


Economics of Land Degradation: Evaluating the Impact of Land Remediation through the Lenses of Natural Capital and SDGs in the Bundelkhand Region in Madhya Pradesh, India

Development Alternatives

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About ELD Initiative

The Economics of Land Degradation (ELD) Initiative is a global initiative established in 2012 by the European Union (EU), the German Federal Ministry for Economic Cooperation and Development (BMZ), and the United Nations Convention to Combat Desertification (UNCCD).

The ELD Initiative aims at transforming the global understanding of the economic value of productive land and fostering stakeholder awareness of socio-economic arguments to promote sustainable land management. It 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.

The ELD Secretariat that coordinates the Initiative is hosted by the Sector Project on Soil Rehabilitation, Desertification and Sustainable Land Management at the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in Bonn, Germany.

Development Alternatives

About Development Alternatives

Development Alternatives (DA) is a premier social enterprise with a global presence in the fields of green economic development, social empowerment and environmental management. It is one of the leading Think Tanks in the field of Sustainable Development. DA is credited with numerous innovations in clean technology and delivery systems that help create sustainable livelihoods in the developing world. DA focuses on empowering communities through strengthening people's institutions and facilitating their access to basic needs. It enables economic opportunities through skill development for green jobs and enterprise creation and promotes greener pathways for development through natural resource management models and clean technology solutions. DA delivers environment friendly and economically viable eco-solutions to communities, entrepreneurs, government and corporate agencies through measures that foster the creation of sustainable livelihoods in large numbers. Development Alternatives drives strategic change through Innovation of eco solutions, Incubation of enterprise-based business approaches, demonstration and capacity building for Implementation of solutions at scale and the Influence of policies for sustainable development. For more information (https://www.devalt.org/)

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Basque Centre for Climate Change (BC^3) is a research centre on the causes and consequences of climate change. BC^3 produces multi disciplinary knowledge to support decision making towards sustainable development at the international level. With a multi disciplinary team, connected to the main scientific institutions, networks and socio-economic agents, for a decade, BC^3's contribution to research of climate change and to the science-policy interface puts a unique position to offer knowledge, tools, new methodologies and cross-cutting proposals, that lead towards action in a collaborative framework with stakeholders, to design and help implement policies aimed at sustainable development. For more information (https://www.bc3research.org/)

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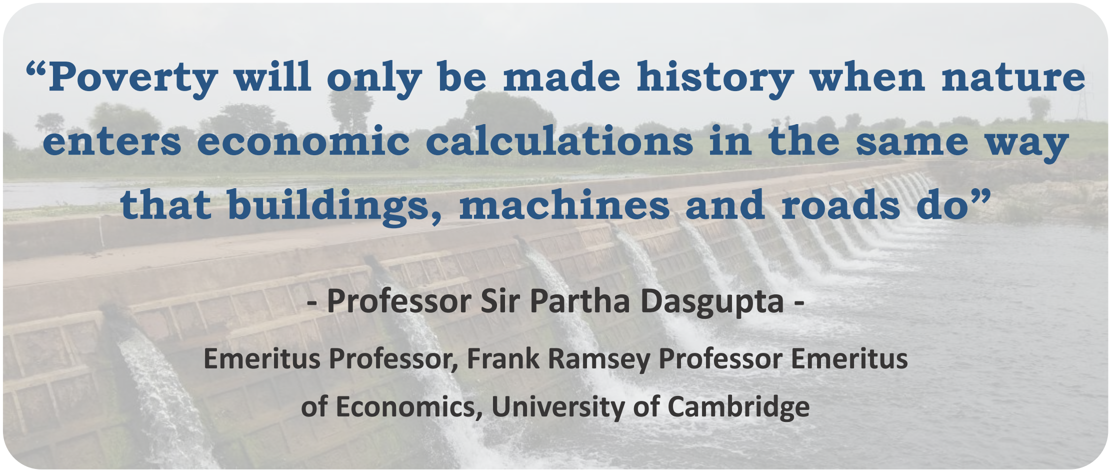

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Contents

List of Abbreviations

AGB	-	Above Ground Biomass
ARMA	-	Auto-Regressive Moving Average
BC3	-	Basque Centre for Climate Change
BGB	-	Below Ground Biomass
BMZ	-	German Federal Ministry for Economic Cooperation and Development
CBD	-	Convention on Biological Diversity
CSE	-	Centre for Science and Environment
COPD	-	Chronic obstructive pulmonary disease
CMR	-	Child Mortality Rate
DA	-	Development Alternatives
EC	-	European Commission
EDS	-	Ecosystem disservices
ELD	-	Economics of Land Degradation
EPCO	-	The Environmental Planning & Coordination Organisation
ESA	-	The European Space Agency
ESPA	-	The Ecosystem Services for Poverty Alleviation
ESZs	-	Ecologically Sensitive Zones
FPO	-	Farmers Producer Organizations
FAO	-	Food and Agriculture Organization
FGD	-	Focus Group Discussion
FFQI	-	Forest Fragmentation Quality Index
FSI	-	Forest Survey of India
GDP	-	Gross Domestic Product
GCP	-	Ground-control point
GHG	-	Greenhouse Gas Emissions
GIS	-	Geographical Information Systems
GIZ	-	Deutsche Gesellschaft für Internationale Zusammenarbeit
IPCC	-	Intergovernmental panel on climate change
IPBES	-	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IRR	-	Internal rate of Return
INVEST	-	Integrated Valuation of Ecosystem Services and Tradeoffs
IUCN	-	International Union for Conservation of Nature
LDN	-	Land Degradation Neutrality
LPG	-	Liquefied petroleum gas
LULC	-	Land Use and Land Cover
MDA	-	Mean Decrease in Accuracy
MEA	-	Millennium Ecosystem Assessment
MMR	-	Maternal Mortality Rate
MSA	-	Mean Species Abundance
NDCs	-	Nationally Determined Contributions
NDVI	-	Normalized difference vegetation index
NIR	-	Near-Infrared
NPV	-	Net present value
NTFP	-	Non-timber forest products
PRA	-	Participatory Rural Appraisal
RUSLE	-	Revised Universal Soil Loss Equation
SEI	-	Simulated Environments Inc.
SOC	-	Soil Organic Carbon
SLM	-	Sustainable Land Management
SWAT	-	Soil and Water Assessment Tool
SDG	-	Sustainable Development Goal
SHG	-	Self Help Group
SEEA	-	System of Environmental-Economic Accounting
TERI	-	The Energy and Resources Institute
UNCCD	-	United Nations Convention on Combating Desertification
UNEP	-	United Nations Environment Programme
UNFCCC	-	United Nations Framework Convention on Climate Change
USGS	-	United States Geological Survey
USD	-	United States Dollar
USLE	-	Universal Soil Loss Equation

Executive Summary

Land degradation causes loss of biodiversity and productivity of a particular land. It affects the entire natural environment through disruption in the ecological processes and has far reaching effects on human welfare and the economy of a country through decline in supply of vital ecosystem services. Several land and water based interventions have been made by the Development Alternatives Group through different programmes for land remediation in the semi-arid, erratic rainfall prone and economically backward Bundelkhand region of Madhya Pradesh, India. This study examined the costs and benefits of the implemented programmes by applying ELD methodology in three districts of Bundelkhand viz Datia, Shivpuri and Niwari by considering both intervention and control villages. The assessments looked into natural, social and human capital based on multiple indicators. The outcomes were obtained through quantitative and qualitative analysis of primary survey data and applications of GIS tools and models using satellite data. The findings of the study highlighted the differences in performances of different forms of capitals across intervention and control villages for the selected time period (2013- 2018). The findings reflected that land use changes have taken place in the study area during this period. Major improvements in agriculture were reported. The cultivated area increased in the study site along with increased practices of double and multi-cropping. Better access to irrigation facilities in the intervention villages, as result of the interventions, was found to be one of the major driving factors for this change. Gains in livestock benefits were observed in several intervention villages. Positive changes in other ecosystem services also took place. Changes in species abundance and carbon sequestration were also observed through quantitative assessment. Derivation of the overall rate of return (Intrinsic Rate of Return) of the interventions turned out to be 74% and 191% and 78% in Datia, Shivpuri and Niwari respectively. Apart from that, in terms of social, human and cultural capital differences between intervention and control villages were also identified through quantitative and qualitative assessments. Along with that, some of the prevalent factors associated with the differences in benefits were highlighted. Finally, the benefits created through these interventions have been mapped against the SDG framework to analyse the contribution to the national and global SDG indicators. The interventions and outcomes were found to have addressed seven SDGs and fifteen national targets. A toolkit for ecosystem valuation using the adopted methodology was developed for possible replication of the study by the research community and for policy decision making. The study also came up with the relevant policy recommendations that could be conducive for informed decision making at both micro and macro level.

Introduction 1

Land degradation currently affects 1.3 billion people worldwide directly and poses a threat to 3.2 billion more (Thiaw, 2019). For a long time, it was assumed that the damaged land would heal with time if left alone, however, this has failed to turn into reality for several years now. Worldwide, and especially in the developing countries, climate scientists believe us to be in a "positive feedback loop" (Bhushan, 2019) where drastic climate change is causing desertification, heading towards major destruction with only one solution, to meet the 1.5°C target.

The chair of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Sir Robert Watson, establishes that "land degradation, biodiversity loss, and climate change are three different faces of the same central challenge: the increasingly dangerous impact of our choices on the health of our natural environment,". Comprising a total of 2.4% of the world's land, 96.4 million hectares of land in India are undergoing land degradation while is already another 83 million hectares are undergoing desertification, adding up to which means about 30% of its land area (CSE, 2019) witnessing declining productivity. This loss is not only threatening the dependence on agriculture for livelihoods and food security of the entire population but also carbon sequestration and the existence of biodiversity in the country. In this context, it becomes imperative to adopt climate change adaptation measures. Owing to the inevitable process of climate change, strategies to build resilience for ecosystems will not only lower the risks posed by the climate but also contribute to enhance livelihoods, secure our food and water as well as promote equity. In the present scenario, climate change adaptation has become as important as mitigation especially since the livelihood of 60% of the country depends on agriculture.

Leading factors responsible for land degradation in India are water erosion, vegetation degradation and wind erosion (Issaka & Ashraf, 2017) (Kurrey, Singh, & Rajput, 2016). Many of the global studies(FAO, 2011)(Olsson, 2019) have also pointed towards high use of chemicals, incorrect farming practices (shifting cultivation, intensive irrigation, unsustainable farming, etc.) and unsustainable use of land (overgrazing, clearing of forests, conversion to agricultural lands, etc.) for adding to the desertification increase. Recent research (Olsson, 2019)was undertaken by IPCC to find the implications of land degradation and climate change. The IPCC Special Report 2019 on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, revealed that 23% of India's GHG emissions are due to human activities with over 1.6 million hectares of forest land lost and more than 500 developmental projects that have cleared the protected areas and ESZs in 2018 (IPCC,2019).Although a target of 33% forest cover(Gooljar,2017) and 26 mHa of degraded land restoration (Business standard, 2019)by 2030was pledged by India in COP21so far for the year 2019, the cover remains at 24% (Business Line, 2019). This has not only deprived the country of 1.4% of its GDP in terms of forest services (collection of medicinal plants, fuel wood, food, construction materials, timber production, etc.)but has also affected the economy and incurred soil erosion losses of Rs. 72,000 crore ($10.68 billion). Apart from that, being the 17th most water-stressed country in the world, land degradation in India is not only going to affect its rainfall pattern but also increase the frequency of occurrence of natural calamities like droughts and floods (Kumar,2019). These in turn further aggravate the intensity of the issue of land degradation by creating a vicious cycle.

The desertification process is in process of becoming a serious, expensive problem. Since, land is one of the vital resources for the existence of all living beings, land deterioration at the ground level will severely affect all ecosystem processes and would lead to decline in human and social well-being. The ecosystems provide provisioning, regulating, supporting and cultural / recreational services to the human society (Millennium Ecosystem Assessment, 2005). Globally, land degradation is jeopardizing their functioning thereby causing events in the form of ecosystem disservices (EDS) such as pest infestation, droughts, river flooding, etc. (Falk, et al., 2017). In developing countries such as India, the rural majority is majorly dependent on provisioning services in the form of agricultural and forest products, clean air, fuel, fresh water and natural medicinal remedy. Regulating services for the poor and marginal are more relatable in the form of climate regulation, pest and disease regulation while supporting and cultural/ recreational services are more seen in the form of soil support, habitat support for species, maintenance of genetic diversity, tourism in natural areas like forests, water bodies, morning walks and worshiping the sacred plants (TEEB,2018). The rural population is constitutes a major proportion of population in India's (69%) dry lands (Stenberg, 2018) comprising of dry sub-humid, semi-arid and arid regions. Wide spread rise in environmental degradation is resulting in higher land replacement costs and affecting the poor and marginal communities to a large extent (Reddy, 2003). For sustainable management of land and other environmental resources, it is vital to adopt bottom-up approaches (Narain, 2019). To achieve the sustainability it is vital to conserve the natural, social and cultural capitals through participatory way. It is also an urgent mandate to assess whether the followed approaches and implemented programmes are working effectively or not.

The following sections of this chapter described the study area and its link to global goals, objectives, rationale and scope of the study.

1.1 The study area, its interventions and link with the global goals

1.1.1 Study Area

The Bundelkhand region (getting its name from the Bundela Rajputs who ruled in the 16th century) is located between the Indo-Gangetic Plain to the north and the Vindhya Mountains to the south comprising of 13 districts- six in the state of Madhya Pradesh (MP) and seven in the state of Uttar Pradesh (UP) (SANDRP,2018). The region had a culturally rich history and famed temples and once there were fertile soils, juxtaposed forests, perennial rivers and streams. These have turned slowly into a desertified region with unsustainable use of natural resources and the change in climatic pattern. Now it is a semi-arid mainly rainfed region, which has undulating topography and shallow soils- red and black being saline and porous with only an average rainfall of 750 mm and is suffering from recurrent droughts (Development Alternatives, 2001). It is highly vulnerable to spatial and temporal climate variability of rainfall, and to extreme temperatures exhibiting intense solar radiation in the daytime. The rains are erratic and often come in a few heavy storms of short duration resulting in high run-off, instead of replenishing the ground water.

Ten out of 13 districts are classified as backward[1] in the Bundelkhand region and 70 % of the population is rural. Its economy is largely agrarian with agriculture, livestock rearing and labour work as major sources of livelihood Bhatt & Shaikh, 2011). In the early decades,

[1]Backward districts within a State has been made on the basis of an index of backwardness comprising three parameters with equal weights to each: (i) value of output per agricultural worker; (ii) agriculture wage rate; and (iii) percentage of SC/ST population of the districts (Planning Commission, Govt. of India, 2003)

major dependence was also on forest products especially for fuelwood which has now immensely reduced due to reduction in the forest cover, introduction of technology, creation of alternative livelihoods as well as change in market demand.

Poverty is one of the predominant socio-economic conditions as a result of which young children have been suffering from serious malnourishment. Farmer suicides due to indebtedness and starvation deaths are other serious concerns in the region as there is lack of irrigation facilities to support the agricultural productivity (DA, EPCO, SEI, 2007). Some of the factors resulting in indebtedness of the farming community include lack of stable income, lack of access to financial aid, among others. Seasonal migration for work, extreme forms of malnourishment, small and/or marginal land holdings, insecurity of stable income, limited access to technologies, lack of industrial development and a decent livelihood are some of the key developmental challenges faced by the region.

The increasing levels of poverty and land degradation led to the initiation of several interventions by Development Alternatives group. The works (Development Alternatives, 2019)revolved around land and water management and afforestation after which clean technology- based livelihood options, capacity building of local institutions, enabling communities to access basic needs of drinking water sanitation, shelter and energy were supported through enterprise development and skill-building for job creation. Although the interventions have been done in many districts of Bundelkhand the precedence in this study was on Niwari, Datia and Shivpuri districts (Figure 1) where the majority of programmes were implemented.

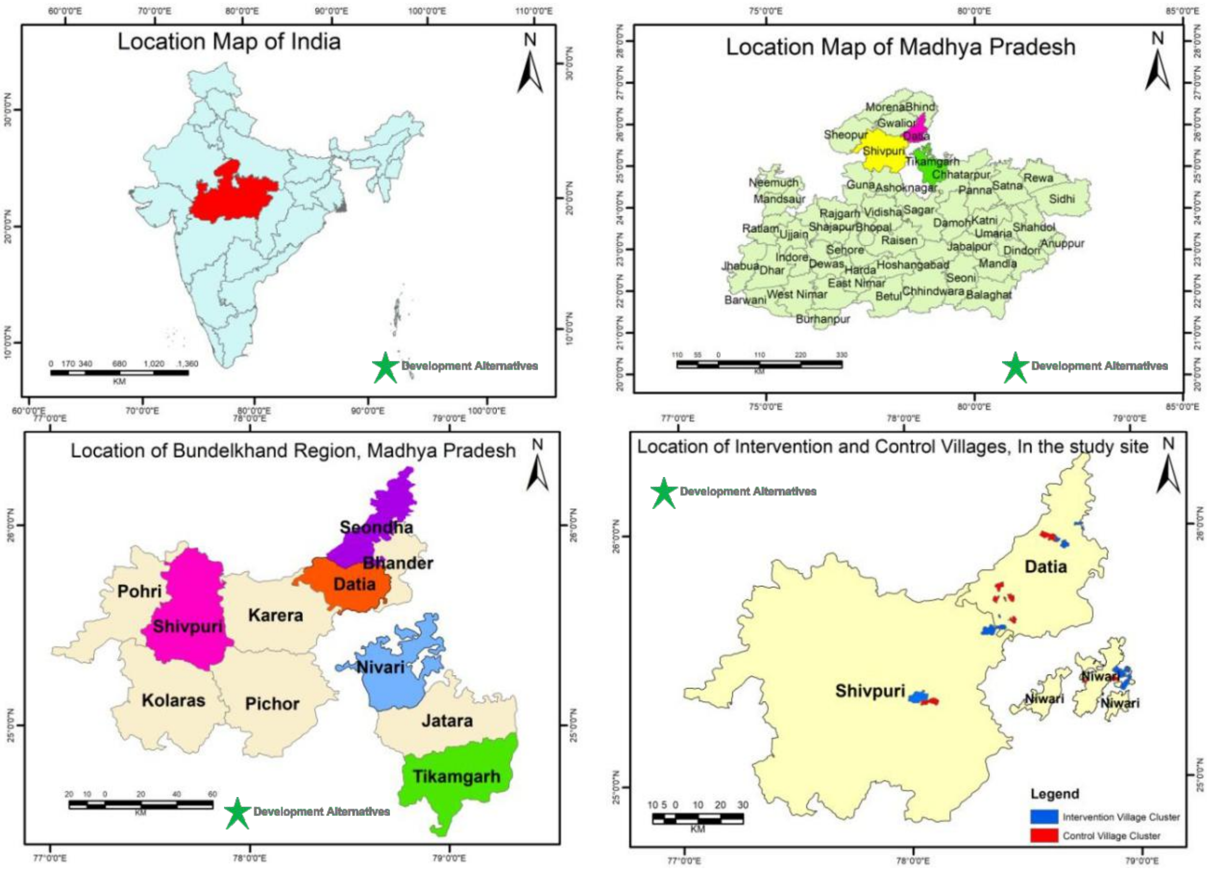


Figure 1: Study Area in Bundelkhand region of Madhya Pradesh, India

1.1.2 Land Remediation Initiatives Undertaken by DA group

In 1985, DA started its interventions all over the Bundelkhand region to transform the lives of communities and the environmental situation in the area. Taking the support of local governments, national and international sources the initiatives aimed at bringing about capacity and confidence of people for independent problem solving. More specifically the land remediation initiatives ranged from establishing water harvesting and erosion control structures as well as promoting sustainable agricultural practices while other initiatives aimed at creating Self Help Groups, Food Producing Organizations and building enterprise ecosystems in the area(Development Alternatives, 2019).

The three districts (Datia, Shivpuri and Niwari) of Bundelkhand on which the study focuses are areas falling under the rural region with major reliance on agriculture for a living. The areas experience high temperatures and recurrent periods of droughts with high relative humidity during the monsoon. Communities from the villages mainly depend on groundwater for irrigation and for drinking water but other small tanks, dams, canals and rivers are also present on which dependence is less due to problems of drying up(Development Alternatives, 2015). To overcome this, soil and water conservation structures like watersheds, check-dams, tanks, ponds, field bunding, gabions and gully plugs were researched and established. To ensure smooth management and monitoring, watershed committees were formed and trained in each village comprising of farmers, panchayat members, women as well as marginalized groups. Additionally, promotion of sustainable agricultural practices and livestock rearing for sale was carried out within the specific villages of the districts. Farmer clubs and women SHGs were created with the help of DA's experts who trained the locals on improving agricultural practices, off-farm and non-farm income generation activities, adopting climate adaptation methods and improving agricultural production. These trainings and promotions included but were not limited to distribution of good quality drought resistant seeds and organic manure for different vegetables and cash crops, vegetable cultivation, training on switching from monocrop to double crop/inter-crop/multi-tiered cultivation, supporting the family through enterprise development such as poultry farming, market production of seed , manure, etc. as well as solar based energy generation, training on vermi-composting, among others(Development Alternatives, 2016).

Figure 2: Land Remediation initiatives taken by DA: (A) Construction of watershed structures (B) Promotion of sustainable farming and (C) Capacity building

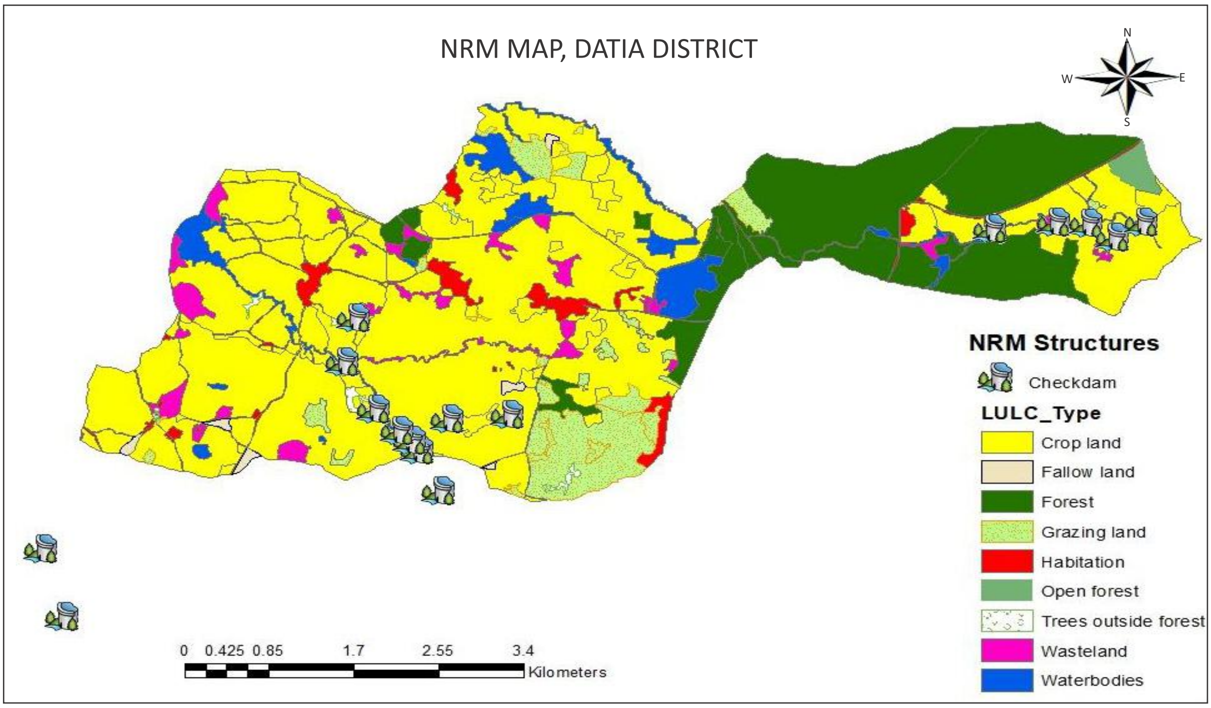


Figure 3: Natural Resource Management (NRM) structures in Datia district

Source: Prepared by the project team of Development Alternatives

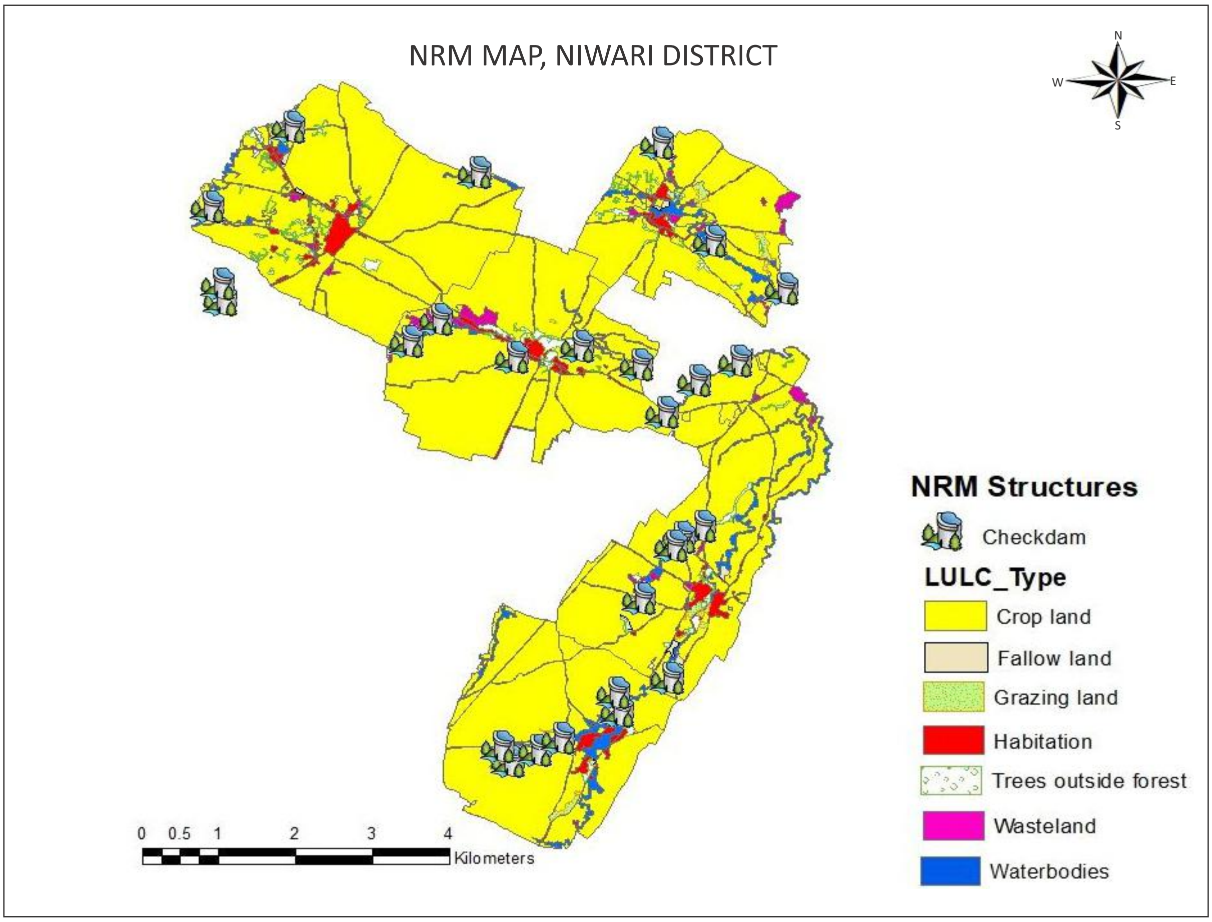


Figure 4: Natural Resource Management (NRM) structures in Niwari district

Source: Prepared by the project team of Development Alternatives

The soil and water conservation structures were created (NRM structures of Datia and Niwari district are shown in Figure 3 and Figure 4) in the villages through rigorous months of participatory and net planning approaches with the locals for the purpose of harvesting water in monsoon season, groundwater recharge as well as controlling the increasing problem of soil erosion. Not only this, technical experts also provided aid in the wells requiring boring for proper utilization of water (Development Alternatives, 2016). Around the years 2011-2013, these Integrated Watershed Management programmes and promotion of sustainable agricultural practices started in the three districts. Through the interventions[2] undertaken by DA, atleast 100 soil and water conservation structures were established over 200 villages in Niwari, Shivpuri and Datia districts.

