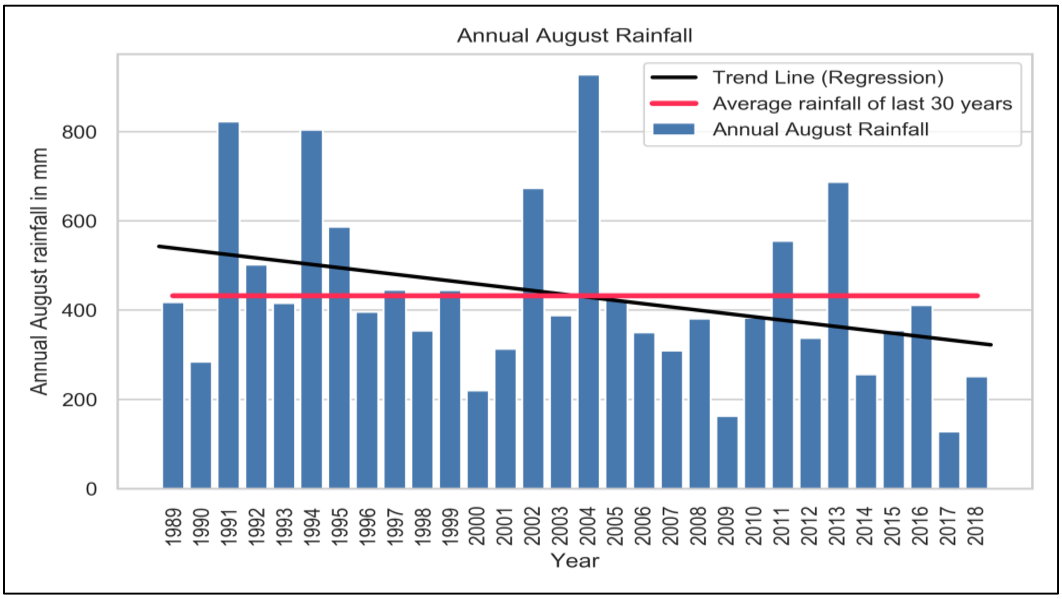


Figure 20. *Decreasing trend in the August Rainfall Katangi village (1989-2018) (data IMD)*

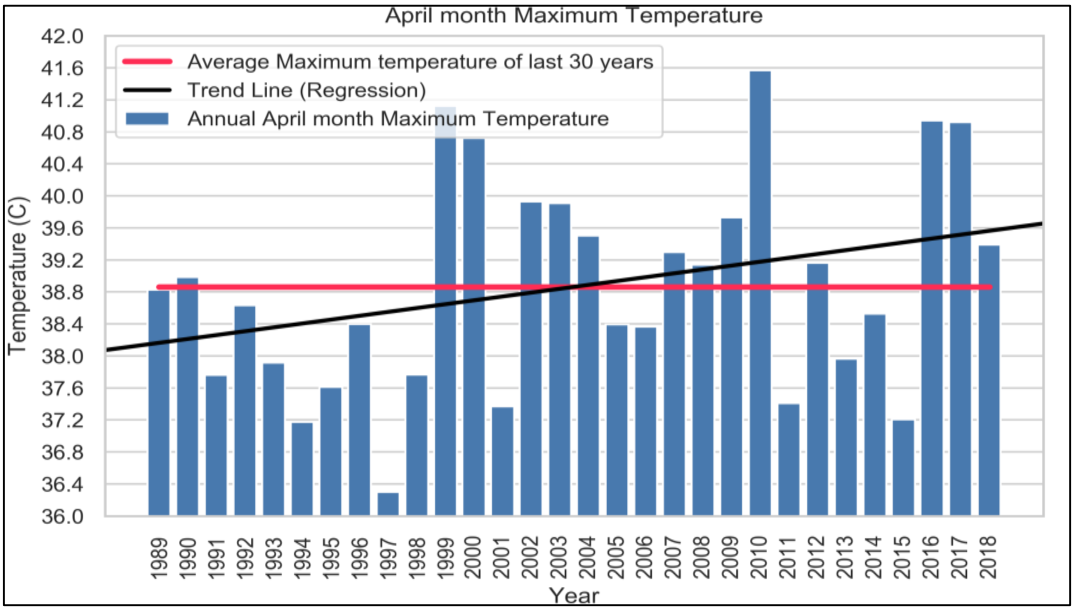


Figure 21. *Increasing trend in maximum temperature of April Katangi village (1989-2018) (IMD data)*

Climate trends and Projections: To understand the impact of rainfall extremes, the various extreme rainfall indices were studied, such as: one day highest precipitation (RX1), simple daily intensity (SDI), rainy days > 10mm (R10mm), rainy days> 20 mm (R20mm) etc. Rainfall extreme indices show a decreasing trend in the area except for R20mm (analysis for the monsoon season from 1989-2018). The daily intensity varies from 8.5mm/day to 21.1 mm/day, whereas range of consecutive dry days (CDD) is between 21 days to 5 days in Dungaria and Partala villages. A significant decrease in consecutive wet days is found in all four villages from 1989-2018.

The ensemble of CMIP5 models is used to look at the future extremes, specifically for near-century (2015 to 2040) period (Fig 22, Fig 23, Fig 24). Major risks identified for Kareli and Sihora villages (Jabalpur district) are the increase in dry spells (10 events/monsoon) and increase in events of rainy days with greater than 20mm rainfall (an increase of 20 events/monsoon) in the near future. Partala, Dungariya, Katangi and their control villages (Madla district) are projected to have an increasing trend of consecutive dry days; rainy days >20mm and intense precipitation (100mm/day). In the future century, there are more deficit rain years as compared to excess rain years which indicates plausible drought-like conditions. With the increase in dry spells and intense rains, the drought would be more severe. Rising temperature trends in *rabi* would be a major concern in these villages. The minimum temperature is projected to rise significantly in summer (March to May) as well as in the winter months (December, January and February).