1.1.3 Link with the Global Goals

India is a party to many international agreements and global goals in an effort to combat climate change, conserve biodiversity, improve the health of land as well as achieve sustainability. India has been emerging as one of the countries dedicated to beating the climate crisis; it was one of the earliest to ratify the UNFCCC. The country declared its Nationally Determined Contributions (NDCs) for 2030 as a commitment to the international agreement and more specifically the Paris Agreement (TERI, 2018). The impacts interventions made by DA therefore, contributed to many of the country's global commitments and achieving national targets on various aspects. The economic evaluation of the land remediation measures undertaken in the last decade was conducted through this study. This study revealed that the remediation activities addressed India's SDGs 1, 2, 6, 13 and 15 (UNDP) in a large extent. SDGs 1 and 2 target poverty and hunger which were addressed by the study by showing the changes in agricultural productivity and household income. This study also looked at SDGs 6,13 and 15 through the developmental programmes that were undertaken for water resource management in the agriculture fields, in climate adaptation in vulnerable sectors such as agriculture and water, thereby protecting the terrestrial ecosystems which helped in reducing the

[2] A brief overview of the interventions done by Development Alternatives is given in the Appendix

process of land desertification and halting the loss of biodiversity. Not only this, it also addressed SDG 17 by involving national as well as international stakeholders for partnering towards sustainable development, therefore, strengthening and revitalizing partnerships. Applying the approach of land and water management over the course of 36 years, this study also supported India's recent commitment to UNCCD's Land Degradation Neutrality (LDN) target of rehabilitating 26 m Ha of degraded agricultural land (UNCCD,2019) to halt the process of land desertification. Last but not the least, the interventions undertaken and the scope of the study were also expected to satisfy India's ratification of the Convention of Biological Diversity (CBD) by addressing National Biodiversity Targets 1, 2, 3, 5, 8 and 9 (NBT,2012-2020) for India through management of major natural resources as well as conservation of ecosystems and its services.

This study, therefore, attempted to inter-link its methodology and results with India's commitment to the several international agreements as well as the global goals. A detailed assessment of these commitments study has been done and described in a separate chapter.

1.2 Rationale

Land degradation is a major result of the poor choices made in terms of management of natural resources. Restoration and identification of the better options for restoration has become extremely important. The rationale of the study emanates from the fact that it is increasingly important to evaluate how the land remediation options have performed at the local level to prove their cost effectiveness. Since the semi-arid region of Bundelkhand is one of the most affected areas of India in terms of land degradation therefore, this study has been undertaken to help evaluate and raise awareness about the cost effectiveness of land remediation for climate change adaptation. The present study aimed to bridge the gap between macro-level assessment and micro-level assessment by also linking the global goals and the results showed that the micro level assessment is equally important to realize that the micro level initiatives on land can contribute to enhance the natural and social capital of the country and help to achieve the global commitments.

1.3 Objectives of the study

The scope of the study explored but is not limited to economic evaluation of land remediation options as a cost effective measure for climate change adaptation for people and for the environment. Within this ecological economics study, natural capital, social capital and environment impacts were considered for a range of the ecosystem services. The study also attempted to understand the association of people with nature, therefore, addressing the cultural capital. Additionally, the study intended that it will be used and replicated into other geographies locally as well as globally.

The specific objectives of the project "Economics of Land Degradation: Evaluating the Impact of Land Remediation through the lenses of natural capital and SDGs in the Bundelkhand region in Madhya Pradesh, India" were:

- To evaluate the potential of land remediation activities as a beneficial and cost effective measure for combating desertification.
- To develop a toolkit for assessment of similar land remediation programmes under similar environmental and socio-economic conditions.
- To evaluate changes in SDG indicator values as a result of the reduction in land degradation.

Research Methodology

2

2.1 Research Framework

To accomplish the above mentioned objectives of the study, both qualitative and quantitative research methodologies have been adopted. The research framework combined the application of the ELD methodology along with a capitals approach.

The ELD methodology was developed through the Economics of Land Degradation (ELD) Initiative[3], whichstarted in 2012 by the Secretariat of the United Nations Convention to Combat Desertification (UNCCD), the German Federal Ministry for Economic Cooperation and Development (BMZ), the European Commission (EC) and hosted by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. It works at the science-policy interface and aims at transforming the global understanding of the economic value of productive land and fostering stakeholder awareness of socio-economic arguments to promote sustainable land management. The ELD Initiative developed a 6+1 step framework for assessing the impacts of land degradation through an ecosystem service approach. This ELD methodology has been adopted in this study to assess the impact of land remediation interventions to deal with land degradation in the study site.

The steps of the ELD 6+1 step approach[4] are:

- Step 1: The identification of the scope, location, spatial scale, and strategic focus of the ecosystem services valuation, based on stakeholder consultations and the preparation of background materials on the socio-economic and environmental context of the assessment.
- Step 2: The assessment of the quantity, spatial distribution and ecological characteristics of land cover types, categorized into agro-ecological zones and analyzed through the use of Geographical Information Systems (GIS)
- Step 3: The analysis of ecosystem services based on the four ecosystem service categories viz., provisioning, regulating, cultural and supporting services for each land cover category (details are provided by the Millennium Ecosystem Assessment, 2005)

[3] https://www.eld-initiative.org/en/who-we-are/about-eld/

[4] 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

- Step 4: The role of the assessed ecosystem services in the livelihoods of communities living in a previously delineated land cover area, and for the overall economic development in the study zone
- Step 5: The identification of land degradation patterns and pressures on the sustainable management of land resources, including their spatial distribution and the assessment of both biophysical and socio-economic drivers of degradation
- Step 6: The assessment of sustainable land management options that have the potential to reduce or remove degradation pressures, including the analysis of their economic viability and the identification of the locations for which they are suitable.

Step +1: *Policy making and adoption of practices*- Policy-orientated results build the core of the ELD approach. This is clearly reflected in the final step that aims to support the actual implementation of the most economically desirable options by private actors and public decision-makers.

Along with applying the ELD approach, the study has been conducted and tracked using the capitals approach within an SDG framework as described below.

Any kind of land remediation program has a range of co-benefits. People dependent on the land for a living will have higher incomes, reducing the chances of them being classified as poor. They will also be less likely to face hunger, especially in places where food consumption is mainly tied to own production.

An evaluation of the program can be made by matching these benefits relative to the investment required to remediate the land. Conventional cost benefit analysis such that outlined in the ELD approach would simply compare the investment costs against the flow of increased benefits that can be measured in monetary terms, taking account of any price distortions due to subsidies and taxes in the prices of inputs and outputs. Where farm outputs were not sold in markets an implicit market price have been used and where labour on the project were previously underemployed, this were taken into account by applying a "shadow wage" to it in the calculations of costs and benefits. Other non-monetary benefits such as reduced hunger and poverty were not valued but were given consideration in the overall assessment of the benefits of the program.

Under a capital approach, land with differing degrees of degradation has different values as a form of natural capital. The program can then also be seen as increasing the stock of that capital, but by taking resources that could otherwise be used to add to the stock of physical capital. Thus the program increasedone stock of capital at the expense of another. In addition, the remediation program also increased the stock of human capital (better fed people are more productive and high employment increases the value of human capital) and the stock of social capital (where there is less poverty, people were able to interact more and participate in social institutions). These changes were also valued in money terms (except social capital) and the net changes in different forms of capital compared.

The capital approach has some advantages. One is that, it deals with restoration of a key form of capital – natural capital – that has a unique function in the ecological-economic system. It has been argued, for example, that loss of some forms of natural capital cannot be compensated for by an increase in physical capital and that at least some of the SDGs seek to ensure that a given stock of natural capital is maintained. The capital method allowedus to calculate the cost of increasing the stock of natural capital to meet a given SDG target and to choose between alternative programs that remediate a given stock of degraded land. Second, the so-called ancillary benefits of remediation were also converted into an increase in a form of capital and the program evaluated holistically, taking account of changes in physical, natural, human and social capital.

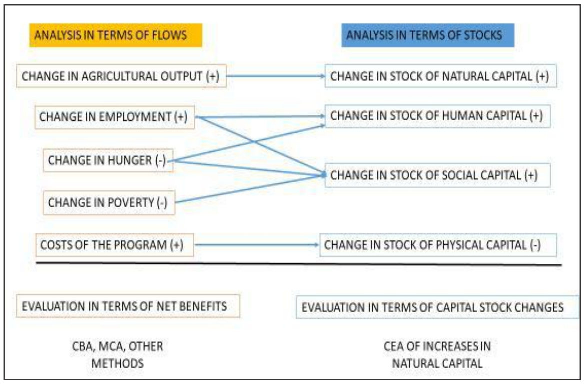


Figure 5: Capital approach

The Figure 5 above lays out the two approaches and how they are linked to one another.

Following the discussed research framework, qualitative and quantitative analysis of the primary and secondary data was performed using various tools and techniques. These are discussed in the subsequent sections.

2.2 Data: Primary and Secondary

Primary data collection was done through interaction with local communities of Bundelkhand, communication with internal field staff and government departments of the three districts. The primary survey was conducted in the identified locations using the Participatory Rural Appraisal (PRA) approach. IUCN ecosystem services assessment tool, Remote sensing and Geographical Information System (GIS) were applied for identifying ecosystem services and their evaluation.

Secondary sources of data collection were done through reviewing online literature on land degradation, ecosystem services; studies of the ELD Initiative in other countries and use of the InVEST (Integrated Valuation of Ecosystem Services and Trade Offs) model subtypes in different regions all over the world. Secondary literature was consulted for collection of specific regional data (Asia, India as well

Figure 6: Collection of primary data through household interview and Focused Group Discussion by the project team

Madhya Pradesh) for running the InVEST model subtypes.

The major GIS datasets used were:

Sentinel- 2A MSI (10 m spatial resolution) and Landsat 8 OLI (30 m spatial resolution), the main source of these images was ESA and USGS.

- ArcGIS 10.7 and Erdas Imagine 16 were used.
- Ground truth points were taken as a reference.
- DEM data from Cartosat.

In this study, satellite data was acquired by two different sensors, Sentinel-2A MSI (S2) and Landsat 8 OLI (L8), to determine crop cover types. L8 satellite provides eight spectral bands with a spatial resolution of 30 m and one panchromatic band with a resolution of 15 m and a repeat overpass every 16 days.

The European Sentinel-2A, (launched in June 2015) was also used in the study.Sentinel-2A MSI (S2) carries the Multispectral Instrument (MSI) which has spectral response functions quite different compared to its predecessor with 13 spectral bands and three different spatial resolution as well as 10 days between revisiting time.

To analyze the dynamics of vegetation in the study areas, a time series of 6 months suitable images with less than 20% cloud cover from each sensor (L8 and S2) were acquired respectively via the United States Geological Survey (USGS) on-demand interface (ESPA). The L8 acquired images were already atmospherically corrected (level 2A) by the Landsat Surface Reflectance Code algorithm, from which NDVI index can be derived and downloaded as a single band product. Then NDVI layers were generated for each image using red and near-infrared spectral bands according to the following equation.

$$NDVI = \frac{(NIR-RED)}{(NIR+RED)}$$

Where, NIR and RED are the reflectance measured in the near-infrared and red bands for each pixel, respectively.

2.3 Tools and Techniques of Data Collection

For the purpose of this study, household level information was collected through individual household interviews and information on human, natural and social capital was collected through focused group discussions. 30 villages in Bundelkhand within the chosen three districts (i.e. Niwari, Datia and Shivpuri) (Table 1) were identified for the assessment. A total of 18 villages, which have received the benefits in a group rather than individually with regard to land remediation and improvement in social capital from DA, have been selected as intervention villages from Niwari, Datia and Shivpuri districts. In addition, a total of 12 villages have been selected as control villages based on the following parameters:

- Easily accessible through transport
- No derived benefits through works from the government or any other agencies in the years 2013-2018
- Similar land use as intervention villages
- A buffer distance from intervention villages of minimum 8 km extending till 15 km so that there is no benefit sharing among the villages

Table 1: Intervention and Control Villages in the study site

Sl No	Intervention Villages	Block	District	Number of Households	Population	Number of sampled households
1	Salayapamar	Datia	Datia	347	1674	10
2	Pathari	Datia	Datia	323	1447	10
3	Kamhar	Datia	Datia	183	834	10
4	Chopra	Datia	Datia	87	429	10
5	Govindnagar	Datia	Datia	72	339	10
6	Kherona	Seondha	Datia	200	920	10
7	Kheridevta	Seondha	Datia	92	479	10
8	Jauri	Bhander	Datia	172	1048	10
9	Parsoda Goojar	Seondha	Datia	426	1991	10
10	Parsonda Baman	Seondha	Datia	175	958	10
11	Manpura	Pichhore	Shivpuri	987	4650	10
12	Dulhai	Pichhore	Shivpuri	512	2389	10
13	Piproniya	Pichhore	Shivpuri	82	338	10
14	Uboura	Orchha	Niwari	877	3998	10
15	Patharam	Orchha	Niwari	558	2618	10
16	Chachawali	Orchha	Niwari	329	1815	10
17	Dhamna	Orchha	Niwari	501	2684	10
18	Bamhori Sheetal	Orchha	Niwari	315	1674	10
			Total	**6238**	**30285**	**180**

Source: Primary survey through field visits and secondary data from Census of India, 2011, Govt.of India

Table 2: Population and sampling information of Control Villages in the study site

Sl no.	Control Village	Block	District	Number of Households	Population	Number of sampled households
1	Sarol	Datia	Datia	324	1477	10
2	Sonagir	Datia	Datia	445	2201	10
3	Samroli	Datia	Datia	45	227	10
4	Bijapur	Datia	Datia	46	291	10
5	Ramnagar	Datia	Datia	97	444	10
6	Kudari	seondha	Datia	658	3170	10
7	Senthri	Seondha	Datia	541	2957	10
8	Uprain	Datia	Datia	614	2576	10
9	Bonti	Pichhore	Shivpuri	1213	6083	10
10	Nandna	Pichhore	Shivpuri	251	1257	10
11	Taricharkalan	Orchha	Niwar	645	7674	10
12	Baman Naiguan	Orchha	Niwari	84	370	10
			Total	**4963**	**28727**	**120**

Source: Primary survey through field visits and secondary data from Census of India, 2011, Govt. of India

This study used the purposive-quota non probability sampling technique to select sample size of 300 households in the identified villages (Table 1 and Table 2). Figure 7 describes the elaborate representation of the sampling technique used.

The study attempted to compare the difference between intervention and control villages with respect to human capital, natural capital as well as social capital which were taken as the study's horizontal scale of comparison. Along with the horizontal scale, a vertical scale of comparison between the years 2013 and 2018 was undertaken to ascertain the results of the study. IUCN´s ecosystem assessment tool and structured questionnaires[5] were administered to

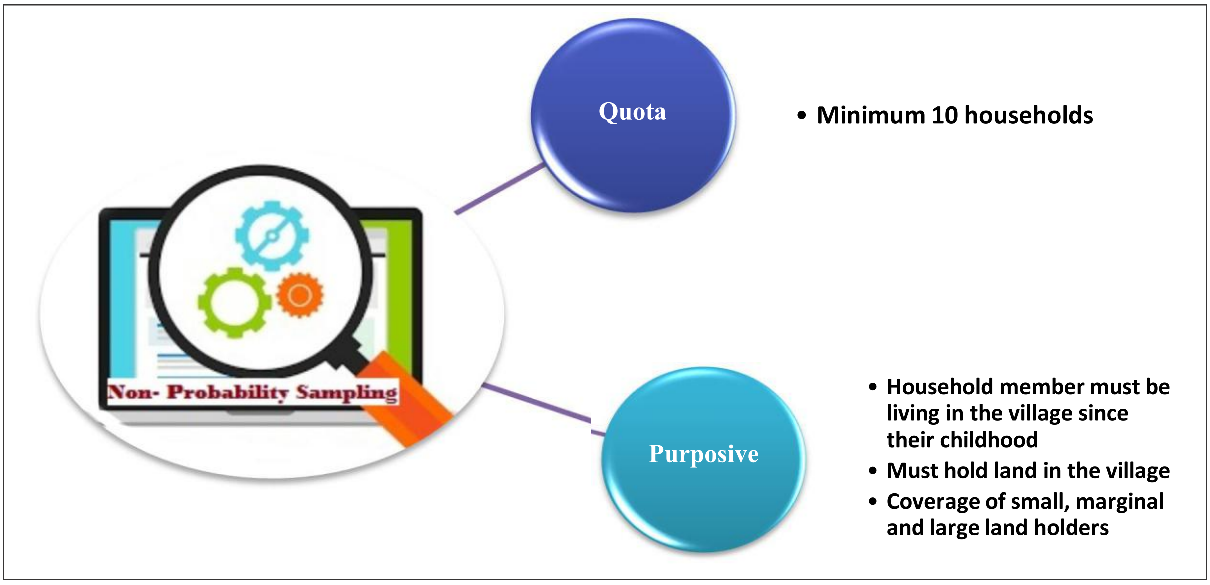


Figure 7: Visual representation of use of non-probability sampling in the study

[5] Household interview and focus group discussion questionnaires are attached in Appendix

collect more detailed information. Bundelkhand team of DA and Madhya Pradesh State government departments (viz.,Krishi Vigyan Kendra (KVK), Public Health Engineering Department (PHED), District Collectorate (Datia and Shivpuri), Agriculture Department, Forest Department) were consulted through semi-structured questionnaires[6]. The open sourced subtypes of InVEST software have also been utilized to analyze the benefits received from the different ecosystem services in the study areas.

2.4 Data Analysis Methods

Both qualitative and quantitative data analysis methods was used to assess community perception of ecosystem services, human, social and natural capital and performing cost benefit analysis of interventions done by DA in the study site.

To assess the monetary benefits generated by the ecosystem services, the major ecosystem service categories were selected through literature review. A perception study also carried out to document the understanding of the communities about the ecosystem services. The four broad ecosystem service categories taken for the study were provisioning, regulating, supporting and recreational/ cultural services(IUCN, 2007); (UNEP, 2006). In the study the quantitative evaluation was carried out mostly for provisioning ecosystem services of different land use categories. Apart from that, assessment of some specific ecosystem services (e.g. carbon sequestration and species abundance) under regulating and supporting services were also done. However, since supporting ecosystem services are considered to be necessary for perpetuation of rest of the ecosystem service flows, therefore, assessment of the other three ecosystem service categories indirectly incorporated assessment of components of supporting services. Quantitative assessment of the cultural ecosystem services was beyond the scope of this study.

A detailed indicative list of ecosystem services (based on the IUCN ecosystem assessment tool (2007) under the four broad ecosystem service categories is given in the appendix. In the following Table 2, the eco system services that were identified in the study site for this assessment are shown.

2.4.1 Data analysis using primary survey data

The primary data collected from the intervention and control villages over the three districts were analysed to assess the changes in human, social and natural capital benefits in the study site during 2013- 2018. Several parameters were used for this assessment.

Table 3: Ecosystem Services assessed in the study site

Ecosystem Service categories	Ecosystem Services	Parameters assessed in the study
Provisioning services	Crop production	Yield of crops
	Fodder	Produced and purchased fodder
	Water	No. of irrigation sources
		No. times irrigation in a year
	Timber and NTFPs	Collection of fuelwood
		Collection of medicinal plants and other eatables from forests
Regulatory services	Carbon	Below and above ground carbon, soil carbon
Supporting services	Soil formation	Soil health[7]
	Maintaining genetic diversity	Mean species abundance (MSA)
Cultural Services	Cultural practices and knowledge system	Qualitative assessment of cultural capital through case study

Source: Prepared based on the IUCN ecosystem assessment tool (2007) through stakeholder and expert consultation

[6] Attached in Appendix
[7] Soil quality assessment for some of the intervention and control villages was done in only Datia district.

Human and Social Capital

In this study, the assessment of "human capital" (Vemuri and Costanza 2006) was measured by evaluating the benefits received by the local people in the intervention villages. The human capital was enhanced by improvements in overall health, education, skills and knowledge of the society. These improvements happened due to the increased access to various ecosystem services through the land remediation activities in these villages which had immense potential impact on the livelihood of the beneficiaries.

Since people living in the rural Bundelkhand region depended mainly on agriculture, forest produce and animal husbandry for food and livelihoods, the parameters under this capital include monetary benefits from production from crops, livestock and fodder and produce from the nearby forests. Additionally, cost benefit analysis was undertaken to understand the benefits perceived by the intervention in comparison to the cost incurred towards making them better through the last five years. The estimation of net output from the human capital was then tracked against the India specific SDG Framework to evaluate their contribution to achieve the sustainable development goals.

"Social capital" is a multidimensional concept and has been recognized as crucial to development. It refers to the trust and bond shared by people. When a community group viz., Farmer Producer Organizations(FPOs) orSelf Help Group (SHGs) is formed, the existing social ties among different actors in a social network are strengthened augmenting the social capital. The members of SHGs or FPOs frequently meet for their regular activities(like collecting, selling or buying farm produces or seeds)which increases the interaction among the individuals' which also helps them to participate in community level problem solving more readily. According to Coleman(1988), social capitals not a single entity but a variety of different entities, with two elements in common and they all consist of some aspect of social structures, and they facilitate certain actions of actors within the structure. Here the concept of social capital is essentially explained by Coleman as a "set of elements that facilitate collective action".

Table 4: Indicator list for social and human capital

Indicators of Social and Human Capital	Sub-Indicators
Social Institutions	No. of people in each village in each social institution
Illness	total no. of people having illnesses
Education	• Percentage of population not educated • Average level of education (Female heads of family) • Average level of education (Male heads of family) • total no. of girls attending school
Migration	• no. of people completely residing outside of the village for work • no. of people seasonally migrating

Humans are greatly dependent on their associational life i.e. their relations with fellow human beings. This plays a crucial role in bringing the community together to collectively act towards solving local developmental problems.

In order to verify the change/augmentation in social capital in the study the following indicators were examined

- Causal effect of involvement in **Social Institutions**: With more social institutions in a village, the probability of individuals getting involved in the same increases. It is necessary to form these groups as they facilitate accumulation of social capital by increasing social dependence and interaction.
- Causal Effect of **Education**: According to Putnam (1995), Glaeser and Sacerdote (1999), and Alesina and Ferrara (2000), education is one of the most important determinants of social capital. Education reflects an orientation towards the future by strengthening human capital and social capital for economic and social development. Schooling spreads knowledge - the basic component of human capital, and cultivates social norms - the core of social capital.
- Causal effects of education differ by **Gender** on Social Capital
- Causal Effect of **Migration** on Social capital: Having a social tie to a current or former migrant dramatically increases the odds of emigration

(Massey et. Al, 1987) and could increase social capital. On the other hand, if the programs improve work opportunities in the villages the need to migrate will decline and offer the chance to strengthen relationships in the community.

- Causal Effect of **Illness** on Social capital – Studies that actually provided evidence that those who are restricted by chronic illnesses enjoy less informal social capital (Tijhuis et al., 1998; Kraaykamp, Oldenkamp, and Breedveld, 2013)

Social and Human Capital assessment was done using the following approach:

- Semi-structured questionnaire was administered for collecting information from Individual households and Focus Group Discussions (FGD) were conducted for collecting overall data from the villages
- In the following Table 3, the sub-indicators of the selected major indicators of social capital are given.