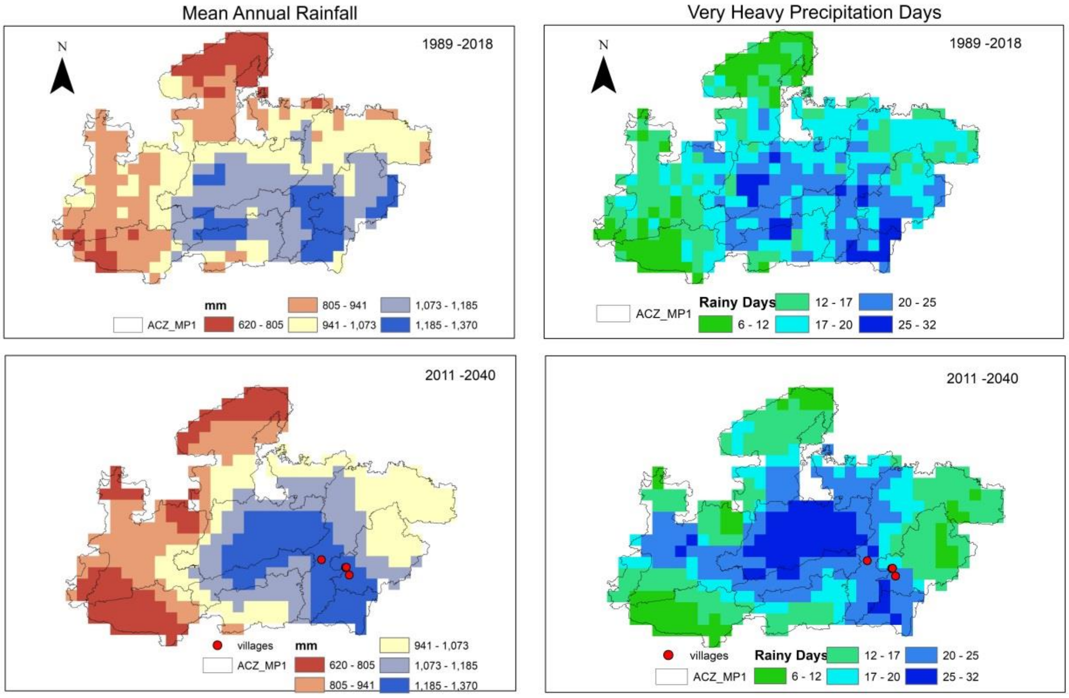


Figure 22: *Maps showing Mean annual rainfall and Very heavy precipitation days (rainfall >20 mm/day) for Historical Period (1989-2018): Using IMD rainfall data (Upper Figure) and Future Projections (2011-2040): using CMIP-5 ensemble outputs (Lower Figure) across the Madhya Pradesh state.*

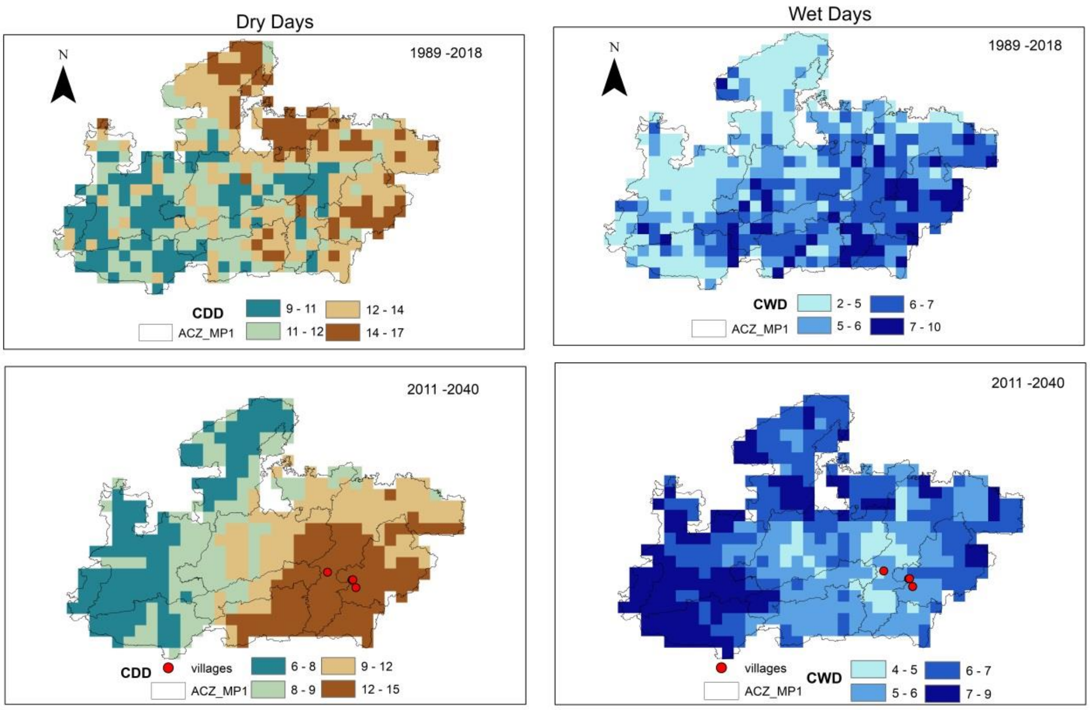


Figure 23: *Maps showing Consecutive Dry Days and Wet Days for Historical Period (1989-2018): Using IMD rainfall data (Upper Figure) and Future Projections (2011-2040): using CMIP-5 ensemble outputs (Lower Figure) across the Madhya Pradesh state.*