Natural Capital

The natural capital of a region is the stock of natural resources affecting all living organisms (Rajapaksa, Islam & Managi, 2017); (Costanza and Daly 1992). In this study, the emphasis is laid on analyzing few of the regulating, provisioning as well as supporting services of the Bundelkhand region as mentioned in Table 2. The methodologies of assessment of these ecosystem services are discussed in the following sections.

- Crop Production

  Suffering from the adversities of soil erosion and frequent droughts, the Bundelkhand region has been in a critical situation with respect to earning their livelihood from agriculture. Use of chemical fertilisers, excessive use ground water and uncontrolled use of mechanisation have been stripping the land of its properties. To understand the net income and difference in the production for the 30 villages targeted for the study, the following parameters have taken into consideration:

$$NVHC_h = \sum_{i} I\ \beta(i)Q(i)PB(i) + (1 - \beta(i))Q(i)PS(i) - C(i)$$

Equation 1: Mathematical equation for computation of net output from crop production

The total net value across all households in each area will be:

$$NV = \sum_{h} NVHC_h\ H(h)$$

Equation 2: Mathematical equation for estimating net value across all households in each area

Where H(h) is the number of hectares that household h farms. The average net value of crops will be ANV, which is:

$$ANV = \frac{NV}{\sum H(h)}$$

Equation 3: Average net value from crops

Time unit for the output will be per year, as there are two seasons.

- Total production of crop ´i´ per hectare: Q(I)
- Percent of the crop that is for self-consumption: β(i)
- Buying price of the crop: PB(I)
- Selling price of the crop: PS(I)
- Cost of inputs (including labour costs) per hectare for the crop: C(I)

- Livestock and Fodder production

  Livestock rearing was another very important livelihood of the local community in addition to agriculture. The communities were dependent on livestock produce for home consumption as well as for sale. The communities majorly had cows and buffaloes as their domestic animals but some were also doing goat and sheep rearing and poultry. The livestock feed was mainly coming from cultivated fodder in their own lands or from the market. Cattle generally graze in the nearby grazing lands or forest areas. For the purpose of this study, cows, buffalos, goat, sheep and poultry have been considered mainly. For evaluating the net output from livestock, costs from fodder production was also taken into account. The results were estimated with the assumption that the locals having one or more type of livestock in their households. Additionally, the costs for grazing animals were considered to bezero. The variables taken for this study were:

- Total production of livestock ´j´ per hectare : S(j)
- Percent that is for self-consumption : γ(j)
- Buying price of the output : PB(j)
- Selling price of the output : PS(j)
- Cost of inputs per hectare for the crop:C(j) for fodder cultivation (each)

The net value for a given household h (NVHLh) will be as follows:

$$NVHL_h = \sum_{i} \gamma(j)S(i)PB(j) + (1 - \gamma(j))S(j)PS(j) - C(j)$$

Equation 4: Mathematical equation for estimating net output from livestock and fodder production

- Collection of Forest Produce (NTFPs & medicical plants)

  Communities in the three districts have been highly reliant on forest products since centuries. Although the collection of the produce has reduced over the years, yet whenever faced with low agricultural productivity the products have provided the communities with a complementary income or source of food and fuel. However, the forest cover has been under threat. To estimate the net output from 2013 till 2018 and between the control and intervention villages, the products collected were valued by looking at the frequency of collection, consumption purpose as well as the market prices used for selling and buying. Net benefits were derived at household level for each of the forest products collected and then those were aggregated.

- Water provision

  Being one of the basic necessities of life, water provision was also one of the most important provisioning ecosystem services. In this study data on provision of water was collected through

Table 5: Characteristics of Sentinel -2A(MSI and Landsat 8(OLI) Sensors

	Sentinel-2A(MSI)		Landsat 8 (OLI)	
Bands	Spectral range (ìm)	Spatial resolution (m)	Spectral range (ìm)	Spatial resolution (m)
Coastal/aerosol	0.43–0.45	60	0.43–0.45	30
Blue	0.46–0.52	10	0.45–0.51	30
Green	0.54–0.58	10	0.53–0.59	30
Red	0.65–0.68	10	0.64–0.67	30
VRE-1	0.70–0.71	20	–	–
VRE-2	0.73–0.74	20	–	–
VRE-3	0.77–0.79	20	–	–
NIR	0.78–0.90	10	–	–
NIR narrow	0.85–0.87	20	0.85–0.88	30
Pan	–	–	0.50–0.67	15

household surveys and FGDs to evaluate the change in the water provision used for drinking purposes as well as irrigation purposes. The parameters for estimating change in water provision were:

- changes in village area under rain-fed, other sources of irrigation and the number of water sources in the identified villages.

2.4.2 Data analysis with satellite data and GIS techniques

Satellite data and GIS techniques were used for further assessment of natural capital in terms of certain other parameters. A schematic workflow of the methodology was applied in this study. First, the smoothed NDVI time series was reconstructed from the L8 and S2 product using Erdas Imagine software to extract phenological metrics from the smoothed curve. Then the Isodata algorithm was exploited to calculate an importance score for all the phenological metrics for each satellite time series data. In this way the most important features were selected for the classification of the seasonal metrics derived from the S2 and L8 time series based on the mean decrease in accuracy (MDA). Furthermore, the Isodata algorithm was used to classify crop types based on the most important phenological parameters. And, finally, the classification accuracy and performance were assessed for each crop and each sensor. These are discussed in the following sections.

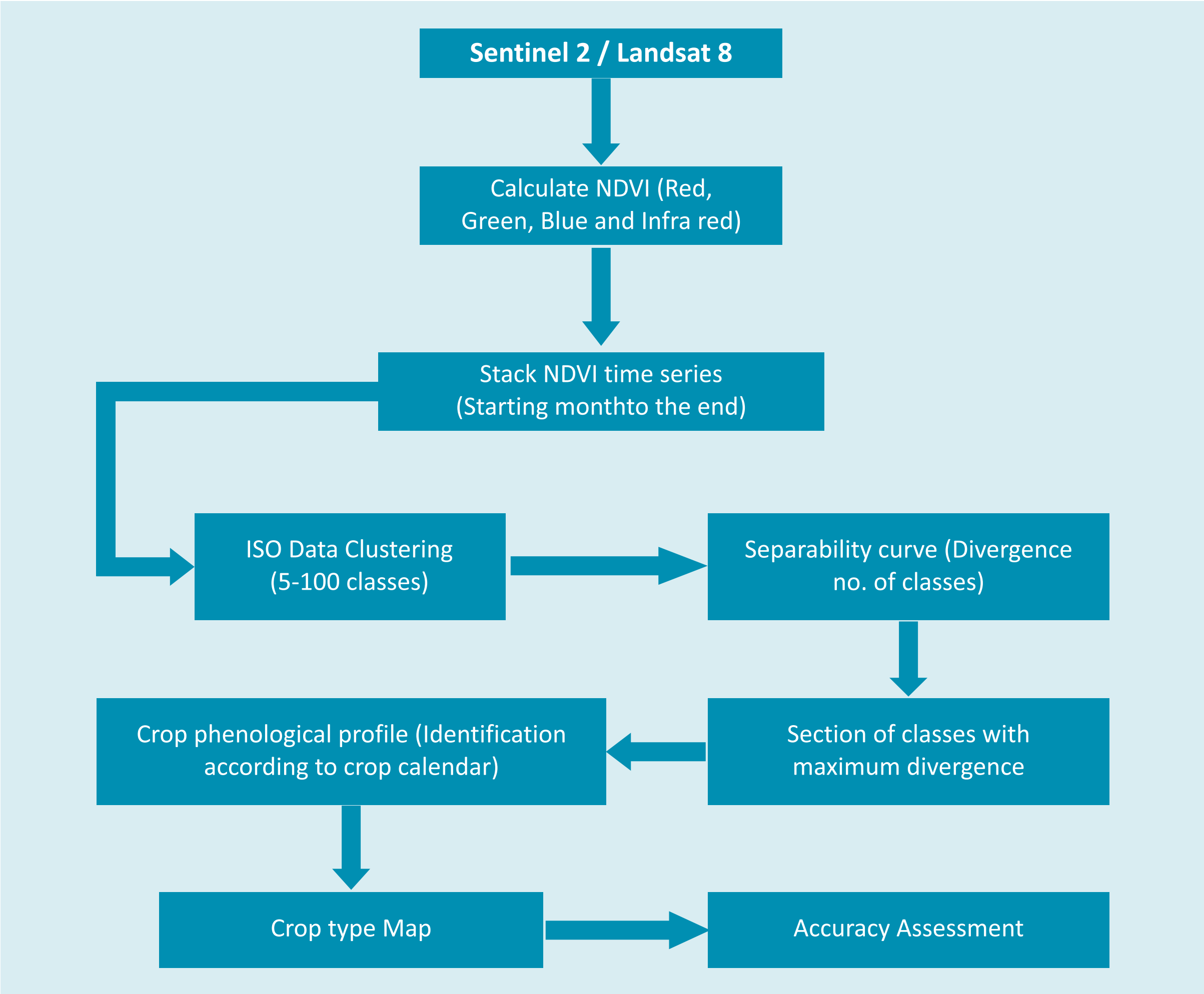
Reconstructing NDVI Time-Series

The parameter used for reconstructing time series is given in the following table.

The workflow of the adopted methodology is shown in the following Figure 8.

To map the crop type, NDVI was computed. After computing NDVI, all the images were stacked from starting period to the end (season data). To map crop type using time series NDVI data, separability of classes were measured using divergence. Divergence measures the separability of a pair of probability distributions based on the degree of overlap of two spectral classes which was defined as the likelihood ratio.

Figure 8: Workflow of the methodology applied



Crop Separability

Classification performance depended on four key factors: class separability, training sample size, dimensionality, and classifier type. In order to characterize the behavior of the phenological parameters, the studied crops boxplots and 2D feature space plot methods were visually analyzed to evaluate their separability and the ability of these parameters to discriminate the crops. These graphical techniques illustrated how training data are distributed across phenological metrics related to L8 and S2. The isolated point clouds, resulted from the scatter plot, indicated the capacity of phenological parameters to detect the behavior of the crops phenological signature.

Accuracy Assessment

The accuracy of the classification results obtained was evaluated using the testing parcels (20% of total ground data) collected during the field visits.

InVEST

To evaluate the benefits received from ecosystem services, the InVEST software was used to measure the changes in natural capital for the different identified villages. InVEST stands for Integrated Valuation of Ecosystem Services and Trade-offs. It is a standalone software developed in partnership comprising of many inbuilt subtypes that require the use of GIS for adding the maps as raw material and then for viewing

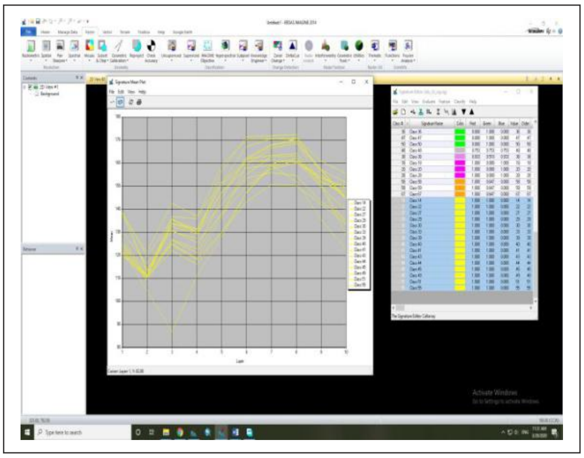


Figure 9: Pulses Profile Spectral Signature

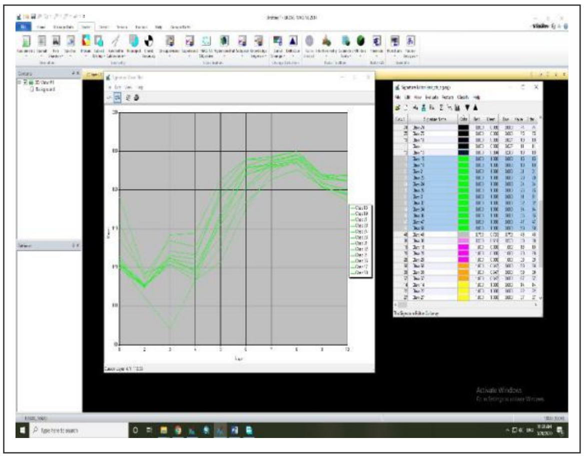


Figure 10: Wheat Profile Spectral Signature

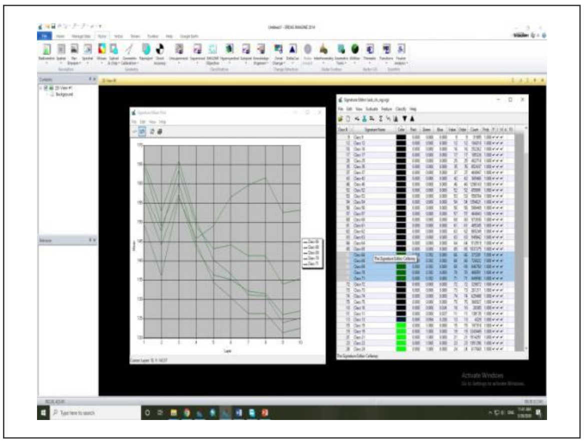


Figure 11: Mustard Profile Spectral Signature

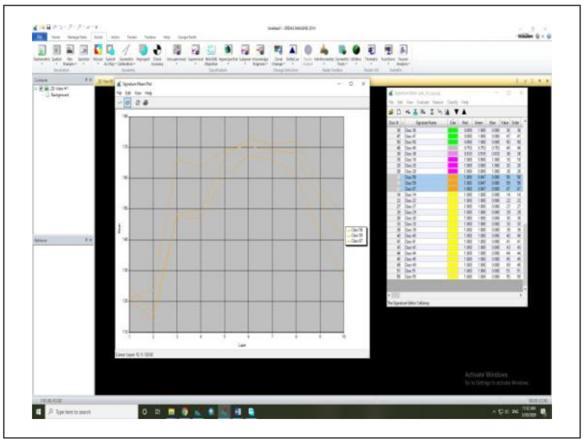


Figure 12: Forest Spectral Signature

the results. Using this software, the study showed the changes in regulatory ecosystem services by utilizing the carbon storage and sequestration and crop pollinator abundance models. The GLOBIO model was used to show the biodiversity specific benefits perceived in the form of supporting services.

Mean Species Abundance

The GLOBIO subtype of the InVEST model showed the changes in the mean species abundance (MSA) of the area. It utilized the different stressors an environment could have such as: change in land use, fragmentation of forests and creation of infrastructure to show how the population species of the area would respond. Different datasets were required to run the model in the formats specified which has been shown in the figure below. The model resulted in values from 0 to 1 with 0 being the area had completely changed in terms of mean species abundance while 1 showing that the area had not changed at all. Both changes were relative to the area´s natural condition.

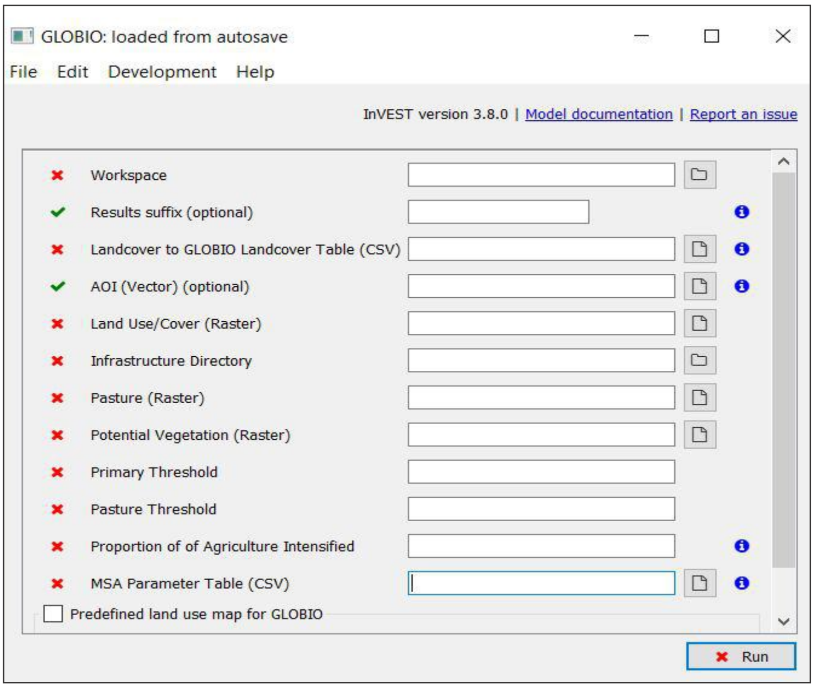


Figure 13: Interface of the GLOBIO model with its requirements

For this study, apart from the MSA value table all parameters have been modified as per the study area. Management specific parameters were used for the purpose of this study.

Globio Data that were used are:

- ESA Landcover
- Roads Database
- Protected Areas

Data on impacts were also used:

- Dose response relations
- Land use
- Climate change
- Fragmentation by infrastructure
- Deposition
- Land use impacts database

The GLOBIO model is designed to assess past, present and future human-induced changes in terrestrial biodiversity at regional to global scales. In GLOBIO, biodiversity responses are quantified as the mean species abundance (MSA), which expresses the mean abundance of original species in disturbed conditions relative to their abundance in undisturbed habitat, as an indicator of the degree to which an ecosystem is intact. The GLOBIO model provides a transparent, flexible and relatively time- and cost-efficient approach to compile national biodiversity accounts. Globio outcomes can also be linked with footprints models (e.g. footprint on land, carbon, water etc.). The results obtained from this would be beneficial for land use planning, water resource planning.

Carbon storage and Sequestration:

The InVEST subtype carbon storage and sequestration showed the amount of carbon stored in the present landscape and the sequestered amount over time for four carbon pools (aboveground biomass, belowground biomass, soil and dead organic matter). The subtype could also estimate the net present value of the sequestered carbon of the area based on carbon price, its annual rate of change and a discount rate. The InVEST model result indicated positive values for carbon storage increased where negative values showed loss of carbon.

The data required to run the model has been shown in Figure 14.

In this study, the current and future land use land cover maps have been added in the model for the years 2013 and 2018 respectively. The carbon pool values for the year 2013, carbon price, market discount and annual rate of change in carbon have been sourced using statistics from FAO (Tubiello,2020), IPCC 2006 guidelines, FSI report of 2013 and other sources[8]. The carbon pool for dead organic matter was not included in this study.

This study assessed the effects of landscape change on the climate regulation ecosystem service, both

[8] A list of data sources for AGB, BGB and SOC for different LULC categories is given in the Appendix.

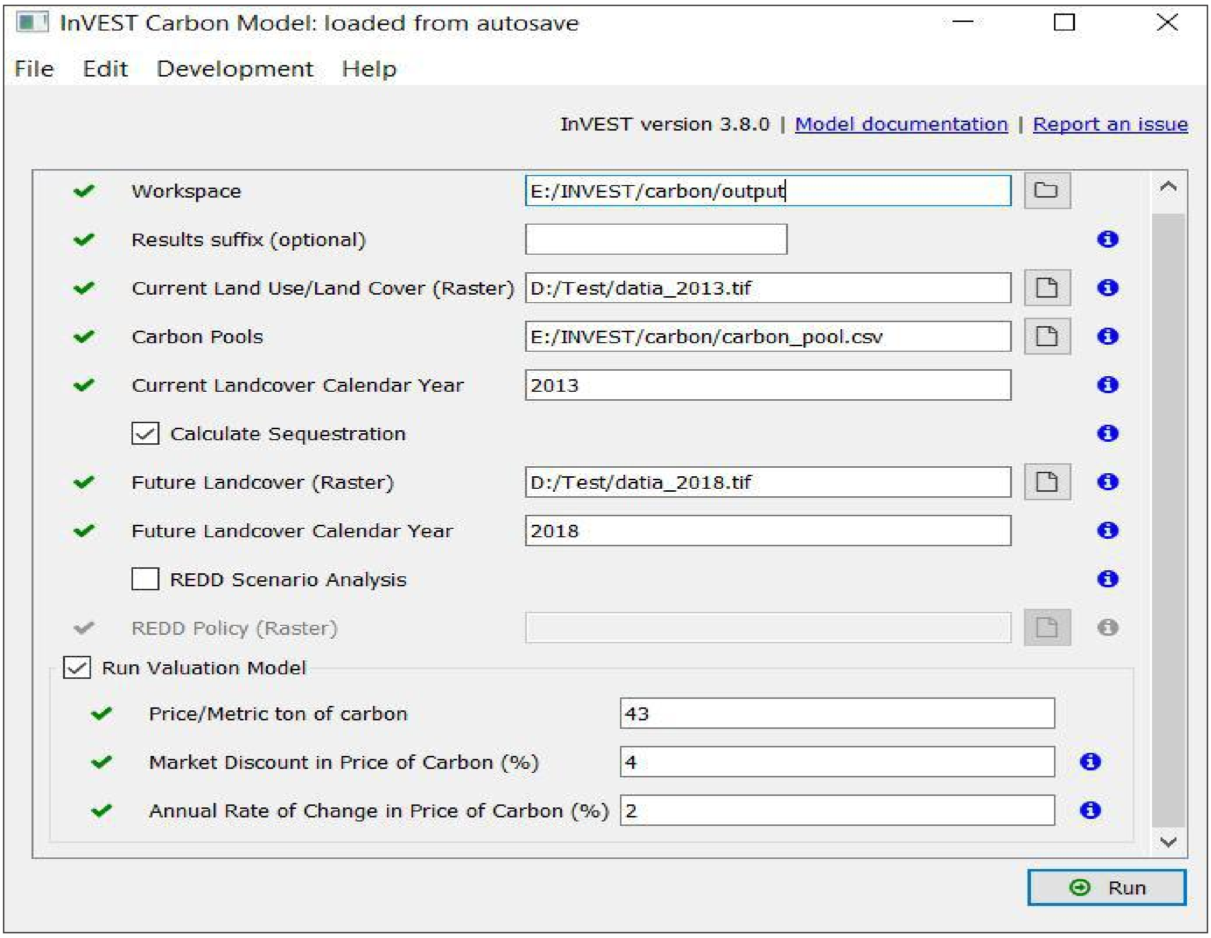


Figure 14: Carbon storage and sequestration model interface with data requirements

biophysically and economically, through the analysis of the carbon storage and sequestration dynamics at the landscape level as a result of Crop Mapping done for 2013 and 2018. The Integrated Valuation of Ecosystem Services model was used for scenario building, carbon assessment and valuation. Several modelling tools were also used to assess past, current and future carbon in four different pools.

The recent and expected landscape changes are likely to affect carbon sequestration and storage. A landscape change that generally promotes carbon sequestration and storage, are found to have a positive effect (both biophysical and economic) on the ecosystem services like climate regulation. Crop mapping further helps in making necessary interventions to extend the capability of the landscape to increase carbon sequestration and storage in the near future. The carbon sequestered and stored in vegetation and soil contributes to avoidance of socio-economic damages from climate change. It also helps in increasing the economic value of particular crop classes and the whole landscape. These results are essential for informed land use planning, by identifying how, where and when changes in landscapes may affect the functioning of regulatory ecosystem services such as climate regulation.

Analysis of The Interventions

3

With respect to the land remediation interventions carried out in the villages in the study site (as mentioned in Chapter 1), the benefits derived through strengthening of natural and social capital were assessed. Quantitative assessment of natural capital was done by considering the major land use categories (e.g. cropland, fallow land, grazing land, forest, habitation, open forest, trees outside forest, wasteland and waterbodies) through which economic outputs were generated by the local communities.

Table 6: Area of the study site

Districts	Total Area (In Hectares)	
	Intervention villages	Control villages
Datia	4665.94	4592.28
Shivpuri	3194.62	1564.31
Niwari	4487.77	883.84

Land Use Land Cover (LULC) mapping was done for the intervention and control villages covering Datia, Shivpuri and Niwari districts of Bundelkhand for 2013 and 2018. Although in the entire study site cropland was found to be the dominant land use category, there were certain differences in LULC between intervention and control villages in different districts. For example, in intervention villages in Niwari more than 86% of the total area was cropland in 2018 and that in Datia and Shivpuri were found to be more than 66% and 37% respectively. In control villages too, Niwari was found to have cropland in more than 80% of the total area[9]. Among these three selected districts, Shivpuri had highest share of forest in intervention villages (more than 33% of the total area) in 2018. In Niwari, no forest cover was found.

9 Refer to table in Appendix

Table 7: Land use land cover in Intervention and Control villages in the study site of Bundelkhand in 2013 and 2018

	Intervention villages in Bundelkhand		Control villages in Bundelkhand	
	2013	2018	2013	2018
Total area (ha)	12348.09	12348.33	7040.46	7040.43
Agricultural land (ha)	7965.74	8191.12	5509.6	5564.25
Water bodies (ha)	681.9	593.06	162.7	144.53
Forest cover (ha)	2011.86	1929.16	174.54	148.59

Source: Land use data- GIS

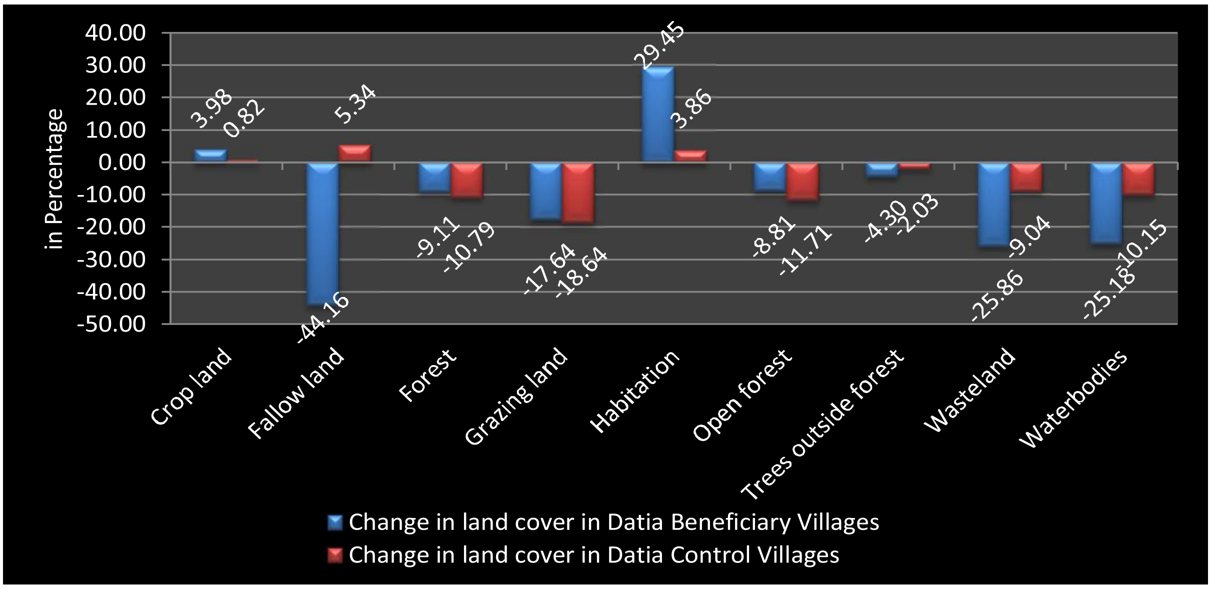


Figure 15: LULC changes in intervention and control villages in Datia between 2013-2018

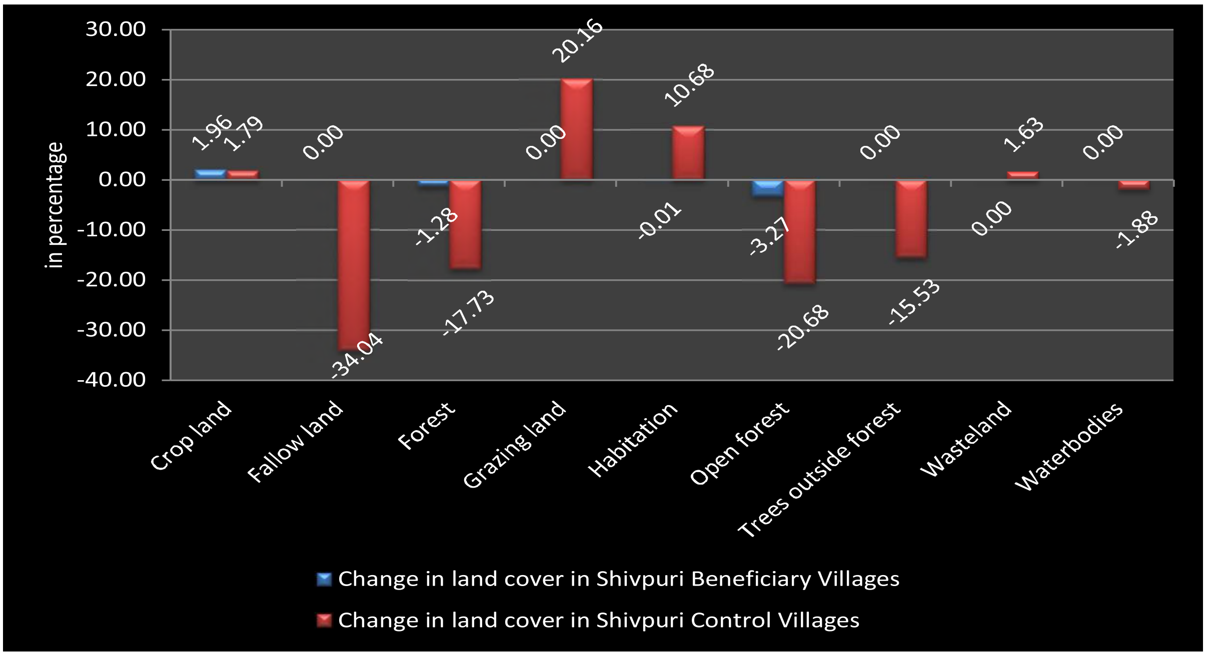


Figure 16: LULC changes in intervention and control villages in Shivpuri between 2013-2018

(Source: Calculation based on LULC classification done through secondary data)

The changes in LULC in the intervention and control villages are shown in Figure 15, Figure 16 and Figure 17. In Datia intervention villages between 2013- 2018 there has been higher rate of increase in cropland and habitation compared to that in control villages of the district. In both Shivpuri and Niwari, intervention villages have experienced a higher rate of increase in croplands during 2013- 2018 compared to control villages. One of the reasons behind increase in area of croplands has been conversion of forest into cropland. The government has distributed[10] *"Patta"*[11] to the farmers for cultivating in some parts of the forest areas in these three districts. This "*Patta*" authorises the farmers to only cultivate in the land, but they can neither use it for any other purpose nor can transfer the "*Patta*" by selling off the land. Another important finding is that, across all the three districts there has been decline in certain LULC categories during 2013-2018 but for some of those intervention villages have experienced a lesser rate of decline in land area compared to control villages. This can also be attributed to the positive impact of interventions which might have limited the rate of decline in some of the LULC categories in intervention villages. Some of these include: forest, open forest and grazing land in Datia; fallow land, forest, open forest, trees outside forest and waterbodies in Shivpuri; fallow land and waterbodies in Niwari. In case of some LULC categories control villages haves hown either higher rate of increase or lower rate of decline in area compared to intervention villages. Some of those are: fallow land, wasteland and waterbodies in Datia; grazing and habitation in both Shivpuri and Niwari. Hence, interventions are required to focus more on these LULC categories and the underlying factors driving the changes in LULC need to be identified.

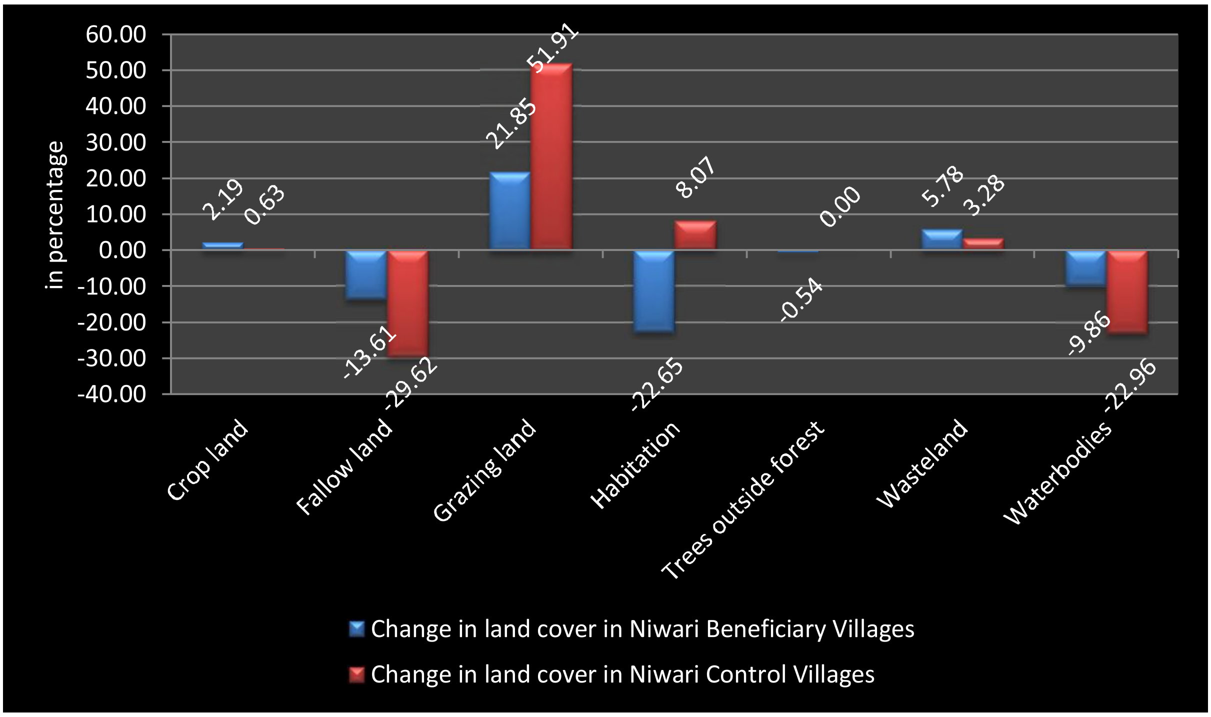


Figure 17: LULC changes in intervention and control villages in Niwari between 2013-2018

Source: Calculation based on LULC classification done through secondary data

In the following section the cost-benefit analysis of the pre-mentioned interventions is done.

3.1 Cost-Benefit Analysis of the Interventions

The first task was to value the benefits from the intervention in terms of changes in crop, livestock and forest income. This was done as follows.

Crop

For crop income the average net income per hectare was calculated for 2018 and 2013 in both the sample intervention villages and sample control villages. Incomes in 2013 were adjusted to take account of inflation between 2013 and 2018. For each type of villages, the difference was computed. The net gain from the intervention was then estimated as the additional gain in the intervention villages compared to the intervention villages. This can be mathematically written as:

[10] Source: Primary survey

[11] A legal proof of land ownership

$$\Delta CropInc = (CropInc_{B,2018} - CropInc_{B,2013}) - (CropInc_{INT,2018} - CropInc_{INT,2013})$$

Where:

ΔCropInc is the net change per hectare of income from crops in the intervention areas.

$CropInc_{B,2018}$ is the income per hectare in intervention villages in 2018.

$CropInc_{B,2013}$ is the income per hectare in intervention villages in 2013.

$CropInc_{INT,2018}$ is the income per hectare in control villages in 2018.

$CropInc_{INT,2018}$ is the income per hectare in control villages in 2013.

Income per crop was estimated based on the methodology explained in Chapter 2(section 2.4.1). The main crops taken for the analysis were maize, urad (Black Gram), mung (Yellow Lentils) sesame, groundnuts, wheat, mustard, masoor (Red Lentils), pea, chana (Bengal Gram), barley, sugarcane, jowar/ shorgam (Millet), soyabean, paddy and vegetables. The resulting data are shown in Table 6for the three districts.

Table 8: Net Gains from Crops in three Intervention Districts in Bundelkhand

Crops	Δ Income/Ha 2013-2018 Rs.000			Area 2018. Ha.	Net Gain Rs.000
District	Intervention	Control	Net Gain		
Datia	8.46	-31.85	40.31	5,638	227,255
Shivpuri	23.18	-25.73	48.91	965	47,216
Niwari	-0.76	-28.74	27.98	2,266	63,398

Source: Calculation based on primary data collected from the field by DA team

Income per hectare increased over the period 2013 to 2018 in the intervention villages in Datia and Shivpuri but declined slightly in Niwari. In the control villages, however the decline in income was sharper and so there was a net gain in income per hectare in each district as a result of the intervention. Multiplying this gain by the hectares under cultivation provided the total gain in crop income in each district, shown in the last column. Datia shows the highest net gain from agriculture which is partially due to the fact that Datia has the highest area of cropland among the three districts. Further, it was found that area under double cropping in the study site has increased over the years (Table 7). In intervention villages over the three districts the percentage of total cultivated area under double cropping increased from 37% in 2013 to 42% in 2018 (Figure 18 and Figure 19). This has resulted in higher income gains from agriculture.

The net gain in benefits in intervention villages can be partially attributed to increase in irrigation facilities. In intervention villages 82% of the respondents in Datia,

Table 9: Cropping pattern in intervention and control villages in 2013 and 2018

	Area (in Hectares) under double cropping			
Districts	**Intervention 2013**	**Intervention 2018**	**Control 2013**	**Control 2018**
Shivpuri	472	532	465	501
Niwari	720	1123	320	272
Datia	1748	2067	1592	1982
	Area (in Hectares) under single cropping			
	Intervention 2013	**Intervention 2018**	**Control 2013**	**Control 2018**
Shivpuri	694.89	657.79	656.15	640.22
Niwari	3165.48	2762.48	398.55	451.05
Datia	1248.68	1048.85	2077.89	1717.98

Source: Calculation done by DA team based on LULC data

53% respondents in Shivpuri and 72% respondents in Niwari reported increase in irrigation facilities during 2013- 2018. But in case of control villages most of the respondents reported either decrease or no change in irrigation facilities. From some of the qualitative responses collected through primary survey it also got reflected that in the intervention villages there has been increased productivity of land resulting in increased yield, multi-cropping practices, better groundwater replenishment, and availability of irrigation sources other than rainfall. In case of control villages some of the constraints to agriculture and water access as reported by the respondents were: lack of groundwater replenishment resulting in lack of availability of water in wells, payment of rent for getting access to water, travelling far away to fetch water, reduction in agricultural productivity.

In intervention villages the area under double crop has increased by 8% during 2013-2018, whereas that for control villages was found to have increased by 7%. On the other hand, the area under single crop in both intervention and control village declined during 2013-2018.

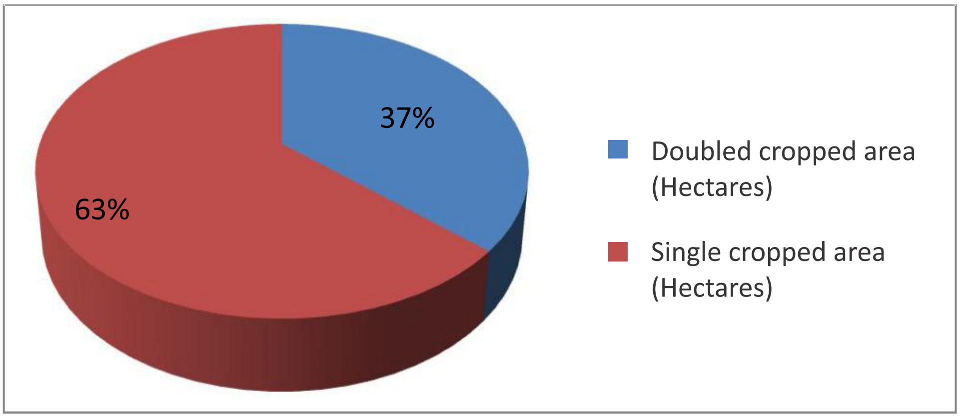


Figure 18: Cropping pattern of intervention villages in 2013

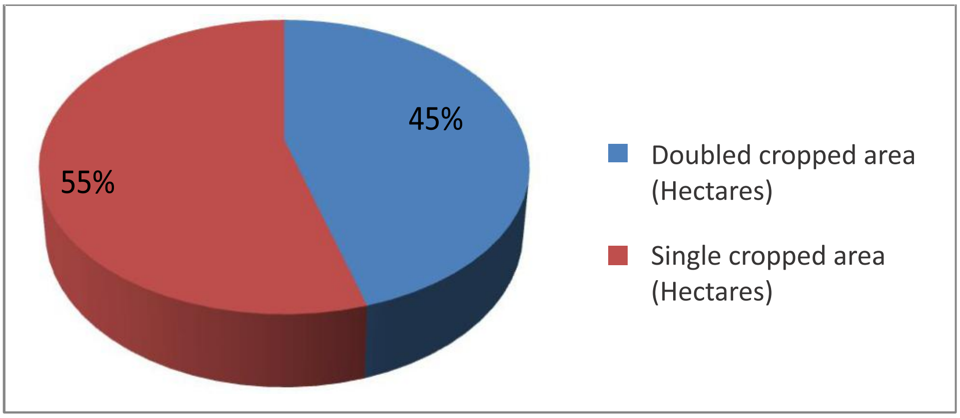


Figure 19: Cropping pattern of intervention villages in 2018

Livestock

For livestock the calculations were undertaken on a per household basis animals share the pasture land available. Specific parcels to different animals were not done during calculation since it was beyond the scope of the study. The net gain from the intervention was estimated as the additional gain in the intervention villages compared to the intervention villages in livestock income per household. This can be mathematically written as:

$$\Delta LstockInc = (LstockInc_{B,2018} - LstockInc_{B,2013}) - (LstockInc_{INT,2018} - LstockInc_{INT,2013})$$

Where:

$\Delta LstockInc$ is the net change per household of income from livestock in the intervention areas

Table 10: Net Gains (in Rs. 000) from Livestock in three Intervention Districts in Bundelkhand

Livestock	Δ Income/HH 2013-2018 Rs.000			Nº HH	Net Gain Rs.000
District	Intervention	Control	Net Gain		
Datia	140.47	46.23	94.24	2,525	237,963
Shivpuri	97.28	0.01	97.27	2,098	204,066
Niwari	103.39	76.27	27.12	2,150	58,308

Source: Calculation based on primary data collected from the field by DA team

$LstckInc_{2018}$ is the livestock income per household in intervention villages in 2018.

$CropInc_{B,2013}$ is the livestock income per household in intervention villages in 2013.

$CropInc_{INT,2018}$ is the livestock income per household in control villages in 2018.

$CropInc_{INT,2018}$ is the livestock income per household in control villages in 2013.

Income per household was valued as explained in Chapter 2. Animals are mainly cattle and buffaloes, goats, poultry and sheep. The resulting data are shown in Table 3 for the three districts.

Income per household increased over the period 2013 to 2018 in all the intervention villages. In the control villages income increased in Datia and Niwari and marginally in Shivpuri. But the change in income per household has been found to be much higher in intervention villages across all districts. Multiplying this change by the households in each district gives the total gain in livestock income in each district, shown in the last column. It shows that the net gain from livestock is the highest in Datia, whereas Niwari has the lowest net gain from livestock. As highlighted by the local stakeholders, the constraints in Niwari for livestock rearing have been lack of productivity and availability of green fodder, which is a vital source of nutrients for livestock. So often they get less livestock benefits due to lesser milk production. Niwari also had been exposed to droughts and water crisis due to which water availability for livestock has been a major constraint. In these villages farmers abandon their cattle after a certain age and donate them in Gaushala (a cowshed where abandoned cattle are taken care of). This custom is called "Annapratha" in the study villages. Apart from that, Niwari has close connectivity to the city people and thus people have alternative employment opportunities apart from livestock. Migration occurs at a high rate in this village.

In some of the villages (both in intervention and control) in the study site the number of goats owned by the households has increased during 2013- 2018, which explains the increased benefits from livestock in both intervention and control villages. In these villages purchase of goats have increased irrespective of the traditional livelihood practices (earlier a few households in the entire village community used to own a large number of livestock traditionally) mainly due to higher flexibility and profitability of goat rearing. As reported by the field experts of DA, unlike cows and buffalos, goats are easily sellable in the market. Availability of fodder, flexibility in selling off goats and availability of goat species with higher rate of reproduction have induced increased ownership of goats across intervention and control villages. The role of social capital was found to have played an important role in this aspect too. Widespread sharing of knowledge and information within and across villages regarding selection of goat species that are more productive and other associated information has expedited it. Access to formal sources of finance in terms of microfinance[12] played an important role towards it. Either through formation of SHGs or individual villagers have got easy access to credit in these villages for carrying out activities for income generation including livestock rearing. These are some of the predominant factors that have resulted in higher income gain from livestock across intervention and control villages in the three selected districts.

Forestry

Apart from the ecosystem benefits of carbon sequestration, which was treated separately, forest areas provide villagers with local benefits in the form of fuelwood, eucalyptus oil and different leaves. Data on the quantities collected were patchy and therefore, treated with highest caution. However, they provided some useful information and have been included while doing the valuation. Four kind of forest products viz., fuelwood, tendu leaves, palash leaves and kino (oil) were collected by the community in each of the villages in the three districts. The estimated quantity of collection and their buying and selling prices were taken for calculation of benefits. The amounts were valued at the average of the two prices. No input costs were taken into account as there is no cultivation. The results are shown in Table 11.

Intervention villages in Datia did see some increase in income between 2013 and 2018 but villages in

[12] Sonata microfinance company has been operating in the study site (Source: Field experts of DA)

Table 11: Net Local Gains (in Rs. 000) from Forestry in Three Intervention Districts in Bundelkhand

Forestry	∆ Income 2013-2018 Rs.000			Net Gain Rs.000
District	Intervention	Control	Net Gain	
Datia	9,706	15,338	-5,633	-5,633
Shivpuri	-30,523	-8,332	-22,192	-22,192
Niwari	0	0	0	0

Source: Calculation based on primary data collected from the field by DA team

Shivpuri experienced a loss. Niwari has no forest areas. On the other hand, control villages in Datia saw an even bigger increase while those in Shivpuri saw a smaller loss than the intervention villages. Overall the forestry sector appears to have suffered a decline in terms of the value of the services it provides to the intervention villages. Decline in forest cover partially explains the decline in net benefit from forest. In Shivpuri the forest area has declined at a much higher rate compared to Datia (Figure 15 and Figure 16). As discussed earlier, conversion of forest land into cultivable land has resulted in decline in forest cover during 2013- 2018 in the study site.

Further discussion revealed that the dependence of the local communities on the forest have reduced over the years. Earlier, collection of fuelwoods was one of the major provisioning services of the forest ecosystem. But most the population have shifted to alternative sources of cooking fuel other than fuelwood and for construction of houses use of alternatives have started instead of wood. Across the intervention and control villages alternative sources of cooking was adopted by the village communities. Due to increase in livestock rearing practices, it was observed that households have increased the use of cow-dung cakes as cooking fuel. Although free LPG cylinder distribution had also taken place in these villages, but a very small percentage of households have continued the use of LPG as a cooking fuel mainly due to the issue of refilling. Hence the demand for fuelwood and other uses of wood have declined during 2013- 2018 due to changes in lifestyle practices. Also forest areas have decreased in the region and therefore, collection of products also was reduced over the years. Hence the use value of forest ecosystem services has declined, which is captured in this study. Assessment of existence value of ecosystem services is beyond the scope of this current study. Assessment of that could have added another perspective to the changes in natural capital of forest.

Biodiversity

The GLOBIO framework was used to estimate changes in biodiversity tracks, changes in the quality of the land due to climate change, nitrogen deposition, forest fragmentation, infrastructure and land use land cover change through the mean species abundance (MSA) index. If an ecosystem is degraded, this leads to a loss of ecosystem services. In the case of agricultural land, this can generally be addressed by promoting low input agriculture. Grasslands and forests that are fragmented can support fewer species. A degraded ecosystem cannot regulate water, air and climate like a well-managed ecosystem.

In the Study sites it has been revealed that the species abundance has been improved in intervention villages from 2013 to 2018 but in the control villages did not show the same abundance of species. Table 12 reported the MSA values for the three districts, both for control and intervention villages. These were based on applying the GLOBIO model using primary, secondary and GIS maps for the areas being studied.

The figures in Table 12 showed an increase in MSA between 2013 and 2018, both in the control and intervention villages. The small change in the control villages of Shivpuri and Niwari could be attributed to increase in grazing land area which was considered as primary vegetation by the GLOBIO model. Whereas in Datia district, the fallow land areas were increased

Table 12: MSA Values in Control and Intervention Villages: 2013 and 2018

District	Control_ 2018	Control_ 2013	∆ MSA	Intervention 2018	Intervention 2013	∆ MSA	∆MSA from Intervention
Datia	0.129	0.110	0.019	0.162	0.136	0.026	0.007
Shivpuri	0.094	0.079	0.015	0.188	0.108	0.080	0.065
Niwari	0.078	0.076	0.002	0.093	0.085	0.008	0.006

Source: Estimation based on primary data collected from the field by DA team and using INVEST software over time which were considered as areas without disturbance by the GLOBIO model. However, the gain was greater in the intervention villages, raising MSA most in Shivpuri, followed by Datia and Niwari. In Shivpuri, this was mainly due to very small changes in land use land cover over time and the retention of natural water bodies owing to the land and water based intervention undertaken by DA group. While in Datia and Niwari districts, the increase in MSA could be attributed to the intensification of agriculture (low input) as picked up by GLOBIO again owing to the promotion of sustainable agriculture practices.

The MSA values are further analysed in terms of three types of anthropogenic stressors i.e. land use change, forest fragmentation and infrastructural impact.

- MSA for land use change (MSA_LU) ranges from 0 (complete change in MSA) to 1 (no change in MSA) which was distributed into 5 categories (0- 0.2, 0.2- 0.4, 0.4- 0.6, 0.6- 0.8, 0.8- 1) based on degree of change.
- MSA for infrastructure ranges from 0.4 (high impact from infrastructure on forest) till 1 (no impact from infrastructure on forest) with 4 possible MSA_I values (0.4, 0.8, 0.9 and 1) depending on degree of impact on forest due to infrastructure.
- MSA for fragmentation ranges from 0.3 (for a Fragmentation Forest Quality Index value less than 0.43) till 1 (for Fragmentation Forest Quality Index value 0.99 to 1). Six possible MSA_F values (0.3, 0.6, 0.7, 0.9, 0.95 and 1) can be obtained depending on the Fragmentation Forest Quality Index value.