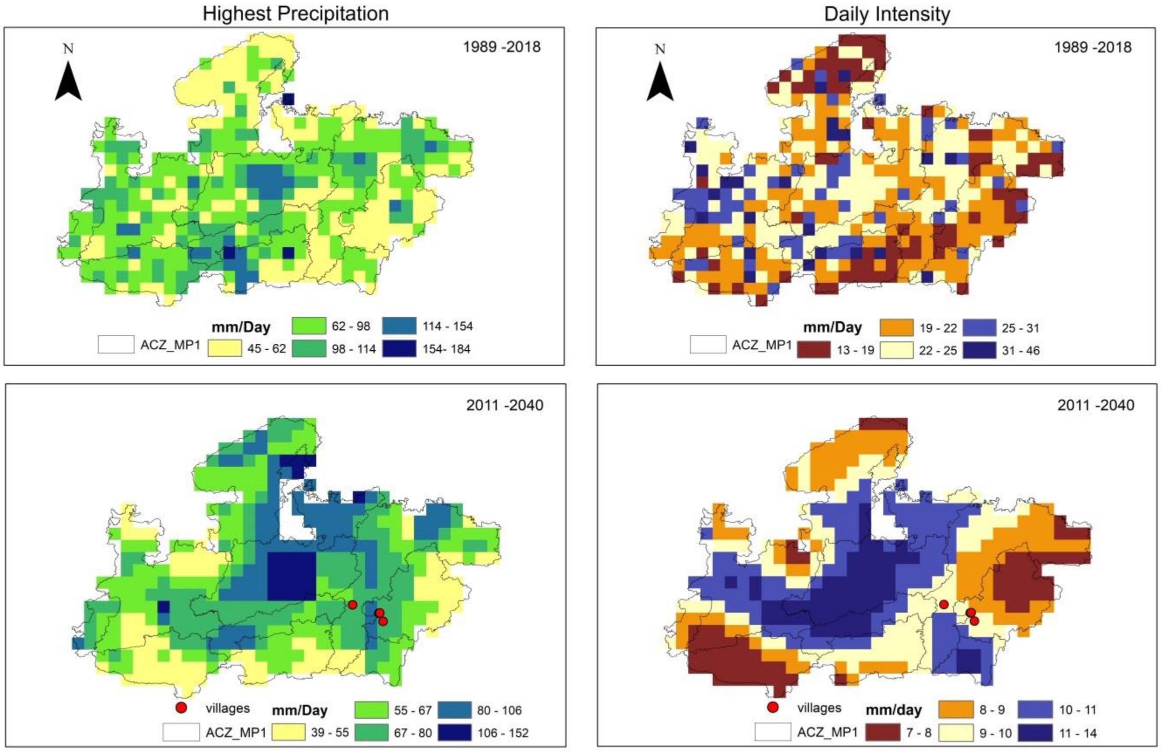


Figure 24: *Maps showing One day highest precipitation and Daily intensity for Historical Period (1989-2018): Using IMD rainfall data (Upper Figure) and Future Projections (2011-2040): using CMIP-5 ensemble outputs (Lower Figure) across the Madhya Pradesh state.*

Findings:

From the study of Fig 22, 23 and 24 above the following are the findings

- Mean annual rainfall of the two zones, of the study area is 1185 to 1370 mm.
- One day highest precipitation varies from 62 - 98mm/day (1989-2018) to 67-80 mm/day (2011-2040).
- Daily intensity of precipitation varies from 19 - 22mm/day (1989-2018) to 9-10 mm/day (2011-2040).
- Rainfall > 20mm of precipitation varies from 17 – 20 days (1989-2018) to 20-25 days (2011-2040).
- Wet days (rainfall for 5 days) vary from 7 – 9 days (1989-2018) to 6-7 days (2011-2040).
- Dry days (rainfall for 5 days) vary from 8 – 9 days (1989-2018) to 12-15 days (2011-2040).