Table 13: MSA values in intervention and control clusters in 2013 and 2018

District	Cluster	2013				2018			
		MSA	MSA_LU	MSA_F	MSA_I	MSA	MSA_LU	MSA_F	MSA_I
Datia	Intervention	0.136	0 to 1	0.6 to 0.95	0.8 to 1	0.162	0.22 to 1	0.6 to 0.95	0.8 to 1
	Control	0.11	0 to 1	0.6 to 0.7	0.8 to 1	0.129	0.22 to 1	0.6 to 0.95	0.8 to 1
Shivpuri	Intervention	0.108	0.1 to 1	0.3 to 0.95	0.4 to 0.8	0.188	0 to 1	0.3 to 0.7	0.4 to 0.9
	Control	0.079	0 to 1	0.3 to 0.9	0.4 to 0.8	0.094	0 to 1	0.3 to 0.9	0.4 to 0.8
Niwari	Intervention	0.085	0 to 1	0.6 to 0.95	1	0.093	0 to 1	0.3 to 0.6	0.4 to 0.9
	Control	0.076	0 to 1	0.3 to 0.7	0.4 to 0.9	0.078	0 to 1	0.3 to 0.7	0.4 to 0.9

Datia District

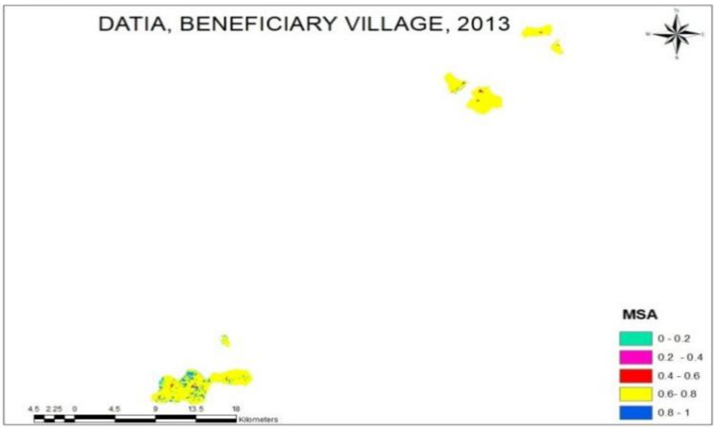


Figure 20: MSA_LU Intervention cluster of Datia in 2013[13]

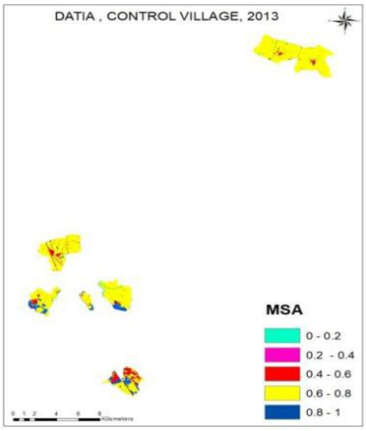


Figure 21: MSA_LU of control cluster of Datia in 2013[14]

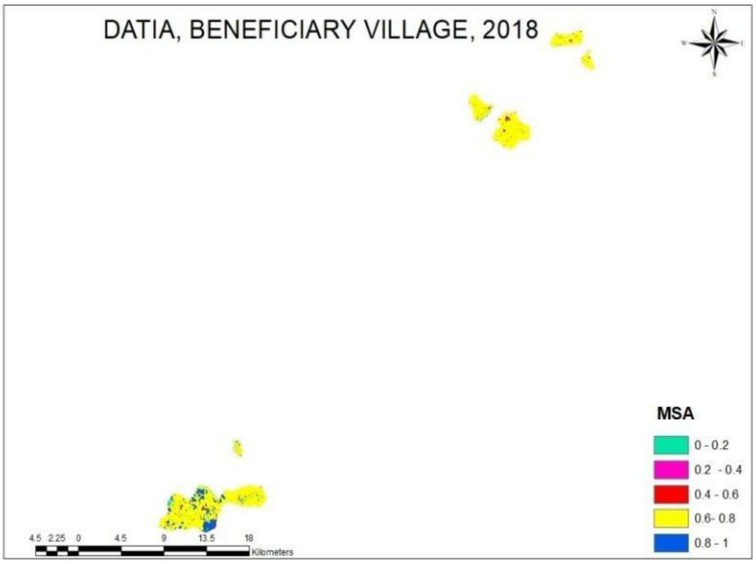


Figure 22: MSA_LU of intervention cluster of Datia in 2018[15]

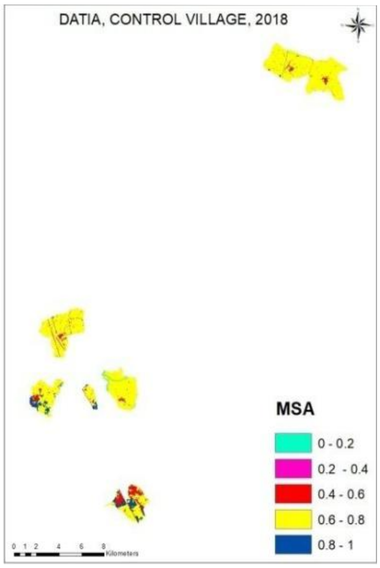


Figure 23: MSA_LU of control cluster of Datia in 2018[16]

The overall MSA values and values corresponding to each of the anthropogenic stressors for the study site are shown in Table 11. The comparisons of benefit and control clusters in the three districts for 2013 and 2018 based on the GLOBIO outcomes (in Table 11) are discussed below:

The GLOBIO results for Datia showed that, in intervention villages there was an increase in overall MSA (Table 11)in 2018 compared to that 2013 and the MSA values in intervention villages were found to be higher than control villages which signified an improvement in species abundance in intervention villages in Datia. The MSA values have been affected by the three pre-mentioned anthropogenic stressors of MSA in the following manner:

- In terms of MSA_LU, both interventiony villages and control villages in Datia experienced a change during 2013- 2018.But, although the overall range of MSA_LU were the same in both intervention and control villages in both the years, the distributions of land use had changed the species abundance in different parts of intervention and control villages. The MSA_LU distributions for Datia are shown in Figure 20, Figure 21, Figure 22 and Figure 23. It is found that, in control villages the proportion of land in the highest category of MSA_LU (0.8-1 i.e. lowest or no detrimental impact on species) declined during 2013- 2018, but in intervention villages proportion of land in this category had increased, which implies that species abundance improved through land use change in some parts of intervention villages.
- In terms of MSA_F, although the FFQI remained the same for 2013 and 2018 for intervention villages, but the control villages also showed an improvement in their FFQI. Therefore, it implies that the control villages had an increase an MSA due to improvement in forest cover.
- In terms of The MSA_I (infrastructure impact), neither of intervention villages and control villages in Datia experienced any change (Table 11) and they had same range of values in both the years.

Hence it is found that, the species abundance of both intervention and control villages were affected by land use change but reduction in forest fragmentation mainly improved the species present in the control villages. The increased value of overall MSA in intervention villages in Datia during 2013- 2018 can be attributed due to the promotion of sustainable agriculture practices and construction of water harvesting structures. The irrigated cropland (groundwater fed and other sources irrigation) comes under low input agriculture (Schipper, Tillmanns, Giesen, & Esch, 2017). It implies that, the more is the water supply in the area, the less is the use of chemicals or other practices to promote faster yield of crops which in turn reduces the harmful impact on the species habitat and thereby helps in increase in MSA.

[13] Higher resolution clusterwise maps are given in Figure 41 and Figure 43 in Appendix
[14] Higher resolution clusterwise maps are given in Figure 45 and Figure 47 in Appendix
[15] Higher resolution clusterwise maps are given in Figure 42 and Figure 44 in Appendix
[16] Higher resolution clusterwise maps are given in Figure 46 and Figure 48 in Appendix

Shivpuri District

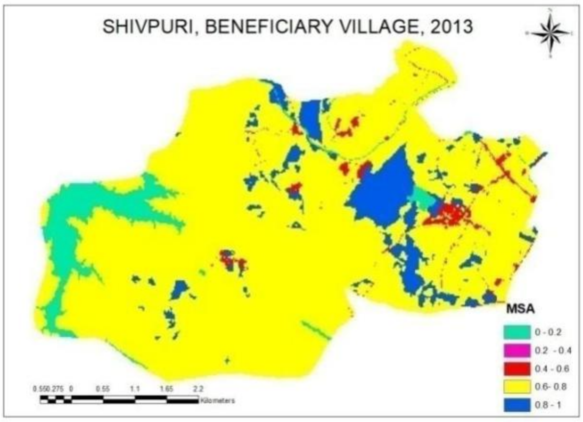


Figure 24: MSA_LU of intervention cluster in Shivpuri in 2013

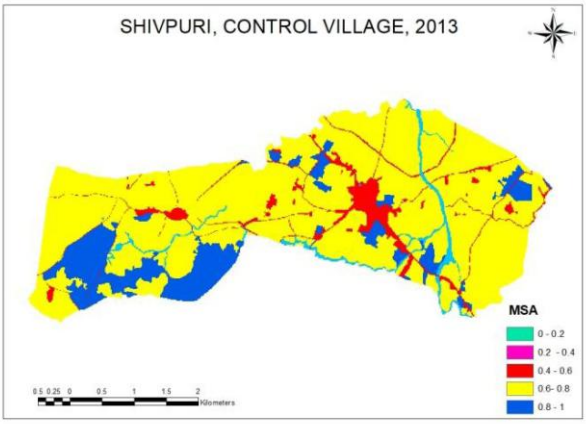


Figure 25: MSA_LU of control cluster in Shivpuri in 2013

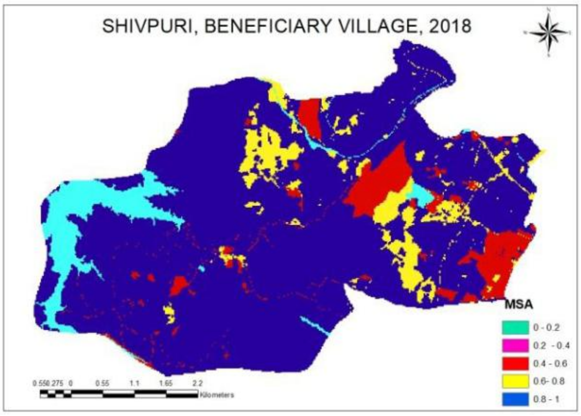


Figure 26: MSA_LU of intervention cluster in Shivpuri in 2018

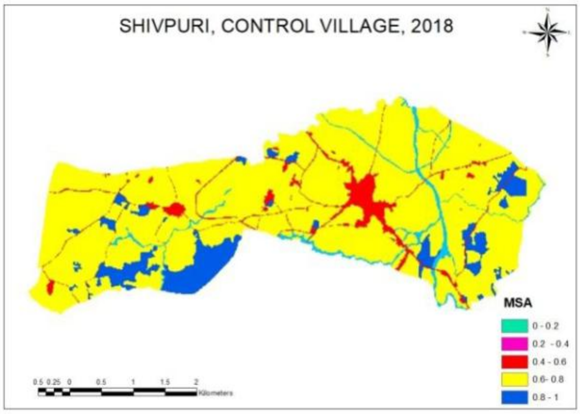


Figure 27: MSA_LU of control cluster in Shivpuri in 2018

The GLOBIO results for intervention villages in Shivpuri showed an increase in MSA in 2018 compared to that 2013 and the MSA values in intervention villages were found to be higher than control villages. The MSA values have been affected by the three anthropogenic stressors in the following manner:

- In terms of MSA_LU, the intervention villages and control villages in Shivpuri experienced a change during 2013- 2018. The MSA_LU distributions for Shivpuri are shown in Figure 24, Figure 25, Figure 26 and Figure 27. It is found that, in control villages the proportion of land in the highest category of MSA_LU (0.8-1 i.e. almost no detrimental impact on MSA) declined during 2013- 2018, but in the intervention villages proportion of land in this category had increased significantly, which implies that species abundance improved through land use change in some parts of intervention villages.
- In terms of MSA_F, the FFQI remained the same in 2013 and 2018 in control villages of Shivpuri while the intervention villages showed a loss in their FFQI. Therefore, the intervention villages were adversely affected by the loss of forest cover during 2013- 2018.
- In terms of The MSA_I (infrastructure impact), the intervention villages performed relatively better than the control villages. The impact from infrastructure changed during 2013- 2018 leading to affecting the species abundance intervention villages a little less while there was no change in case of control villages over the years.

Thus it can be said that the species abundance improved in the intervention villages in Shivpuri due to changes in land use and infrastructure during 2013-2018 and the intervention villages were at a better position than control villages in terms of all the three anthropogenic stressors of species abundance. Although the overall MSA in Shivpuri intervention villages increased (Table 11) during 2013-2018, but placing the achieved MSA value with respect to the lowest limit of 0 and highest limit of 1 of MSA value, it can be said that the overall MSA value is still low implying loss in species abundance is ongoing with reduced intensity of loss. It was also found that the intervention villages were affected by forest fragmentation, but the loss was made up by reduction in the impact from infrastructure as well as increase in irrigated crop land area owing to DA's land and water intervention.

Niwari

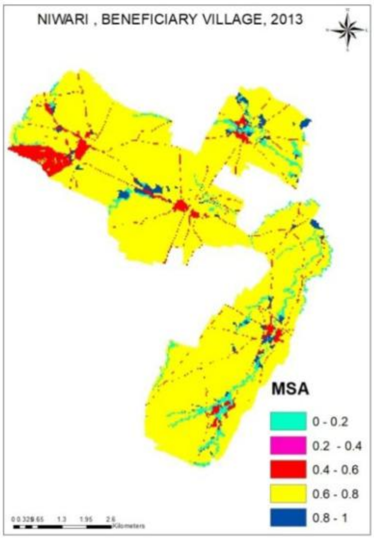


Figure 28: MSA_LU of intervention cluster of Niwari in 2013

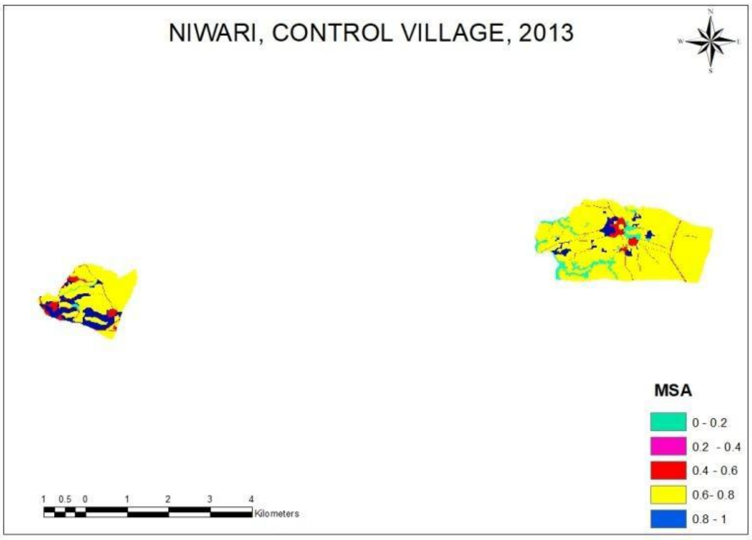


Figure 29: MSA_LU of control cluster of Niwari in 2013

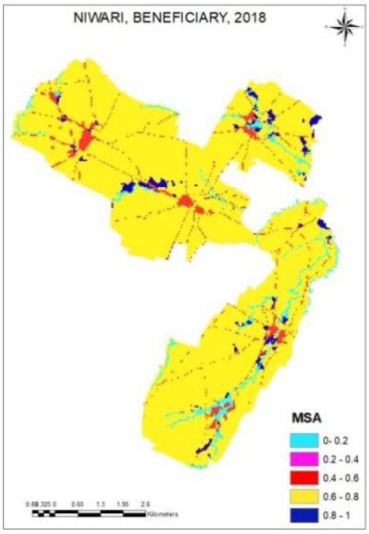


Figure 30: MSA_LU of intervention cluster of Niwari in 2018

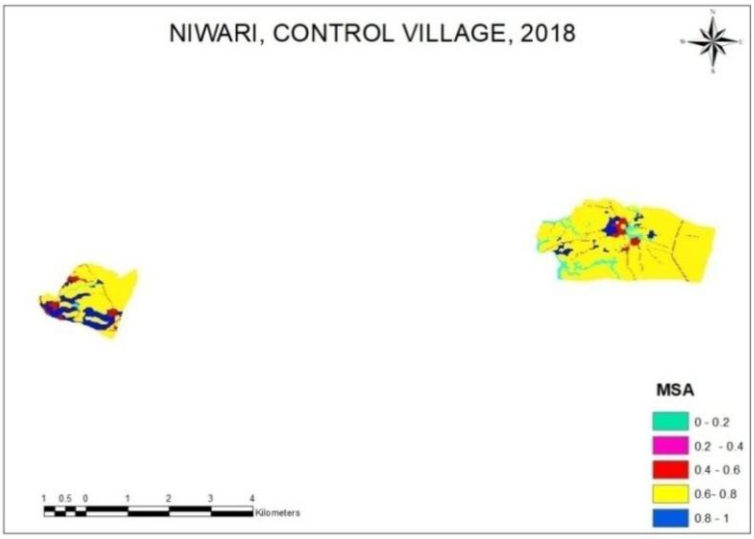


Figure 31: MSA_LU of control cluster of Niwari in 2018

The GLOBIO results for intervention villages in Niwari showed an increase in MSA in 2018 compared to that of 2013 and the MSA values in intervention villages were also found to be higher than control villages. The MSA values have been affected by the three anthropogenic stressors in the following manner:

- In terms of MSA_LU, the intervention villages in Niwari experienced a better change. The MSA_LU distributions for Niwari are shown in Figure 28, Figure 29, Figure 30 and Figure 31. It is found that, while in control villages the proportion of land in the highest category of MSA_LU (0.8-1) declined during 2013- 2018, but in intervention villages proportion of land in this category had increased, which implies that species abundance improved through land use change in intervention villages.
- MSA_F remained the same for control villages while worsened for the intervention villages

during 2013- 2018. This implied that effects from forest fragmentation impacted the species abundance more in the intervention villages than the control villages by 2018.

- In terms of The MSA_I (infrastructure impact) no change was observed in control villages, but the status of intervention villages had worsened. It implied that infrastructure impacted the species abundance in intervention villages to a great extent during 2013-2018.

It is observed, that during 2013- 2018the ecosystem health in terms of the mean species abundance improved to some extent in the intervention villages of Niwari even if the species of the intervention villages were detrimentally affected by infrastructure and forest fragmentation during this period. The gain in intervention villages can be attributed to improvement in species abundance due to land use change. Apart from that, the status of overall species abundance was found to be better in intervention villages compared to the control villages by 2018.The benefits were achieved due to the water management interventions done by DA in the intervention villages, which have made up for the losses due to forest fragmentation and impact of infrastructure. But, since the overall MSA value was found to be 0.16 in intervention villages, it indicates that there is a scope to make further improvement in species abundance in intervention villages in Niwari to achieve a MSA closer to 1 implying no harmful impact on biodiversity.

To capture the gains from forest ecosystem services (use value) in monetary terms the value of services from land-use and coverage in 2018is multiplied by the change in the MSA index between 2013 and 2018attributable to the intervention[17]. The average hectare would produce greater biodiversity services in due to the combined effects of all factors that influence the quality of the land as measured in the MSA index. This calculation, which follows the method used in Braat et al. (2008) therefore, builds on a broad assumption that the MSA, which is an indicator of species abundance and reflects the health of the ecosystem, in turn broadly reflects the provision of services, at least at an aggregate level. The resulting increases in the value of non-market services from the land due to the intervention are given in

Table 14.The net gains in MSA are greatest in Shivpuri. It is followed by Datia and Niwari.

Table 14: Net Gains in ES from Changes in MSA in three Intervention Districts in Bundelkhand

Biodiversity	Δ MSA 2013-2018			Gain in ES. Rs.000
District	Intervention	Control	Net Gain	
Datia	0.026	0.019	0.007	5,636
Shivpuri	0.08	0.015	0.065	24,068
Niwari	0.008	0.002	0.006	1,980

Source: Calculation based on data collected by DA team

Carbon Sequestration

Carbon sequestered in the land was estimated using the InVEST model, taking account of different crops grown and taking account of different rates of carbon held in the ground in the Kharif and Rabi seasons. In order to obtain an estimate of the gain in carbon held in the ground it is necessary to calculate the change in carbon per hectare as a result of the intervention. To do this the following are estimated from the InVEST model:

C (Intervention) 2018 = Carbon held in intervention villages in 2018 in two seasons[18].

To obtain the gain per hectare as a result of the intervention the following are calculated:

$$\Delta C\ (Intervention/Ha) = C\ (Intervention)_{2018}/A(Intervention)_{2018} - C\ (Intervention)_{2013}/A(Intervention)_{2013}$$

and

$$\Delta C\ (Control/Ha) = C\ (Control)2018/A(Control)_{2018} - C\ (Control)_{2013}/A(Control)_{2013}$$

[17] Note that the method does not allow a valuation of the biodiversity-related services to be made. It does, however, make an estimate of the change in the value of these services.

[17] An average of the carbon held in the two seasons is taken as the carbon held over a year.

C (Intervention) 2013 = Carbon held in intervention villages in 2013 in two seasons.

C (Control) 2018 = Carbon held in intervention villages in 2018 in two seasons.

C (Control) 2013 = Carbon held in intervention villages in 2013 in two seasons.

Where:

A (Intervention) 2018 = Area under crops in intervention villages in 2018.

A (Intervention) 2018 = Area under crops in intervention villages in 2013.

A (Control) 2018 = Area under crops in intervention villages in 2018.

A (Control) 2018 = Area under crops in intervention villages in 2013.

This gain is then valued at the social cost of carbon, which is taken as $92/ton of carbon (Rennert, K. and Kingdon C., 2019). The most recent reviews of the social costs gave a wide range. The figures vary for many reasons, of which a key one is the discount rate applied to future damages from a release of CO_2. A suggested middle ground by the Resources for the Future (RFF) suggests value of $50/ton of CO_2 at 3% discount rate and $14/ton CO_2 at 5% discount rate in 2019 (Rennert, K. and Kingdon C., 2019). The preferred discount rate for this study has been 4%, in which case an approximate value would be around $25 per ton of CO_2. Since we are working in tons of carbon. the figure has to be multiplied by 3.67, the conversion factor in going from CO_2 to C. That gives a value per ton sequestered of $92, assuming it is permanently sequestered.

The gain as a result of the intervention in carbon held in the ground is estimated as:

$$\Delta G\ (\text{Intervention}) = [\Delta C\ (\text{Intervention/Ha}) - \Delta C\ (\text{Control/Ha})] \text{x}\ A\ (\text{Intervention})_{2018}$$

The resulting estimates of carbon stored as a result of the intervention are shown in Table 15. The largest gain is in Datia, followed by Niwari and Shivpuri.

Table 15: Carbon Sequestered Benefits as a Result of the Intervention (Rs. 000)

District	Intervention Village					Control Villages					Increase in C Due to Intervention		Value Rs.000
	2013		2018		Change/ Ha.	2013		2018		Change/ Ha.			
	Carbon	Area	Carbon	Area		Carbon	Area	Carbon	Area		Per Ha.	Total	
Datia	215,531	5,179	316,788	5,638	15	143,746	2,630	143,955	3,071	-8	22	126,072	811,905
Shivpuri	291,978	881	292,602	965	-28	200,672	499	201,782	553	-37	9	8,909	57,376
Niwari	155,158	2,526	153,099	2,266	6	45,101	475	43,723	520	-11	17	38,608	248,635

Source: Calculation based on data collected by DA team

Costs of the Interventions

Information on costs of the interventions in the intervention villages of the selected three districts are summarised in Table 16. Costs are divided into construction, inputs and support for agriculture and support to build up social institutions. Expenditures were undertaken over a number of years in each case. For the analysis it is assumed the expenditures are spread equally over the period.

As seen in Table 16, the interventions include construction (e.g. watershed structure), agriculture (e.g. provision of seeds, capacity building of farmers, promotion of vegetable cultivation etc.) and formation of social institutions (carried out in different time periods like 2011- 2016, 2012- 2017 in different administrative blocks of the selected districts). It is found that in Datia, the cost of interventions was the highest in Datia, Shivpuri had the highest cost of intervention in agriculture among the districts, while no agricultural intervention was done in Niwari. The cost of interventions for formation of social institutions was the highest in Datia among the three districts.

Table 16: Costs of the Interventions in the intervention Villages (Rs. Lakhs[19])

Districts	Construction	Agriculture	Social Inst. 1	Social Inst. 2
Datia	2011 to 2017	2015 to 2018	2011 to 2016	2012 to 2016
	406.09	2.40	10.75	1.90
Shivpuri	2016 to 2018	2013 to 2020		2012 to 2014
	272.0	4.5		5.7
Niwari	2011 to 2018			2008 to 2014
	224.3			5.4

Source: Calculation based on primary data collected from the field by DA team

Cost Benefit Analysis

Overall changes in monetary benefits from crop production, livestock and forest in the study site are shown in Figure 32, Figure 33 and Figure 34. It reflects a visibly positive impact of interventions for land remediation in the intervention villages.

It has been revealed that the biodiversity (measured in terms of mean species abundance) has been improved in intervention villages from 2013 to 2018 but in the control villages it was not the case.

Carbon sequestered in the land showed largest gain in Datia, followed by Niwari and Shivpuri. But the overall carbon sequestration per hectare of land had remained almost unchanged in intervention villages and slightly declined in control villages.