The Climate analysis for the study villages are provided in Table 5 below:

Table 5. Summary of the climate change analysis

Variables (1989-2018)	(Katangi) Mandla district	(Dungariya and Partala) Mandla dist.	(Kareli) Jabalpur district
Annual Rainfall	13.71.05mm	1275.73mm	1236.05mm
Deficit rainfall years (meteorological drought years)	2007, 2009, 2012, 2016, 2017 and 2018	2007, 2009, 2012, 2014, 2017 and 2018	2007, 2012, 2014, 2015, 2017 and 2018
Rainfall trend (annual)	Decreasing trend (1989-18)		No trend (1989-18)
Rainy years	More deficit years		
Trend in rainfall (seasonal / monthly)	Decreasing trend: Aug and Sept, *kharif* and *rabi* seasons		Increasing trend: July Decreasing trend: Aug *kharif and rabi* seasons
Trend in temperature	Increasing trend: annual, seasonal, steep rise in *rabi*		
Annual rainy days (1989-2003 vs 2004 – 2018)	Rainy days decrease and rainfall increase		
Annual Temperature	32.16°C[5], 18.83°C[6]		31.88°C, 18.70°C
Temperature trend	Increasing trend (Annual, April, May and June, *kharif* and *rabi* season)		
Future rainfall (2015-2040) trend	Increase in annual rainfall. Increasing trend of rainfall in July and decrease of rainfall in September months; *rabi*-decreasing, *kharif*-increasing trend.		
Excess and deficit rainfall years	More deficit rainfall years		
Future months of maximum temperature (2015-2040)	Increase in maximum temperature in all months except May, June, October and November		
Trend in maximum temperature	Increasing trend in annual and seasonal temperature		
Future minimum temperature (2015-2040)	Increase in min. temperature in all months except May, June, October and November.		
Rainfall extremes (1989-2018)	Decreasing trend: RX1 and SDI	Increasing trend- CDD Decreasing trend: CWD, RX1 and SDI	Increasing trend: CWD Decreasing trend: RX1, SDI and CDD
Rainfall extremes (2015-2040)	Increasing trend in CDD and RX1	Increasing trend- CDD, RX1 and R20mm	Increasing trend in CDD and R20mm

[5] Mean maximum annual temperature
[6] Mean minimum annual temperature

4. FINDINGS & DISCUSSION

- Land-use change in the project and control villages are somewhat similar. There is a 50% shift from uncultivable land (open scrub and barren land) to cultivable land (cropland and fallows) in both the treated and control villages. This indicates the growing need for agriculture land across villages. However, the cropping intensity in project villages Partala, Katangi and Kareli is comparatively higher than their respective control villages Amdara, Paundi Mal and Sihora. In Dungariya, while the cultivable land area has increased, not much change is observed in cropping intensity, which requires further inquiry.

- Soil carbon detachment is significantly reduced in project villages because of WSD interventions. In control villages, soil carbon detachment is comparatively higher than in project villages. For example, in Dungariya an upper catchment village, it is reduced by 64%, but in case of its control village Kui-Ryt, reduction in soil carbon detachment is only about 23%. In Sihora the control village of Kareli, also an upper catchment village, the increase of soil carbon detachment is 567% of the baseline; while in Kareli, the soil carbon detachment has reduced by 32.7%.

- Land productivity dynamics in both project and control villages are mostly under *stable, but stressed* category; cropland and natural vegetation area are under *stress*. This may be due to the agriculture practices followed and also to climate change i.e. longer summers and higher annual temperatures, as well as decreasing rainfall; both of these impact vegetation. In control villages, the *early signs of decline* in land productivity are increased in croplands and open scrub area. In project villages, the forest area showed improvement in land productivity, indicating the influence of afforestation activity done.

- The overall crop productivity in project villages is higher than that of the control villages, and productivity has increased over time. As the benefits from soil erosion control and water availability improved, interest in farming increased and farm allied work opportunities in the local area emerged. While climate extremes, i.e. drought and flood-affected the crops badly, the crop productivity values are higher in the project villages as compared to control villages.