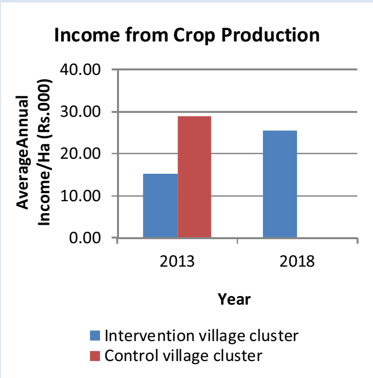


Figure 32

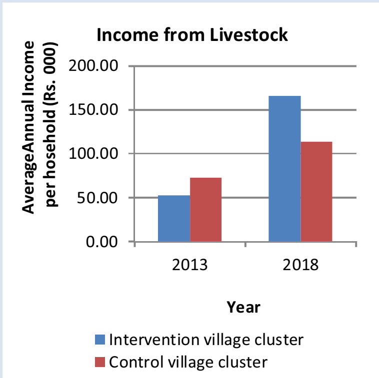


Figure 33

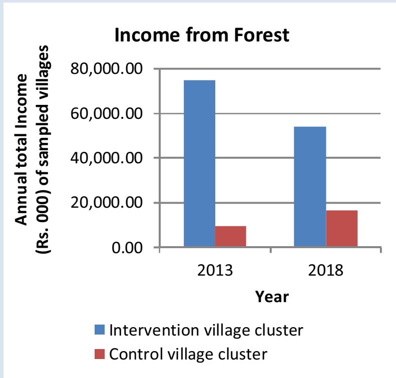


Figure 34

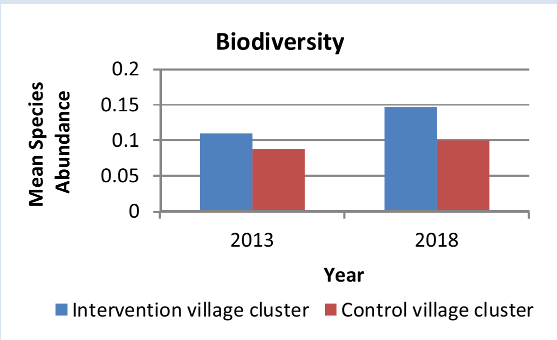


Figure 35

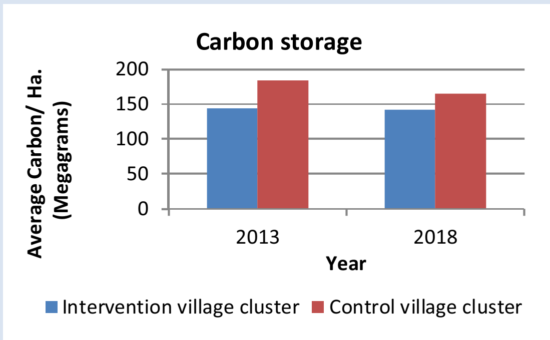


Figure 36

A comparison of the benefits and costs using a standard cost-benefit method has been reported in Table 17. The details of the calculations were laid out in Annexure III. The method consists of adding up all the benefits by year and all the costs by year and deriving a time profile of both. Future costs and benefits with the interventions were estimated based on the expected period that the benefits will last long. It is important to note that all future costs and benefits are projected at constant pries i.e. net of any inflation.

[19] A Lakh is 100,000

Where necessary the raw data were adjusted to allow for market imperfections or taxes and subsidies. (e.g. prices were net of taxes and subsidies). The present value (PV) of the costs and benefits were then calculated using an agreed discount rate that reflected rates typically applied to projects in this sector in the country. Here a discount rate of ten percent has been applied, which has been used in India for public sector project appraisal. It is assumed here that the benefits as reported in Tables above in terms of better ecosystem services from cropland, livestock, forest and improved biodiversity will continue to be sustained until 2040 (i.e. for 22 years)[20].

From the PV of the costs and benefits summary three indicators are derived. The first is the net present value (NPV) of the project, which is the difference between the PV of the benefits and that of the costs. A necessary but not sufficient condition for the project to be considered a success is that the NPV be greater than zero. A second indicator is the ratio of the PV of the benefits divided by the PV of the costs. This is called the benefit-cost ratio and a minimum value for it to be acceptable is greater than one. Where resources are scarce values greater than one may be required. The third indicator that is commonly also reported is the internal rate of return (IRR), which can be thought of as the discount rate at which the NPV is zero. The higher the IRR the better the performance of the project; a minimum value for IRR, however, is the discount rate applied to the project.

The intervention yields highly significant direct benefits in Datia and Shivpuri and significant but somewhat less benefits inNiwari. The benefit to cost ratios are respectively 124, 148and 69in the three districts. The interventions yield huge IRRs of 74% and 191% and 78% respectively in Datia, Shivpuri and Niwari.

The figures provided here have considerable ranges of uncertainty. It was not possible to estimate these from the data provided but as an alternative a sensitivity analysis can be carried out. One way of doing that is to assume that the benefits are lower than estimated, and scaling them down (or up if the project has an NPV<0) until the project has an NPV=0 (i.e. it is on the verge of being viable). Another is to suppose that the costs are underestimated and scale them up (or down if the project has an NOV<0) until the stream of annual costs are just enough to give an NPV=0 for the project. Table 9 shows that benefits need be less than2% of the estimated values in Datia and 1% in Shivpuri to give a just positive NPV. In Niwari benefits would have to be closer to 3% of actual amounts to reach the same goal. In terms of costs they could be 6,200% higher in Datia, 7,500% higher in Shivpuri and 3,500% higher in Niwari to still yield an NPV greater than zero. This is important because some of the labour costs of the intervention have been underestimated in the data; from this analysis it is unlikely, however, that they would be enough to make a difference.

Table 17: Summary Cost Benefit Indicators

				Sensitivity Analysis for NPV>0	
District	**NPV of Net Benefits (Rs. Crore)**	**Benefit Cost Ratio**	**IRR**	**Max Decrease in Benefits**	**Max Increase in Costs**
Datia	483	124	74	98%	6,200%
Shivpuri	228	148	191	99%	7,500%
Niwari	130	69	78	97%	3,500%

Source: Calculations done by the project team. Note: A crore is 10 million. IRR: Internal Rate of Return

3.2 Analysis in Terms of Capitals

In this section the impacts of the intervention in terms of the increases in natural and other forms of capital achieved was measured and their contribution to the SDGs were analysed. In this case, efforts were given to estimate the increase in the value of natural capital and made an appraisal of the change in the social capital (in non-monetary terms) as well as of the change in human capital (partially in monetary terms). A qualitative analysis of cultural capital was also performed in this context.

Natural Capital

The change in natural capital is measured as the increase in the value of the services provided by the land that has been remediated. The increase in annual value is the difference in value in 2018 and that in

[20] For carbon it is assumed the benefits are held permanently; if they cease in 2040, however, the difference in the social cost of carbon will be small.

[21] This assumption needs some justification. It may require, for example, limits on some unsustainable practices. Further information on these will be required to analyse how these might change the flow of services into the future.

2013. This is assumed to continue into the future and the stream of services is discounted at 10%[21]. The results are shown in Table 16. Increases in natural capital are found in all three districts, ranging from Rs. 517 crores (US$73.9mn) in Datia, Rs. 239 crores (US$34.1mn.) in Shivpuri and Rs. 218 crores (US$31.1 mn.) in Niwari. This reflects that Datia had the highest gain in natural capital value during 2013- 2018.

Table 18: Changes in Natural Capital

	District	Datia	Shivpuri	Niwari
Ha.	Area Cultivated 2013	5,179	881	2,526
Rs. Crore	Crop Income	15.0	0.03	4.09
	Livestock Income	22.0	7.1	5.7
	Forest Income	0.3	7.2	0.0
	Value of Natural Capital	373.5	143.0	98.1
Ha.	Area Cultivated 2018	5,638	965	2,266
Rs. Crore	Crop Income	21.1	2.3	3.5
	Livestock Income	58.1	28.9	28.0
	Forest Income	1.26	4.14	0.00
	Value of Natural Capital	805.2	352.9	315.2
Rs. Crore	Ä in Biodiversity Services	20.9	28.2	2.52
Rs. Crore	Ä in Carbon Services	65.2	0.4	-1.3
Rs. Crore	Ä in Total Natural Capital	517.9	238.6	218.3
Rs. Crore	Cost of Program	3.9	1.5	1.9
Natural Capital Leveraging Per Crore Rupees		132	154	114

Source: Calculations by the project team

When the increase in the value of the natural capital is compared to the costs of achieving it we found that the leveraging obtained per crore rupees spent on remediation was lowest in Niwari, highest in Shivpuri and intermediate in Datia.

Social Capital

It was quite difficult to collect enough data to make the desirable assessment of changes in social capital since there was no base line data for 2013. Data were

Table 19: Indicators of Social Capital

No. of social institutions		2018	2013
Intervention	**Niwari**	27	34
	Shivpuri	55	108
	Datia	-	87
Control	**Niwari**	10	0
	Shivpuri	44	0
% Adults migrating		**2018**	**2013**
Intervention	**Niwari**	14.9	57.2
	Shivpuri	14	26.9
Control	**Niwari**	39	75
	Shivpuri	9	57.1

Source: Calculations based on primary data collected from field by DA team solicited on number and quality of institutions and individual participation in them, on education and health status of the population in the intervention and control villages and on the rates of migration and work done outside the villages. The only consistent data obtained were for migration and social institution numbers and membership. These are presented in Table 19.

The data showed a decrease in the number of social institutions between 2013 and 2018 in intervention villages. Discussions with local residents and officials revealed that the number of social institutions that were set up initially (in 2013) were not all functional with the reasons being low motivation to participate in social institutions, differences in opinion among members, lack of savings resulting in financial unsustainability etc. The situation changed gradually and therefore, in spite of having lesser number of social institutions, the existing ones became more effective with higher levels of participation. The limitation of some missing data on number of social institutions also existed. In spite of that, it was found that the number of social institutions was higher in intervention villages than that of control villages. Also, the diversity in terms of types of social institutions increased in 2018 in both intervention and control villages as seen in Table 20 and Table 21.

Table 20: Types of social institutions in intervention villages

District	2013	2018
Niwari	Watershed committee, SHG, FPO	Watershed committee, SHG, FPO
Shivpuri	Watershed committee, SHG	Watershed committee, SHG, Anganwadi
Datia	Data not available	Data not available

Source: Primary field survey

Table 21: Types of social institutions in control villages

District	2013	2018
Niwari	- Data not available	SHG
Shivpuri	- Data not available	SHG, Anganwadi
Datia	- Data not available	Data not available

Source: Primary field survey by DA team

In terms of migration one might take the view that if opportunities for income from land improved in the villages, the rate of migration would have declined. In general, all groups (intervention and control) showeda smaller percentage of the population of the villages migrated for work in 2018 than in 2013. This could be a sign of increased social capital.

The locals in the areas studied, when asked about migration, revealed that both push and pull factors were responsible for migration in the region. The migrants often get exposed to difficulties in pay, payment of rent, adjusting with the new place and people, etc. The people who have left had a difficult time setting up their homes in the urban areas due to lack of familiarity with the socio-cultural norms in the destination area. Although some were able to get successfully established and have stable income, but majority still want to visit their origins villages frequently and transfer their income majorly for their home in the villages. In general, It can be inferred that the decline in migration is a sign of increase in social capital.

Perception of the local community about the ecosystem services is also another vital aspect of social capital. Based on a perception mapping carried out in the intervention and control villages in Datia some important observations were made regarding the awareness of the local community about the ecosystem linkage of the benefits they derived either directly or indirectly through ecosystem services. The outcomes are shown in Table 22 and in Appendix Table 29. The intervention villages in Datia had shown a better awareness (in terms of higher proportion of respondents who are aware) about the ecosystem connections of some of the ecosystem services like freshwater, food, fuel, natural medicines under provisioning services, air quality, climate regulation, pollination under regulatory ecosystem services, recreation and tourism, aesthetic value under cultural services and habitat support for species and water cycling under supporting services. The respondents in Datia were found to have extensive knowledge[22] about the existing pollinator and non-pollinator insects. Through the perception mapping they reported the usefulness of both pollinators and non-pollinators[23]. Hence it is a good sign that some of the major services that are related with use of natural resources for livelihood and healthcare practices, recreational practices are perceived by a major proportion of the local communities in intervention as ecosystem benefit. But in case of some of these ecosystem benefits the control villages had a lesser awareness. But for ecosystem services like pest and disease regulation, collection of fiber, mineral resources, water purification, erosion control, salinity regulation both intervention and control villages had lesser awareness. These were mostly related with the ecosystem processes that create other visible impacts. Hence it is required to address these gaps to improve social capital through capacity building and awareness development interventions for the village communities. It would eventually aid in sustenance of the natural capital and human well-being.

[22] But, the respondents from the local communities found it difficult to differentiate between the four species of Apis, however after showing the differences in size of the species, they were able to tell. They were also not able to tell the difference between different Xylocopa species unless prompted.

[23] Detailed list of pollinator and non-pollinator insects along with their usefulness are given in Table 29 of Chapter 6

Table 22: Perception mapping of the ecosystem services for Intervention and Control villages in Datia

Ecosystem service categories	Ecosystem Services	Datia Intervention Villages			Datia Control Villages		
		% of respondents unaware about ecosystem connection of the benefit	Benefit is derived from ecosystem		% of respondents unaware about ecosystem connection of the benefit	Benefit is derived from ecosystem	
			% of respondents not perceiving the ecosystem benefit to be important	% of respondents perceiving the ecosystem benefit to be important		% of respondents not perceiving the ecosystem benefit to be important	% of respondents perceiving the ecosystem benefit to be important
Provisioning services	**Fresh water**	0.00	0.00	100.00	0.00	0.00	100.00
	Food	0.00	0.00	100.00	0.00	0.00	100.00
	Fiber	63.38	28.17	8.45	14.56	60.19	25.24
	Fuel	0.00	29.58	70.42	50.60	0.00	49.40
	Natural medicines	28.17	39.44	32.39	51.81	1.20	46.99
	Genetic resources	77.46	0.00	22.54	24.10	18.07	57.83
	Ornamental resources	77.46	14.08	8.45	81.93	18.07	0.00
	Clay,mineral, aggregate harvesting	100.00	0.00	0.00	81.93	18.07	0.00
Regulatory services	**Air quality regulation**	8.45	28.17	63.38	32.53	0.00	67.47
	Climate regulation	0.00	0.00	100.00	32.53	0.00	67.47
	Water purification and waste treatment	17.86	0.00	82.14	100.00	0.00	0.00
	Regulation of water flow	8.45	0.00	91.55	66.27	0.00	33.73
	Natural hazard regulation (flood, drought, storm, fire etc)	0.00	0.00	100.00	33.73	0.00	66.27
	Pest regulation	63.38	8.45	28.17	84.34	12.05	3.61
	Disease regulation	63.38	8.45	28.17	97.59	0.00	2.41
	Erosion control	56.34	0.00	43.66	40.96	24.10	34.94

Ecosystem service categories	Ecosystem Services	Datia Intervention Villages			Datia Control Villages		
		% of respondents unaware about ecosystem connection of the benefit	Benefit is derived from ecosystem		% of respondents unaware about ecosystem connection of the benefit	Benefit is derived from ecosystem	
			% of respondents not perceiving the ecosystem benefit to be important	% of respondents perceiving the ecosystem benefit to be important		% of respondents not perceiving the ecosystem benefit to be important	% of respondents perceiving the ecosystem benefit to be important
	Water purification	100.00	0.00	0.00	91.57	0.00	8.43
	Pollination	0.00	28.17	71.83	0.00	31.33	68.67
	Carbon sequestration and storage	0.00	63.38	36.62	0.00	91.57	8.43
	Salinity regulation	100.00	0.00	0.00	-	-	-
Cultural Services	Culture	28.17	0.00	71.83	33.73	0.00	66.27
	Recreation and tourism	0.00	0.00	100.00	33.73	24.10	42.17
	Aesthetic value	0.00	28.17	71.83	33.73	24.10	42.17
	Spiritual and religious value (temples)	28.17	0.00	71.83	33.73	0.00	66.27
	Social relations	28.17	0.00	71.83	33.73	0.00	66.27
	Education	42.25	14.08	43.66	33.73	0.00	66.27
Supporting services	Soil formation	0.00	0.00	100.00	42.17	0.00	57.83
	Primary production (accumulation of energy and nutrients)	42.25	21.13	36.62	100.00	0.00	0.00
	Nutrient cycling	100.00	0.00	0.00	100.00	0.00	0.00
	Habitat support for species	0.00	28.17	71.83	0.00	57.83	42.17
	Water cycling	0.00	7.04	92.96	32.53	0.00	67.47
	Maintenance of genetic diversity	56.34	8.45	35.21	60.24	24.10	15.66

Source: Based on primary data collected by DA team

Human Capital

Indicators of human capital include the health status of the population and the level of education that children attain, one affecting its current productivity and the other its future productivity. Human capital can also be measured in terms of earnings per individual or household. Of these three sources only data are available on income per household[24]. This is shown in constant prices in Table 21.

Table 23: Income per Household (Rs. 000 year)

Income Per HH Rs. 000/Yr.		2018	2013	% Gain
Intervention	Datia	319	152	110%
	Shivpuri	176	82	116%
	Niwari	154	46	232%

Source: Calculations by DA and BC3 team based on primary data

Income per household in intervention villages increased significantly in all villages, with the greatest increase in Niwari, followed by Shivpuri and Datia. Thus the ranking by income per household was not the same as that by net benefits and natural capital gains, where Datia performed best and Niwari the least well. Here Niwari was the best performer. However, human capital assessment in terms of household earning is also associated with gains from natural capital (e.g. gains from cultivation, livestock rearing etc.).

Some of the indicators of health and education were also used to assess differences in the status of human capital in 2018 between intervention and control villages. The percentage of sampled population with illnesses and the literacy rates were evaluated in intervention and control villages. The outcomes are reported in Table 22. It was found that in terms of literacy rate (i.e. educational indicator) intervention villages in Niwari had performed better than that of control villages and thus implying better strength in human capital.

Table 24: Status of Human capital[25] based on indicators of health and education in Intervention and Control villages in 2018

District	% of population with illnesses		Literacy rate (%)	
	Intervention villages	Control villages	Intervention villages	Control villages
Niwari	6.95	1.94	79.54	74.24
Shivpuri	10.08	3.70	67.13	76.42
Datia	Data not available	Data not available	Data not available	Data not available

Source: Primary field survey

Cultural Capital

Cultural ecosystem services which constitute cultural capital are the "nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (Millennium Ecosystem Assessment, 2005). Cultural capital refers to the cultural value systems (Throsby 1999) that are carried over generations mostly through oral traditions. Although the cultural services cannot be easily quantified like the other ecosystem services, yet the intangible benefits of cultural ecosystem services such as physical, emotional and mental contributions perceived cannot be foregone (Kenter et al. 2011). The interconnectedness between natural capital and human comes even close through the cultural ecosystem services as indicated through the Convention on Biological Diversity, Millennium Ecosystem Assessment, Economics of Ecosystems and Biodiversity and European Landscape Convention (Vasiljevic et al., 2019). Some other examples are recreation, tourism, spirituality, aesthetic peace and overall human well-bring (IUCN)[26]. The idea behind

[24] Even for this indicator we do not have income from outside the farm. Migration and working away from home has declined, so such income would probably decline but this needs to be confirmed.

[25] Calculations based on sampled population

[26] https://www.iucn.org/sites/dev/files/import/downloads/urbes_factsheet_08_web.pdf

ecosystem services has been gaining a lot of attention especially by the decision makers and the cultural capital seems to be missed in such cases. With nature being looked at for answers to the human problems (Gould, Morse, & Adams, 2019), decision makers can also integrate them. On the basis of this concept, this study looks at how land remediation interventions in the intervention villages of Bundelkhand have maintained the relationship between people and nature which in turn aided in sustainable use of natural resources and the provisioning ecosystem services. Two case studies on cultural capital have been presented in this section.

Integrated watershed management projects have significant effects on the land and water which have not only enhanced the natural capital of the region but also have strengthened its ties to people. The case study on Kamhar village depicts the local communities celebrating the festival of Akshaya Tritiya in an unique way other than rest of the country. The locals worship the Banyan Tree and than kit for all its contribution to tie the villagers together. Due to the integrated watershed management, recharge in the ground water, the biodiversity remains intact. The case study on Medicinal plant collection for herbal healing shows the combined benefit from provisioning ecosystem services and cultural ecosystem services. The natural vegetation of the area is not only strengthened by the interventions but the interventions have also indirectly contributed towards maintenance of traditional medicinal knowledge and practices of local communities by ensuring availability of the natural resources. It also potentially leads to community empowerment through self-sustaining healthcare and human wellbeing practices.

Therefore, people are not only engaged in traditional cultural practices of the village, thus bringing social cohesion and enhancing collective decision making but the ecosystem health is also being maintained. Hence sustainability of ecosystem and ecosystem services also strengthens cultural and social capital at the micro level. Thus in the policy dimension too, the value of cultural capital needs to be recognized for having a holistic approach to development.

Cultural Capital: Case Study 1

Watershed Development Programme for harnessing cultural ecosystem services: The case of Kamhar village and its festivals

Kamhar village, a sparsely populated hamlet located in the Datia district, is one of the few villages that traces its roots back to Bundelkhand's cultural and glorious past. Growing up together as well as spending leisure times in each other's courtyards, each household in the village is somehow related to the neighboring household. The people in the village are simple and have always loved celebrating festivals and other traditions together. From Diwali, Lodhi to Vat Vriksh and even Amalaka Ekadashi, among others, the people of Kamhar have been celebrating them all since the ancestral times. All these festivals have their roots in nature. Although, the social solidity (i.e. social capital) had been seen reducing over the years, yet the people of the village have not forgotten to rejoice in the natural surroundings. The Integrated Watershed Management Programme has one such prominent example of the Kamhar locals reveling in mother Nature which is through the Akshaya Tritiya festival.

Commonly known as "Akha" in Datia district, the festival falls on the lunar day of Shukla Paksha (waxing moon period) of the Indian month of Vaisakha (during the English calendar month of April- May). The day of Akshaya Tritiya is an emblem of eternal prosperity and parts of India generally celebrate this festival by buying gold or by starting a new venture in hopes of wealth and fortune throughout the year. In the village of Kamhar, this festival is celebrated differently. The Banyan tree has been an immortal symbol of Trimurthi and wish fulfillment and has, therefore, always been considered a focal point by the village communities. On this auspicious day the women of the village gather, worship and prepare a religious offering under the Banyan tree (Ficus bengalensis) thanking nature and wishing for good fortune and a continuous supply of rainwater and agricultural produce.Mean while, the rest of the people fall in line and wait for the distribution of Prasad(made of rice, dhol and Chana dal with some tulsi leaves and flowers served on a Banyan leaf) prepared by the women.

The fortunate day is remembered as an important one throughout the Indian mythology for several events - the occasion when Lord Krishna presented Yudhishter (eldest of the Pandavas) a bowl – Akshaya Patramthat supplied unlimited amount of food and the birth of the Goddess of Food, Annapurna, among others. Thepeople of Kamhar associate this day relishing the fruits of the natural environment including the sanctity of the trees along with the other materialistic benefits.

Figure 37: Ficusbengalensis

Realizing the role nature plays in bringing people together; people have been willing and appreciative in maintaining the natural heritage of the area. The people understand that were it not for the trees (symbolizing natural heritage) there wouldn't be any relief from the heat and lack of electricity during summers, the air wouldn't be good and the beauty of the surroundings would be far less than what it is presently. Moreover, the leaves of the tree have medicinal properties, which are used to cure diarrhea and urine disorders. Ficus is a symbol of 'strength and solidarity' and it stands as one of the most sacred and medicinally important trees, therefore an integral part of Kamhar's fundamental core.

The diversity of such celebrations may have reduced in the village but the frequencies of the existing festivals remain. The awareness and practices of the local communities, supplemented with interventions like integrated watershed management programme have significant potential to conserve trees and thus nature. The people thereby are able to build on the foundation of the village thereby maintaining balance with each other and nature. The community of Kamhar understands the value of biodiversity, natural ecosystems, natural capital and various ecosystem services. Natural capital is well managed in this small village of Datia district with its full value being reflected in the cultural, social and economic choices of the people, and the people have inculcated this as a fundamental part of their happiness and wellbeing.

Integrated watershed management projects have an enormous impact on the water supply of the area. They are also able to replenish the ground water, thereby not only providing enough water for use but also retaining the natural vegetation of the areas. These are likely able to help the people enjoy not only the provisioning ecosystem services but also cultural ecosystem services offered.

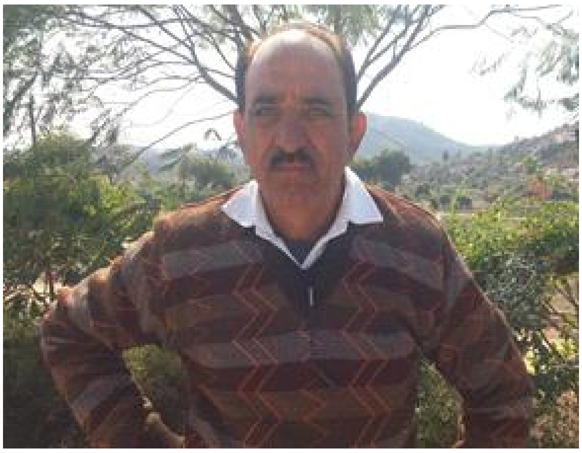


Figure 38: Mr. Narendra Parmer Singh (Farmer from village Kamar in Datia said: "Ye Bargad hai toh hum mil jate hain saal mein ek baar, nahin toh sab apne apne kaam mein itne vyast hain ki bhul jate hain ek dusre ko" (Translation: "The existence of the Bargad tree in our village is the reason we are all able to take out time meet otherwise everyone just forgets to spend time owing to our busy lives.")

Cultural Capital: Case Study 2

Cultural and Provisioning ecosystem services through implementation of Watershed Development Programme: Maintaining a centuries-old tradition of herbal medicinal practice by a Community Herbalist

Trees have been playing a major role in the lives of people since the beginning of time. From providing food and oxygen initially, to shelter, medicines and tools as people evolved, trees have been central to humankind. Although a lot of modern medicines are being used widely by mankind, locals of Chopra village of Datia district in Bundelkhand prefer to get treated through herbal medicinal practitioner.

Anand Das, popularly known as "Maharaj" is a resident of Chopra village. Growing up with the knowledge of indigenous plants through his ancestors, not only does he know the ways around the dense forests but also the medicinal significance of each plant component whether present inside the village or not. This rich traditional knowledge system signifies existence of the cultural ecosystem service which is retained mainly through inter-generational knowledge flow in the village community. Anand Das took over this natural healing practice in his middle age realizing the importance of natural cures, the severe side effects

Figure 39: "Maharaj" Anand Das

that allopathic medicines create and to contribute towards sustainable management of plantation and forest areas. A humble and robust man, residing within the walls of a Hanuman temple he is often visited by people from all over Datia district and sometimes other parts of India in search of relief through a natural remedy.