- Capacity enhancement of local institutions work positively for the implementation of Watershed development and sustain it over a longer period. The example of Dungariya is notable. They have utilised funds of the project as well as government schemes for the development of community assets, which has provided benefits and contributed to reduced migration. Bringing the village to work together for regenerating their natural resource base also incentivised inhabitants to give preference to local work, i.e. agriculture, rather than migrate.

- Overall, it has been seen that the investment in WSD generates greater benefit for agriculture, water for household purposes and migration. However, the case of Paundi-Mal indicates the importance of building linkages with government projects. Convergence, awareness generation, local institution building, strengthening of the gram panchayat are crucial for on-going development. For sustaining the benefits of WSD measures, knowledge of the 'how-to' implement and wage work through MGNREGS can assist in the continuous repairs and maintenance of structures required.

- The time required for water collection for household needs is less in project villages than that in control villages, particularly during drought. It indicates that WSD measures are vital for disaster risk reduction.

- Results of the climate analysis project that the region is expected to have a greater number of drought and flood-like situations in the future. This stresses the importance of regular maintenance of WSD structures and also the need to make timely modifications (e.g. flood control). For agriculture to respond to climate change, 'adaptive sustainable agriculture' needs to be promoted. Addressing farming practices, choice of crops, return to a native variety of seed and crops as applicable, as well as locale-specific crop weather advisories are required.

- The economic valuation of selected ecosystem services has been conducted in this study. However, the economic valuation of all ecosystem services e.g. carbon sequestration, non-agriculture fodder, i.e. from the forest; valuation from fish in streams, non-forest timber produce etc. have not been assessed. Therefore, this is an undervaluation of all the ecosystem services that watershed development does.

- All project villages do not show an equal increase in benefits; control villages fare better in a few aspects. It is therefore important to include a review mechanism where the local committee/*gram panchayat* assesses and record benefits received / losses incurred and make course corrections as required. This is relevant in a climate change context.

- The B-C ratio greater than 1 and the NPV per household value in project villages are higher than those of the control villages, which prove the economic viability of WSD intervention. While Katangi underperforms in the aggregate value as compared to Paundi-Mal its control village, the latter scores higher with regard to water for household purposes, while in most of the other parameters of Katangi showed higher value.

- The residents in the project villages overall were pleased with the WSD measures implemented. Motilal a *gram panchayat* member, said, *"These types of works helped to reduce poverty to a great extent. However, we need your organisation to continue to work in our village again so that we villagers can further improve."*

5. CONCLUSION

Land degradation is an on-going process which significantly influences food, water and energy security and other ecosystem services on which we humans depend. Regular assessment of land degradation is essential to plan management activities that arrest or reverse the process. In this context the study highlights the relevance of watershed development in controlling land degradation in east Madhya Pradesh, as assessed by the LDN indicators i) LULC change, ii) soil organic carbon change iii) land productivity dynamics.

Measures to reduce degradation are taken up in Madhya Pradesh and across the country, through major projects such as the Integrated Watershed Management Programme (IWMP), the NABARD supported Watershed Development Fund, bilateral and corporate-funded projects. The impacts observed in the study villages even after 7 years since project closure, is encouraging. However, the study findings highlight the importance of continuous monitoring and repairs of the structures constructed such as continuous contour trenches, water Absorption trenches, farm bunds, gabions, check-dams etc. as well as of tree cover. Hence regular maintenance needs to be an on-going activity during project period, and continued beyond. This is of particular importance in regions where the soil is loose, i.e. erosion-prone, as in the study location.

When the ecosystem provides the services sought by local inhabitants such as livelihood (agriculture in this case) within the locale, food, and water availability that reduces their stress, people prefer to work nearer home than move in distress migration.

Watershed development (WSD)/ Sustainable land management measures are observed to have a positive benefit under climate risks such as drought and floods. However, with the wide range of uncertainty from both, the climate and other externalities, e.g. market forces, “adaptation” needs to be considered an ‘on-going’ process. It is important to maintain the health of the ecosystem so as to benefit from its services that are essential for human existence.

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