Mr. Das has been practicing traditional healing in Chopra village not only using the common medicinal plants but also through the wild and uncommon from the intact forests of Chopra as well as the plantations outside the village. Dakshini babool (gum Arabic tree), Kele ki gaanth (Banana node), arjun ki chaal (Arjun tree bark), safed musli (Indian Spider plant)and ban tulsi (wild basil) are some of the plants he advises people for acute as well as chronic diseases. These medicinal plants, which play a vital role in local healthcare services and meet growing population needs, have been experiencing over-exploitation for several years, as pointed out by Mr. Das.This leads to reduction in provisioning services of the forest ecosystem. He has not only seen the depletion of lush forests of the village, but also the reduction in the awareness of traditional knowledge in India. Hence, the traditional practices involving the use of the ecosystem services for a sustainable living are under threat. He believes that to create a legacy and preserve the local plant knowledge, documentation of the same has now become crucial. He does not believe in the practice of charging a high cost rather, to pass information as well as help cure people providing a normal budget consultation for curing ailments.

Figure 40: The temple from where Mr. Anand Das continues his practice

Integrated watershed management projects have significant effect on the land and water which have the capacity for enhancing not only the provisioning ecosystem services like availability of medicinal plants but also have potential to maintaining the cultural practices through proper implementation by ensuring participation of the local communities. These are likely to enable the people of the village to retain their traditional knowledge (i.e. cultural ecosystem service) through sustainable use of the provisioning services like medicinal plants.

The following section looks at the links between these indicators of natural, social, human and cultural capital and the SDGs.

3.3 Mapping the scope of land remediation programs on the SDGs

As noted in the Chapter 1, the land remediation programmes in Bundelkhand was closely linked to the SDGs. The programmes contributed to the outcome of the seven goals and fifteen targets of the Sustainable Development Goals (SDGs). The objectives, scopes and relevant findings of the study were mapped against the national indicators of the SDGs. Eighteen national indicators under each of the targets of SDG were found to be relevant in the context of this study. Observations in the SDG assessment were in the form of higher positive changes in intervention villages over control villages during 2013-2018.

SDGs 1, 2 and 8 is about ending poverty, hunger as well as promoting inclusive and sustainable agriculture, economic growth, full and productive employment and decent work for all within which national indicators on SHG formation (1.3.4), implementation of local disaster risk reduction strategies (1.5.2), expenditure on social protection (1.5.2.1.a.2), wheat and rice agricultural productivity (2.3.1), degraded land to net sown land proportion (2.4.1) and migrant workers (8.8)were addressed by the implementation of the land remediation programs. Setting up of a number of social institutions including SHGs has contributed towards social protection and protecting labour rights (national indicators 1.3.4, 1.5.2.1.a.2, 8.8) which has improved the social capital of the study area. In the year 2018, SHGs in control villages for Niwari and Shivpuri grew only to 10 and 42 respectively as compared to 22 and 50 in the intervention villages for the districts. Apart from that there were other social institutions like FPOs, Anganwadi workers etc. in the study site. The migration rate in the intervention villages reduced more than control villages during 2013 to 2018. Although the change in the adults migrating from the control villages has also drastically reduced but for Niwari district, the migration rate change for intervention villages is much higher than the control villages. The human capital has been improved in the form of increased income, betterment in health and education system by utilising drought-reducing approaches and strengthening of social capital happened by building capacities of the rural communities, formation of social institutions etc. (these are linked to SDGs 1.5.2, 2.3.1, 2.4.1 and 2.4.2). These in turn result in better resilience against adverse climatic conditions and other natural threats. Rise in income was directly associated with benefits from increased agricultural and livestock productivity. In the case of wheat and rice production, it was found that rate of change in average yields was higher for intervention villages during 2013-2018. In the control villages yield had reduced during 2013 - 2018.SDGs 6 and 12 are about ensuring water and sanitation for all and sustainable consumption and production. The national indicators for river basins brought under integrated water resources management (6.5.1), per capita use of natural resources (12.2.1) and per capita food availability (12.3.1) are also linked to the programs directly. More than 15 soil and water harvesting structures were constructed in each of the intervention villages in the study site which have contributed towards integrated water resource management (6.5.1). Ensuring sustainable management and reducing food waste were addressed by this study by showcasing the change in income from agriculture as well as forestry sector (12.2.1 and 12.3.1). The change in crop production income from 2013- 2018 for intervention villages of Datia, Niwari and Shivpuri districts were much higher as compared to the control villages.

Action towards climate crisis and it's impacts linked to SDG 13 within which national indicators on strategies for climate adaptation (13.1.1), pre 2020 action regarding climate change (13.2.1) and integrating climate change in outreach programs (13.3.1) were addressed in the study. Overall assessment of the climate adaptation strategies in terms of natural, human and social capitals contributed towards strengthening climate resilience, adaptive capacity and reduction in impact of hazards. The policy implications from the outcomes of the study have potential to contribute towards incorporation of the climate change measures into national policies, strategies and planning. SDG 15 incorporates protection, restoration and promotion of sustainable use of terrestrial ecosystems, sustainably managed forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Under SDG 15, national indicators on percentage of trees outside forest (15.1.2), net sown area (15.3.3), Aichi target 2 (15.9.1), expenditure on conservation and sustainable use of biodiversity (15.9.1.a.1) and expenditure on environmental conservation (15.9.1.b.1)were addressed in the study. Classification of different land use land cover categories showcasing the change over the years in the three districts contributed towards conservation, restoration and combating desertification on land affected by droughts (15.1.2, 15.3.3 description as above). In 2013, the double cropped area for all the three districts was much higher than the control villages. By the year 2018, the double cropped area for all the intervention villages of the three districts increased significantly. The area of double cropped area reduced for control villages of Niwari and the % of change in the double cropped area for Shivpuri intervention villages was higher than control villages. Evaluation of the change in the mean species abundance in Datia, Niwari and Shivpuri districts over the years via the GLOBIO model for the purpose of this study, formulated a way for contributing towards integrating ecosystem and biodiversity into poverty reduction (15.19.1). The change in income during 2013-2018 comparatively higher in intervention villages for all the three districts. By aiming at economic evaluation of the ecosystem services primarily important for the local communities, the study also highlighted the necessity of policy making for mobilization of financial resources in terms of allocation of financial resources for strengthening natural, social and human capitals to conserve and promoting sustainable use forest and biodiversity (15.9.1.a.1 and 15.9.1.b.1). This can act as important information for decision makers to prepare informed decisions for similar geographies in terms of climate change adaptation. SDG 17 is about strengthening the means of implementation and revitalization of the Global Partnership for Sustainable Development under which 17.19 target (building on existing initiatives) was addressed. The tracking of each of the indicators and the outputs from the study is built upon existing initiatives that are being assessed in this study. Also by preparing a toolkit for valuation of natural capital this study also builds scope for replication and modifications under different contexts. Hence through these it is addressing the target 17.19. In this way the study would be conducive for developing measurements of progress to achieve sustainable development and would support statistical capacity-building in developing countries like India.

A detailed mapping of all the SDGs have been done in the following table.

Table 25: Linking Sustainable Development Goals (SDGs) - National Indicator Framework with DA's land remediation programs

Target	National Indicator	DA-ELD Contribution	ELD Indicator (parameters)	Data Source	Observations
Goal 1 : End poverty in all its forms everywhere					
1.3 : Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable	1.3.4 : Number of Self Help Groups (SHGs) formed and provided bank credit linkage	Comparative assessment of social capital	64 SHGs were set up by 2013 in intervention villages in Shivpuri and 22 in Niwari whereas 22 SHGs remained in Niwari and 50 SHGs in Shivpuri in 2018. No SHGs in control villages.	Primary	In the year 2018, SHGs in control villages for Niwari and Shivpuri grew only to 10 and 42 respectively as compared to 22 and 50 in the intervention villages for the districts.
1.5 : By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters	1.5.2 : Proportion of States that adopt and implement local disaster risk reduction strategies in line with national disaster reduction strategies	Assessment of benefits (by evaluating changes in natural, human and social capital) of land remediation initiatives by DA	Cost benefit analysis of effective land remediation initiatives between 2013 (base year) and 2018 for control and intervention villages in three districts in Bundelkhand	Primary and secondary	Difference in rankings for district wise performance showing best climate adaptation strategies for reducing the effects of droughts
1.a : Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions	1.a.2 : Proportion of total government spending on essential services (education, health and social protection)	Comparative assessment of social and human capital	Social institutions in control and intervention villages for 2 districts in 2018	Primary	By the year 2018, social institutions in intervention villages in Niwari and Shivpuri were 31 and 57 respectively and in control 11 and 45 for the respective districts mentioned.

Target	National Indicator	DA-ELD Contribution	ELD Indicator (parameters)	Data Source	Observations
Goal 2 : End hunger, achieve food security and improved nutrition and promote sustainable agriculture					
2.3 : By 2030, double the agricultural productivity and incomes of small- scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	2.3.1 : Agriculture productivity of wheat and rice (yield per hectare)	Comparative assessment of wheat and rice crop productivity assessment done in both control and intervention villages	Average Wheat and rice yields between 2013 and 2018 for intervention and control villages collected human capital	Primary	By the year 2018, the wheat yield for the intervention villages of Niwari increased from 14.98 to 18.54 Q/ha and for rice it increased from 0 to 27 Q/ha for Shivpuri. The control villages saw decrease in wheat and rice yields.
2.4 : By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	2.4.1 : Proportion of degraded land to net sown area	Comparative assessment of crop land and wasteland areas	Land use land cover for 2013 and 2018 years in intervention and control villages for three districts collected and compared	Secondary (RS and GIS)	The results have indicated decrease in wasteland area for Datia district in both intervention and cont. villages by the year 2018. The wasteland area decreased from 138.62 Ha to 102.78 Ha for intervention villages and 260.02 to 236.52 Ha for control villages by 2018 for Datia district. Additionally, cropland area for intervention villages and control

Target	National Indicator	DA-ELD Contribution	ELD Indicator (parameters)	Data Source	Observations
					villages of Datia, Niwari and Shivpuri also increased from 2013 to 2018. It changed to 3115.84 from 2996.68 Ha for Datia, 3885.48 from 3802.16 Ha for Niwari and 1189.79 Ha from 1166.89 Ha in Shivpuri district for the intervention villages. While, cropland area changed to 3699.98 from 3669.89 Ha in Datia, 723.04 from 718.55 Ha in Niwari and 1141.22 Ha from 1121.15 Ha in Shivpuri for the control villages of the three districts.
Goal 6 : Ensure availability and sustainable management of water and sanitation for all					
6.5 : By 2030, implement integrated water resources management at all levels, including through trans-boundary cooperation as appropriate	6.5.1 : Percentage area of river basins brought under integrated water resources management	Number of check dams, gully plugs, loose gabions, canals, etc in intervention villages of the three districts.	By the year 2013, construction of watershed management structures for soil and water harvesting.	Primary	**Construction of more than 15 soil and water harvesting structures in intervention villages of Datia, Niwari and Shivpuri districts.**

Target	National Indicator	DA-ELD Contribution	ELD Indicator (parameters)	Data Source	Observations
Goal 8 : Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all					
8.8 : Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment	8.8.2 : Number of migrant Workers	Comparative assessment of migration in intervention and control villages	Total no. of people migrating seasonally and permanently in 2013 and 2018 for 2 districts	Primary	For the year 2013, the no. of people migrating in control villages for Niwari and Shivpuri were 375 and 1500 respectively. While for the intervention villages, it was 830 and 942 respectively. By the year 2018, the numbers for control villages for Niwari and Shivpuri were 7 and 61 respectively. While for intervention it was 37 and 16 respectively.
Goal 12 : Ensure sustainable consumption and production patterns					
12.2 : By 2030, achieve the sustainable management and efficient use of natural resources	12.2.1 : Percentage variation in per capita use of natural resources	forestry as part of natural capital	Forest products collected and income generated in 2013 and 2018 in intervention of Datia district	Primary	2013-2018 change in income for Datia district intervention villages was Rs. 9,706,000 through collection and selling of forest products.

Target	National Indicator	DA-ELD Contribution	ELD Indicator (parameters)	Data Source	Observations
12.3 : By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	12.3.1 : Per capita food availability	Comparative assessment for crop production component of human and social capital per district	Percentage of self consumption of crop sown and produced for 2013 and 2018 in intervention and control villages	Primary	The 2013-2018 change in aggregate income for intervention villages of Datia, Niwari and Shivpuri districts were 8.46, 23.18 and -0.76 (in Rs. 000) while for control villages for all the three districts, it was seen in negative.
Goal 13:Take urgent action to combat climate change and its impacts					
13.1 : Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	13.1.1 : Number of States with strategies for enhancing adaptive capacity and dealing with climate extreme weather events.	Assessment of implemented climate adaptation strategies through natural, human and social capital evaluation	Land remediation initiatives such as construction of soil and water harvesting structures and promotion of agro-horti models for sustainable agriculture as livelihood	Primary	Ranking of the three districts based on performance in natural capital, social capital and human capital evaluation.
13.2 : Integrate climate change measures into national policies, strategies and planning	13.2.1 : Pre 2020 action achievements of pre 2020 Goals as per country priority.	Assessment of implemented climate adaptation strategies	Land remediation initiatives such as construction of soil and water harvesting structures and promotion of agro-horti models for sustainable agriculture as livelihood	Primary	Ranking of assessed cost-effective and successful climate adaptation strategies that can be further used in similar geographies

Target	National Indicator	DA-ELD Contribution	ELD Indicator (parameters)	Data Source	Observations
13.3 : Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	13.3.1 : Number of States that have integrated climate mitigation and adaptation in education curricula and outreach programs	Economic valuation of land remediation initiatives in context to maintenance and enhancement of natural, human and social capital	Already implemented outreach of adaptation strategies such as integrated watershed management programmes and sustainable agriculture and formation of social institutions	Primary	Ranking of the three districts based on performance in natural capital, social capital and human capital evaluation.
Goal 15 : Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss					
15.1 : By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and dry lands, in line with obligations under international agreement	15.1.2 : Percentage of Tree Outside Forest (TOF) in total forest cover.	Comparison of TOF between control and intervention villages.	GIS based calculation of land use land cover categories including trees outside forest.	Secondary (RS and GIS)	By the year 2018, the TOF cover for intervention villages for Niwari and Shivpuri were 83.65 and 65.53 respectively. While for control it was 4.73 and 27.7 respectively.
15.3 : By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	15.3.3 : Percentage increase in net sown area	Comparative assessment of LULC between 2013 and 2018 for intervention and control villages	GIS based Land use land cover changes for 2013 and 2018 in three districts	RS & GIS (secondary)	In the year 2013, the double cropland area for intervention villages in Datia, Niwari and Shivpuri districts were 1748 Ha, 720 Ha and 472 Ha while in control villages it was 1592 Ha, 320 Ha and 465 Ha

Target	National Indicator	DA-ELD Contribution	ELD Indicator (parameters)	Data Source	Observations
					respectively. By the year 2018, the double cropland area changed. In intervention areas, it was 2067 Ha, 1123 Ha and 532 Ha for datia, Niwari and Shivpuri districts. While in control areas, it changed to 1982, 272 and 501 Ha for Datia, Niwari and Shivpuri districts respectively.
15.9 : By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	15.9.1 : Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategies Plan for Biodiversity 2011-2020	Monetary valuation of change in mean species abundance as part of integration of biodiversity in national accounting	Mean species abundance for 2013 and 2018 for intervention and contl villages per district	Primary and secondary	2013-2018 amount of gains between control and intervention were higher in intervention by 5636, 24068 and 1980 (Rs. 000) for Datia, Shivpuri and Niwari districts.
15.a : Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	15.a.1 : Official development assistance and public expenditure on conservation and sustainable use of biodiversity and eco system.	Economic valuation of ecosystem services in context to maintenance and enhancement of natural, human and social capital	Already implemented outreach of adaptation strategies such as integrated watershed management programmes and sustainable agriculture and formation of social institutions	Primary	Ranking of the three districts based on performance in natural capital, social capital and human capital evaluation.

Target	National Indicator	DA-ELD Contribution	ELD Indicator (parameters)	Data Source	Observations
15.b : Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation	15.b.1 : Percentage of fund utilized for environmental conservation.	Cost-benefit analysis taking total cost spent for implementing climate adaptation strategies	Land remediation initiatives such as construction of soil and water harvesting structures and promotion of agro-horti models	Primary and secondary	Ranking of the three districts based on performance in natural capital, social capital and human capital evaluation.
Goal 17 : Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development					
17.19 : By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries		Tracking of progress achieved within each of the SDG goals	Economic valuation of natural, human and social capital for 2013 and 2018 per district	Primary and Secondary	The study recommends that the natural, social and human capital also could be mainstreamed and contribute in country's GDP calculation and further achieve sustainable development goals of the developing country like India.

The conclusions based on the outcomes of the study and the relevant policy recommendations are discussed in the following Chapter 4

Conclusion and Policy Recommendations

4

The study has evaluated the benefits for programmes for land remediation in the Bundelkhand region of Madhya Pradesh, India, by looking at changes in ecosystem service flows in the form of crop, livestock, forest product provision and biodiversity. In addition to looking at ecosystem flows the method also involved examining changes in different forms of capital in the remediated areas. These focused on natural capital, as well as social, human and cultural capital. The method involved comparing intervention or Intervention areas against control areas in the same districts.

The results were analysed using a cost benefit methodology set out by the ELD program as well as a natural capital approach developed as part of related work. The cost benefit estimates show very high net benefits from the remediation programs, especially for crop and livestock services but also to some extent in terms of biodiversity. There is potential for additional interventions too to ensure that they can indeed be sustained along with the economic viability of the interventions. But overall it can be concluded that the programs have been a major success with modest costs and high benefits.

The cost benefit analysis does not pick up all the impacts of the programmes, such as changes in all aspects of human, social and natural capital. In this study since only the use and marketed value of natural capital or ecosystem services has been assessed, so there is additional scope for assessing the existence values of tangible and intangible ecosystem benefits although it is a challenge to estimate the values of intangible ecosystem benefits. However, a qualitative assessment can be performed to make it more holistic. The capital approach shows that there are significant increases in natural capital, which corroborates the results from the cost benefit analysis. The ranking of the districts according to natural capital gains, however, is not the same as the ranking according to the cost benefit indicators. In this respect the capital approach gives a different perspective on where the programmes have had the greatest success. Social capital is not measureable in a single quantitative indicator but the interviews and data point to more effective social institutions in the intervention villages, with greater participation. There is also some indication of less migration from these villages than there was before. Discussions with affected households indicate that this is something they see as a positive development. In terms of human capital, it was not possible to get enough information on health indicators. One important factor in this regard (and also in relation to social capital) is income per household. This went up significantly in all three districts, but the ranking across the districts with respect to this indicator was not the same as with respect to the cost benefit indicator. Again this provides further information to evaluate the success of the different programs. The findings of the study indicate that the interventions were successful to support India's Land Degradation Neutrality (LDN) target set during United Nations Convention to Combat Desertification (UNCCD) COP 14 at New Delhi to halt the process of land desertification and its consequences. Although the target still remains under review, yet it paves a way for proper planning and implementation of land remediation initiatives and evaluation of best adaptation options that can be locally utilized (Ministry of Environment, Forest and Climate Change, 2012). Apart from that, establishing SDG linkages of the studied interventions and the outcomes is expected to aid in construction of policy directions to achieve various aspects of sustainable development.

Taking into consideration the current climate crises that threatens biodiversity, land, water, air as well as energy among other resources, monitoring and evaluation for proper management of natural resources has emerged as the most significant component in adaptation and mitigation strategies. Along with management and sustainable use of resources, effective governance has now become the need of the hour especially in terms of reducing the negative impacts on livelihoods of people mainly the poor. The direct and indirect impacts of the depletion of natural capital on the wealth or GDP of a country have been recognized by the international research community (Managi and Kumar, 2018) too. The inclusive wealth framework (Managi and Kumar, 2018), identifies natural capital, produced/ manufactured capital and human capital as the three pillars of wealth of a nation. But in the traditional accounting of the wealth or income of a country in terms of GDP, very limited categories of resources are taken into account. This indicates that there is lack of substantial evidence and accounting framework to make the accounting of national income and wealth more holistic.Hence in the process of policy framing it is extremely vital to prepare a strong research base that can enable efficient policy making and governance. Carrying out in depth studies of the successful cases of natural resource management all over the world under different contexts is the need of the hour to gather knowledge and understanding of the intricate dynamics of the social-ecological systems. This current study has the potential to set a model for other land remediation activities (in both ex ante and ex postscenarios) taking place across the country through more initiatives. Identification of the challenges and gaps would also be helpful to increase the effectiveness of the measures. The information from the ex ante application can help design the most effective interventions while the application ex post will help understand how things have turned out and could provide feedback to future programs to strengthen target based interventions through more informed decision making at various scales. This will help to achieve India's target for Land Degradation Neutrality (LDN) in the near future and will provide a thrust for sustainable management of natural resources as well.

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APPENDIX

I. Case Studies on natural and social capital assessment across globe

Case Study 1: Assessment of Agroforestry in East Sudan using ELD approach

Ricome et al(2014) in their study on agroforestry in East Sudan, assessed the socio-economic and environmental consequences of land degradation on the ecosystem of Al Gedaref state in East Sudan, Africa, lying between the geographical co-ordinates of 12.6 to 14.4 o N and 33.6 to 36.4 o E, having a plateau topography interspersed with hills and knolls. The main villages taken into consideration was Hawata, Mafasa, and Sharman. Some of the characteristics and prevalent issues in the region are,

- For decades mono-cropping and rain fed agriculture has led to degradation of land, degraded soil quality, hill denudation, and deforestation. Land degradation posed serious problems on the local communities living in the area, like food insecurity, risk to climatic changes, and also affect the provision of ecosystem services, degradation of water quality, reduction in animal resources.
- Changes in the current land-use practices and soil restoration was required to recover the land-degradation scenario that was prevalent during the time.
- A.senegal trees had soil nitrogen fixing properties and also produced high quality gum Arabic, it was hence believed that, intercropping A.senegal trees with staple crops like sorghum, would be beneficial for the ecosystem and increase the environmental quality of the region, as well as the economic growth rate, since value of ecosystem services would expect to rise by 25%, when intercropped with A.senegal as compared to when land was under pure sorghum cultivation. This was the main rationale proposed for the study.

The main aim of the study was to adopt a sustainable land management (SLM) practice by adopting agroforestry in Gedaref, by inter-cropping Acacia Senegal (A.Senegal) trees along with the traditionally grown sorghum crops. Parallel to this, the degraded hills would be reforested with Boswellia trees.

Ecosystem valuation and production of ecosystem services for environmental restoration was monitored over a period of 25 years (2014-2040), and in order to estimate the benefits of the restoration scheme and sustainable land practices, 6 steps were followed:

- Establishing a baseline scenario
- Identification of degraded land use patterns in the area
- Designing a future land-use scenario
- Analysing changes in ecosystem services flow between baseline and future scenario
- Economic valuation of ecosystem services
- Sensitivity and uncertainty analysis

For restoration, 2 types of land management practices were adopted- inter-cropping the farmlands with A.senegal trees along with sorghum crop, and restoring barren hills by reforestation with Boswellia trees, locally known as taratar trees. To estimate the net profits primary data on crop production, livestock, input and output prices were collected for the village of Um Sagata. This established the base for bio-physical analysis using an integrated soil and water assessment model, called AquaCrop, and a Soil and Water Assessment Tool, ArcSWAT, having a GIS plugin. A LULC map was prepared for the area of May 2014, assessing collected bio-physical data and ground-control point(GCP) collection. ArcSWAT is a watershed modelling tool in ArcGIS, whose outputs are used to assess the impact of land management and restoration on soil, water and prevailing agricultural practices in the watershed, and also for economic valuation of ecosystem services. AquaCrop model was used to analyse the impact of increasing soil moisture on agricultural production, and directly used outputs from the SWAT model as inputs into the model.

In order to assess the benefits derived from future land-use proposed scenario through 3 economic valuation methods-

1. Productivity change method, where such ecosystem services are valued which are sold in the commercial market, along with the inputs that are used for the production of such goods.
2. Market price method, which includes the valuation of ecosystem goods and services, bought and sold in the commercial market, and the benefits they would reap in future land-use scenario.
3. Avoided cost and replacement method estimates value of ecosystem services based on the lost services or cost of replacing certain ecosystem services.

Results were derived based on the differences in net profits between the baseline scenario and the future land-use scenario, based on of sustainable land management practices, over a time period of 25 years. The results derived were as follows,

- AquaCrop results on the impact of agroforestry on the nitrogen quantity of the soil showed that soil stress due to deficient soil nitrogen decreased by 5% to 10% when A.senegal trees matured.
- Soil water content as estimated by the ArcSWAT model resulted in the statistic, that soil moisture increased by 1.53mm/yr under the SLM (sustainable land management) scenario relative to that of the baseline scenario.
- Inter-cropping of A.senegal trees along with sorghum would ultimately lead to an increase in production of sorghum, and average yield increased by approximately 22.50%, than under the previously implemented mono-cropping system.
- Observed and future predicted prices of sorghum, found out according to the Auto-Regressive Moving Average (ARMA) model, showed that future prices of sorghum increased.
- Annual soil loss became almost half after sustainable land management practice was carried outand sediment loss was reduced by 500kh/ha/yr.
- Gum Arabic produced from A.senegal trees produced an additional profit of 460 SDG/ha/yr. After the capacity of trees to produce gum decreased, wood from the trees were sold as fuelwood which further produced a benefit of 220 SDG/ha/yr.
- Based on SWAT analysis on carbon sequestration and water infiltration, a benefit of additional 2000 SDG/ha/yr was produced and 2.3gms of additional carbon was sequestered. Also, water infiltration in the area improved.

This concluded that farmers can take up A.senegal agroforestry as an efficient and sustainable land management practice in the long run.

Case Study 2: Improving Economic Sustainability in Central Asia using ELD approach

Quillérou et al (2016) in his study aimed at establishing a long-term sustainable management practice for socio-economic benefit of Central Asia, and to create an awareness about sustainable land management practices, based on of ELD methodology. The study was initiated in 5 republics of Central Asia, namely, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. The main concerns in the study region were as follows,

- Central Asia has an overall dryland topology with semi-arid climate, with 400 million hectares of land that were subjected to soil fertility loss, decreasing crop and agricultural productivity, and mono-cropping leading to extensive land degradation.
- In each of the 5 countries, approximately 40% of the land was degraded and 30% of the highlands in Kyrgyzstan was degraded due to extensive weeding, mono-cropping and abrupt land conversions.
- There was an urgent need to take into consideration this issue, and establish sustainable land management practice, specifically under the biophysical aspect of land use changes.
- In 2015, Economics and Land Degradation (ELD) initiative was undertaken over a range of landscapes across the region, to decide the economically viable choices for sustainable land management practice and decide

the optimal strategy which would reap the maximum benefits, both economically and environmentally. The analysis took into account the economic valuation of ecosystem services like nutrient provisioning, carbon sequestration and storage, which would ultimately increase the knowledge of people on land ecosystems and the services they provide.

- Cost-benefit analysis also helps to analyse the net benefits that are shared among the farmers and distributed among other people in the society. Sustainable land management practices could result in the provision of benefits to the farmers and the society and result in the stabilization of natural resources in Central Asia.

The main aim of the project was to economically valuate the current land-use scenario and the possible alternatives in terms of net benefits derived from sustainable land management practice adoption, in the 5 countries of Central Asia, using the methodology derived from ELD 6+1 approach.

ELD Central Asia study took one case study in each of the 5 republics of Central Asia, following an altitudinal approach. Each of the 5 republics were arranged according to their overall economic and environmental importance and then for each of the countries, ELD methodology was applied, weighing the net benefits derived from each economy under the current land-use pattern and then under the proposed alternative scenario, based on multi-criteria analysis and valued in economic terms. The multi-criteria analysis took into account 3 types of analysis-

- General Criteria: Application, feasibility and replication capacity
- Production Criteria: Increasing carrying capacity of land and ecosystem conservation
- Social Criteria: Importance and support of local communities in protection of ecosystem services
- Financial Criteria: Maintainance and investments in ecosystem services valuation

Criteria was assessed for each alternative using the ELD 6+1 approach, which took into account the following steps,

Table 26

STEP	DESCRIPTION
STEP 1 : INCEPTION	Identification of study scope, spatial scale of each ecosystem and main goal of the study were identified
STEP 2: GEOGRAPHICAL CATEGORIZATION	For each country, geographical and ecological boundaries were demarcated and a land use land cover map was prepared, and agro -economic zones were delineated
STEP 3: IDENTIFICATION OF ECOSYSTEM SERVICE TYPE	Ecosystem services in each country were analysed, both the ir role and the net benefits derived from them. This was categorized according to 4 main types- provisioning, regulating, cultural and supporting.
STEP 4: ROLE AND VALUATION OF ECOSYSTEM SERVICES	For each of the identified ecosystem types, the prevalent ecosystem service was identified based on the net benefits derived in monetary value.
STEP 5: IDENTIFICATION OF LAND USE PATTERN AND PRESSURE	Land degradation patterns in each ecosystem was mapped and on the basis of this, business -as-usual (baseline) scen ario and an alternate scenario was developed.
STEP 6: COST-BENEFIT ANALYSIS	Monetary benefits from ecosystem services were analysed based on net profits accrued between baseline scenario and future action scenario.
STEP 7: TAKE ACTION	This involved the a ctions taken by decision makers, farmers, and policy makers in removal of barriers in sustainable land management.

Following this methodology, results were analysed under each of the steps, and the following conclusions were derived

- For each ecosystem, 4 types of ecosystem services were analysed - provisioning, regulating, cultural, and supporting. Tajikistan study focused on crop production, irrigation, agricultural yield, and management of natural resources. All these aspects helped in achieving food security.
- In Kazakhstan, the major sources of income were mainly provisioning and cultural like forest resources, livestock, fishery, and tourism. In Kyrgyzstan fodder production and livestock rearing were more economically intervention. In Tajikistan, agriculture accounted for almost 73.5% of total income.
- After the identification of ecosystem services prevalent in each country, economic valuation of these services were conducted in monetary terms. In Kazakhstan, number of livestock was calculated for monetary evaluation, which was around 753 USD in 2014.
- In Kazakhstan, there was an increasing ecosystem pressure due to lack of water resources availability. In Kyrgyzstan, land was not being used to its full capacity, while in Tajikistan, soil erosion due to gully erosion led to land degradation pressures.
- In Kazakhstan, economic benefits were derived from increasing fodder production and fishery from Ili delta. In Kyrgyzstan, favourable climate and carbon storage resulted in increasing net benefits of 7.8 USD to 9.4 USD million dollars. Both Kyzyl Unkur and Son-Kol in Kyrgyzstan has a positive net-present value for alternate scenarios in terms of carbon storage as compared to business-as-usual.
- In Tajikistan, net present values from agricultural production has increased in the alternate scenario and in Turkmenistan, productivity from pastures and forage increase accrued economic benefits by developing economic benefits.

Case Study 3: Land Use Planning in Sumatra using InVEST model

Bhagabati et al (2012) in his study assessed the economic benefits derived by the people of East Sumatra in alternate land management scenarios adopted in future. The study area was the RIMBA area covering 3 provinces-Jambi, Riau, and West Sumatra, which was among the few healthy forest remaining in Sumatra. The environmental condition of the area was as follows:

- Land degradation and deforestation had led to reduction in water quality, soil erosion, loss of biodiversity, and increase in greenhouse gases. There was an urgent need to take action to improve environmental, climatic and societal condition and stop deforestation and damage to ecosystem services in Sumatra.
- Sumatra Ecosystem Vision for the year 2020 was proposed based on off biophysical and socio-economic conditions using ecosystem service evaluation and the Integrated Valuation of Ecosystem Services and Trade-off's (InVEST) tool, which maps the amount of ecosystem services in a given location and future estimates of service quantity in an alternate scenario.
- InVEST model analysis was performed on 4 ecosystem services- carbon storage and sequestration, erosion control, water yield, and water purification. This was done to assess the quantity and spatial scale of tigers in RIMBA forest zone, and to analyse how patterns would change under present land-use scenario and proposed future alternate scenario under Sumatra Vision 2020. The time period framed was from 2008 to 2020.

Methodology followed were different for each of the 4 ecosystem services taken into consideration:

- Carbon Storage and Sequestration: Total carbon stock was estimated for above-ground and below-ground biomass, soil, and organic matter. Carbon stocks were modelled using InVEST for different LULC categories and carbon pools, both under present and future scenarios. A soil carbon layer was modelled using Harmonized World Soil Database and soil carbon amount was estimated for peat and non-peat soils. After this, opportunity cost method was applied to estimate the revenue accrued per hectare and also differentiate returns from different soil types to prioritize investments in carbon projects.
- Hydrological Services; Water Yield and Water Purification: Six watersheds in central Sumatra was taken into consideration, among which 5 was within the RIMBA boundary. InVEST was used to model water purification, water yield, and sediment retention. For water yield, Tier 1 of InVEST model was used to evaluate the water yield across different land use and land cover for each watershed and sub-watershed in terms of average

runoff depth. Sediment retention in the watersheds were modelled by InVEST's sediment retention model, based of Universal Soil Loss Equation (USLE) based on the amount of sheet wash erosion and the sediment load to the streams is calculated as an yearly average for each watershed. Waterpurification was modelled using the InVEST Nutrient Retention model to estimate the nitrogen and phosphorus loading into streams, as an annual average.

- Habitat Quality and Biodiversity Conservation: For this, the number of tigers in the RIMBA forests were assessed and their future numbers predicted based on the Sumatra Vision for 2020. Habitat quality was mapped for both 2008 and 2020 and then the districts falling under RIMBA was ranked according to their biodiversity, using Habitat Quality Score.

The results derived from the study were as follows:

1. Carbon Storage and Sequestration: There would be an increase in carbon stocks after implementation of the Sumatra Vision of around 350 million tonnes in Sumatra and 60 million tonnes in the RIMBA priority area. Investments in carbon projects were mainly prioritized in the districts of Dharmasraya and Kampar. Sumatra Vision led to carbon sequestration while under the Government Plan, there would be an increase in net emissions of carbon.
2. Hydrological Services: After the implementation of Sumatra Vision, nutrient pollution was reduced by approximately 80%. Reforestation under Sumatra Vision would lead to a reduction in sediment export especially in watersheds of Reteh and Kampar. Nitrogen and Phosphorus export would decrease under the Vision, while it would stay almost similar under the Government Plan, specifically in watersheds of Rateh and Pengabuan Lagan for nitrogen export and in Siak and Indragiri for phosphorus export.
3. Habitat Quality and Biodiversity Conservation: There would be an increase in habitat quality in districts like Indragiri, Tanahdatar, and Timur. This would be due to the reforestation of approximately 636,000 million hectares of land. Plantation in Central Sumatra would lead to reduction in habitat risk for the high-quality Sumatran Tiger. Habitat Quality scores were generated ranging from 0 (worst) to 1 (best) and according to this, districts were categorized to assess gains and losses. Sumatra Vision would maintain habitat quality in all districts under RIMBA area and also the peatlands to the north of RIMBA.

Thus, it was concluded that the Sumatra Ecosystem Vision 2020 provided greater net benefits in terms of ecosystem services in monetary value, than the initial 2008 land management scenario as well as the Government Plan.

Case Study 4: Biodiversity Accounting in Mexico Using GLOBIO model

Schipper et al (2017) aimed to valuate biodiversity characteristics in Mexico using the GLOBIO 3.5 model for Mexico, known for its diverse ecosystem varieties and highland topography with high forest abundance. Degradation of forests have put forward the need of valuating ecosystem services as a form of natural capital, in monetary terms. Ecosystem accounting quantifies ecosystem service changes as variations in the stocks and flows of ecosystem services for ecosystem accounting. Ecosystem accounts related to biodiversity were quantified based on the past, present, and future terrestrial ecosystem changes, applying the GLOBIO model. Changes in biodiversity was quantified as Mean Species Abundance (MSA) expressing the abundance of species in undisturbed reference condition relative to that in disturbed conditions, to assess the degree of ecosystem change. Quantification involved change detection in ecosystem extent in total area covered by each ecosystem type and ecosystem condition as area-weighted MSA value both on 3 maps- A raster land-use map of 2010, 2 vector maps of Mexico of 2011-2013. Even after launching SEEA-EEA network, practical application in monetary evaluation of ecosystem services were limited, and control on biophysical stocks and flows were not smooth either. MSA values derived from GLOBIO model were assured to provide a transparent and smooth accounting of ecosystem services, and also be cost and time efficient.

Before the main methodology could be derived, some pre-requisites were taken into account as follows:

- Extent of different ecosystem types were quantified
- Biodiversity was quantified to be affected by 2 main anthropogenic factors- land use and infrastructure.
- For biodiversity quantification, MSA values were used as an indicator of biodiversity changes between undisturbed and disturbed conditions. Values ranged from 0 and 1(no change).

The methodology derived for the study was segregated into the following steps:

1. Ecosystem Functional Units: Land-use maps were used and to that effect, 3 land-use maps were prepared: A land-use map compiled using the GLOBIO model (GLC2000) and interlinked with regional land-use data. The map was prepared for 2010 and had 23 land-use classes. Second, a vector land-use map was also derived for 2011-2013 from the National Institute of Statistics and Geography in Mexico, covering 19 land-use types.
2. Quantifying Extent of Ecosystem: Extent of each land-use type in the raster GLOBIO map was quantified according to land area in sq.km. For the vector maps, maps were re-projected using ArcGIS and then area for each land-use type was calculated using the 'Calculate Geometry' function in ArcGIS.
3. Biodiversity Quantification: Biodiversity quantification was achieved by MSA value quantification in 2 areas of pressure- land-use and infrastructure. In land-use, MSA values were analysed on the basis of abundance of species in a particular land-use type, in disturbed conditions relative to an undisturbed condition. In infrastructure, GLOBIO model was used wherein first, a 1km buffer disturbance zone was delineated having an MSA value of 0.78 and on the basis of that, infrastructure disturbance for each biodiversity type was calculated. Land-use and infrastructure impacts were combined and an aggregated MSA value developed by using the 'Union' function in ArcGIS for a combined value for each land-use type.
4. Delineation of Ecosystem Types: For the raster GLOBIO map, 5 types of ecosystems were identified- cropland, herbaceous plants, forest, pasture, and urban area. For the vector maps, 3 main land-use types were delineated- grassland, forest, and shrubland. For each land-use type, total extent was calculated and area-weighted MSA values were calculated for each type of ecosystem.

Following the methodology, the results derived were as follows:

- Spatial variability in MSA values was large. Higher MSA values were found in the northern region and comparatively low values were found in the southern part. In the vector land-use maps, human footprint was quantified along the established road network, which showed higher footprint around the capital and along the eastern coast of Gulf of California.
- For biodiversity accounting, extent and condition of ecosystem was analysed. As per the analysis on extent, Mexico is covered by primarily forests (40%) followed by pasture and then shrub land. As per condition of ecosystem, the weighted average MSA values were 0.65, 0.72, and 0.75. MSA values were lower for the vector maps because of the inclusion of secondary vegetation, covering 21% of the area and having a MSA value of 0.5. Infrastructure impacts had a higher MSA value for all maps.

It can be concluded that GLOBIO modelling can provide a quick and efficient method to compile biodiversity accounts. It is cost and time efficient, and can be used to quantify biodiversity stocks between different time periods and among different locations.

Case Study 5: Assessment of Social Capital on management of community owned grazing land in Uganda

Call et al (2017) had put forward the objective of sustainable management in community owned grazing lands, by combining social capital. It was believed that along with biophysical criteria, linking social capital could help in taking collective action in maintaining community resources. Previously, there was a belief that community owned resources could not be properly managed or maintained without some form of external regulation. However, research has proved that collective action through social capital bonding, bridging, and linking could effectively and sustainably manage property owned resources through community management. Uganda, a country in Central East Africa, primarily deals with livestock rearing and agriculture as their occupation and majority of the population had at some point involved with communal grazing. Livestock in the area has been on the rise, however, land availability is scarce and fragmentation and land degradation are a cause of concern, putting stress on the available environmental resources. There was an urgent requirement of protection of these community owned grazing lands linking different social capital methods and access the condition of grazing lands through collective action. This was the main rationale behind the study.

The main aim of the study was to explore the role of social capital in maintaining the communal grazing lands in Uganda and also analysing the condition of land, through socio-environmental data. To this context, social capital was analysed in 3 ways,

- Bonding social capital: connecting within homogenous groups
- Bridging social capital: connecting between different groups and communities
- Linking social capital: Connecting individuals and organizations having different social status and influence.

Data for the study was secondary, derived from the 2003 dataset of Research on Poverty, Environment, and Agricultural Technology (RePEAT), and analysed using collected survey data, econometric analysis, and other quantitative methods.

Methodology charted for the study was separated into two main parts, and explained as follows:

1. Socio-environmental Approach: Community data was collected from surveys and interlinked with spatial socio-economic data. 107 villages were surveyed regarding communal grazing lands and condition of the lands were derived from group discussions involving an average of 10 farmers, and analysed using perceived patch condition. Bonding, bridging, and linking social capital were examined, involving individual households, local organizations, public aid groups, and NGOs. For spatial socio-environmental data, raster and vector data was generated using ArcGIS. Data included cattle corridor boundary, survey household locations, population data, forest density data, and climatic data.
2. Analytical Approach: Econometric analysis was used to link collective action for communal grazing lands and social capital. Chance of presence of communal grazing lands in a village was identified using a logistic regression model, based on of the following steps-
    - Interlinking social capital and the probability of grazing land presence (1st iteration)
    - Controlling property rights (2nd iteration)
    - Implication of land tenure measures (3rd iteration)
    - Inculcation of spatially derived tools (Final iteration)

Community usage of grazing lands was predicted using the Generalized Linear Model, ranging from 0.1 (low) to 1(full usage). Different social capital types were inculcated in the study as individual variables which could yield varying outcomes. Community attributes might play a role in affecting collective action, and to that effect, data relating to no of households, cattle per household, amount of land per household, and population density in the area was collected. Bio-physical attributes like proximity to market was also taken into consideration, which might affect the land value and cattle output. The data was checked for duplication using variation inflation factor test, quantifying it as a least square regression analysis.

Probability of households using communal grazing was produced using an odds ratio, presenting the odds of communal grazing occurring in an area to the odds of not occurring in the same area. Outcomes were given as a relative proportion, and an increase in the factor proportion would lead to a certain percentage change in output. The results derived from the study were as follows:

1. With regional diversity increase, there was a decrease of 73% in communal grazing and also a decrease in land quality.
2. If variation of cattle increases, odds of a community having communal grazing increased by approximately 32%
3. If monetary assets increase, grazing land increases by 61% and increase in public aid groups would lead to decrease in land quality by 66%.
4. Inclusion of microfinance groups would decrease the odds of communal grazing land ownership by 32%.
5. Equitable usage of land would decrease with religious diversity and cattle variation.
6. Biophysical and community variables were also included, which showed that population having owned lands have a 5% more chance of having communal grazing lands.
7. Higher population density would lead to a higher demand and usage of communal grazing lands. Increasing market distance would decrease the probability of grazing land being in good quality and being used equitably.

II. Primary Survey Questionnaires

Natural Capital Survey

The survey must be done by trained staff, researcher of the project with guidance from subject experts.

Who to interview?

The person to be interviewed will be an adult, not too old, not too young who will be able to answer the

Date	Community	Household #	Name of the village/tola	Male or female respondent?

questions. TO SAY TO EXPLAIN WHY YOU WANT TO ASK QUESTIONS: Hello, I am working for research into how natural resources contribute to your life. Can I ask questions related to how these natural resources contribute to the wellbeing of the region and what value they add to your life?

The questionnaire will cover provisioning services and regulatory ecosystem services and this will be done through a detailed survey covering 6 sub services.

A. Crop Production

B. Water

C. Livestock

D. Fodder

E. NTFPs'

F. Erosion control

SECTION A - CROP PRODUCTION

Acreage of land managed by your household	Own & use (a)	Own & lease out (b)	Borrow without payment (c)	Farm for another (d)	Lease land from someone (e)
Main use of your land last year (in acres)	Farming	Livestock	Fallow	Any other	

Type of farming carried out 1. Rainfed 2. Irrigated 3. Flood recession						
What are the <u>maincrops</u>, <u>vegetables</u> and cash crops you cultivate?	1	2	3	4	5	6
Season during which you cultivate these?						
No. of harvests per year						
Quantity harvested (per acre)						
What is the cost of cultivation? (approx. per acre) Note: You can break it further and ask how much do they spend on seeds, fertilisers, irrigation, pesticides etc. and use standard rates to calculate the price						
What percentage of the produce do you sell?						
What is the selling price per kg*/quintal for each product produced? Note- For vegetables you can specify price/kg						

SECTION B - WATER

	Questionnaire - Sections & Questions	No. of Data Points	Experimental		Control	
			2013	2018	2013	2018
A	*Village Level Survey*					
A. 1	***From village records or databases available at block/district level or on online portals or GIS maps***	NA (per village)				
1	What are the various water sources in the village?					
2	How many units of each source type are there in the village?					
3	Which of these were constructed during the period 2013-2018?					
A. 2	***From Focus Group Discussions***	2 (per village)				
A. 2. a	**FGD with farmers**					
1	What are the major sources of irrigation in the village?					
2	What is the relative dependence on each type? (e.g. % of farmers majorly dependent on each type; seasonality in dependence)					
3	What is the number of irrigation done for each major crop?(number of times each main crop is irrigated)					
4	What are the water sources used for livestock management?					
5	What is the average status of water availability in each of these water types (depths of water level, flow, through the calendar year)? (get it from any agency					

	that manages water or ask the approx. depth of wells, no. of months the water sources remain dry etc.)					
6	Has there been any change in the status between 2013 and 2018?					
A. 2. b	**FGD with women**					
1	What is the source of water for domestic use?					
2	Has there been any change in accessibility of water for domestic use between 2013 and 2018?					
3	If the answer is +veY to above, how has it affected the lives of these families?					
B	*Individual/HH Level Survey*	NA				
C	***Empirical Data through Testing***	1 set from 10 randomly selected villages (7 experimental, 3 control)				
	10 samples each from the following type of sites: (soil moisture, water holding capacity, pH., Organic carbon, N, P ,K , Micronutrient status)					
1	a. Soil from non-intervention agricultural field					
2	b. Soil from intervention field (wadi / farm bund / other)					
3	c. Soil from sites at standardized distances from the water conservation structure					
D	***Project Information***					
1	Data on water level in monitoring wells (if available)					
E	***Secondary Data***					
1	Rainfall data for the years 2013 to 2018 - (block level data)					

SECTION C - LIVESTOCK

Does your household manage livestock? (1) Yes (2) No						
Livestock owned	Local cow	Buffalo	Goat	Sheep	Poultry	Other specify
Number of animals managed by the household						
Number owned						
Number loaned or managed for other people						
Q26 Do you get any milk, meat, hides/skins from the animals? (1) Yes (2) No	Milk (from cow)	Meat (all animals)	hides/skins (all animals)			
Q27 How much do you produce each day, week, month?						
Q28 Is it for (1) home consumption (2) or for sell?						
Q29 If for home consumption, if you had to buy it, how much would it cost you? *Rs per unit*	Price	Quantity unit	Price	Quantity unit	Price	Quantity unit
Q30 If you sell it, at what price for each product? *Rs per unit*	Price	Quantity unit	Price	Quantity unit	Price	Quantity unit

During dry season, what are the main sources of water for cattle, sheep and goats? (1) pond, (2) river, (3) borehole, (4) dugout well, (5) dam, (6) other specify	
During dry season how many times a day do you water your livestock?	*times per day*
During wet season, what are the main sources of water for cattle, sheep and goats? (1) pond, (2) river, (3) borehole, (4) dugout well, (5) dam, (6) other specify	
During wet season how many times a day do you water your livestock?	*times per day*

During **DRY SEASON**	Free roaming near the pond (a)	Free roaming in the open forest (b)	Free roaming in the Forest reserve (c)	Free roaming in bush (d)	Own land (e)	Cut grass (f)	Purchased feed (g)	Other (h) *specify*
During dry season where are grade/cross-breed cattle grazed? (*tick relevant sources*)								
No. times/day fed (*for sources used*)								
Cash cost of using this source each time (*for sources used*) (1) Free (2) Cash specify price per unit								
During **WET SEASON**	Free roaming near the pond (a)	Free roaming in the open forest (b)	Free roaming in the Forest reserve (c)	Free roaming in bush (d)	Own land (e	Cut grass (f)	Purchased feed (g)	Other (h) *specify*
During wet season where are grade/cross-breed cattle grazed? (*tick relevant sources*)								
No. times/day fed (*for sources used*)								
Cash cost of using this source each time (*for sources used*) 1) Free (2) Cash specify price per unit								

SECTION D - FODDER CULTIVATION

Do you cultivate any fodder?	Yes No				
If yes which ones? (Barseem, Napier, Bajra, Sorghum, Guinea grass, Maize, Any other?)					
What is the quantity of fodder that you purchase from outside? (specify in kg/ quintals)					
Price per kg of fodder					
What is the quantity of fodder that you get by cultivating it? (quintals/ acre) (ask about production per unit land)					

SECTION E - NON-TIMBER FOREST PRODUCE

Do people from outside the area ever go to forest for collecting forest products (1) Yes (2) No						
If so, which ones	1	2	3	4	5	6
How frequently you collect these products from the forest? 1. Weekly 2. Monthly 3. Quarterly 4. Once or twice in a year						

What purpose are these NTFPs' used? 1. Own consumption 2. Sale 3. Any other uses						
If sold at what price do you sell these? (Rs per unit) Note: Even though not sold, then ask what price would it be sold for?						
Do you notice any change in availability of these NTFPs' over the last 5 years?						

SECTION F - EROSION CONTROL *

Are you aware of any activities that are done to control soil erosion? (1) Yes (2) No					
If so, which ones (field bunding, Gabion, Gully plugs, drainage line treatments)	1	2	3	4	5
How many such structures have been constructed in your village?					
Ha of land treated? (ask approx. ha or derive it from the structure numbers and use standard calculations for getting treated area)					
What was the cost of constructing the structures? (approx. cost per structure)					

*cross check all these with the project reports. This data may be gathered from the project closure documents.

Social Capital Survey

Instructions

- Q1 to Q11 are to be asked at household level. 10 HH per village.
- Q7 can be asked monthly/ annually but during data compilation give figures annually
- Other data on this question has to be collected from Health workers

Household member name :

Village name :

Block and District :

S. No.		Kids	Man	Woman	Total
Q1	No. of people living in the household most of the time?				
Q2	No. of other household members who work away from home most of the time but contributing to the household income?				
Q3	No. of members who have left for cities and have not returned to work in their home village?				
Q4	No. of members who have left for cities and have returned?				
Q5	What is your household's <u>main</u> source of livelihood? (1) Fishing, (2) Farming, (3) Trading, (4) business, (5) artisans, (6) employment (7) Other (*specify)*				
Q6	Does your household have other sources of livelihood? (1) Fishing, (2) Farming, (3) Trading, (4) business, (5) artisans, (6) employment, (7) Other (*specify)*				
Q7	No. of people earning? Total-				

No.	Fishing	Farming	Trading	Business	Artisans	Employment	Other (*specify*)
INR Annual							

Q8	How much does the migrated member of household contribute? (take for year 2018)
Q9	Does some of your land remain fallow because of migration? If so how much?
Q10	Do you employ labourers for your land? If Yes, How many person days. And how much is the payment per day?
Q11	What Kind of problems do you face while working outside?
Q 12	Do kids (under 16) attend schools? (1) Yes (2) No (3) Other
Q 13	Reasons for any school age children that do not attend school?
Q14	No. of girl children attending school?

Q15	What is the level of education for male head of the family?
	What is the level of education for female head of the family?
Q16	How many people above the age of 16 are uneducated?
Q17	Reasons for not attending educational institutions?
Q18	Do people in your house have any physical disability? (1) Yes (2) No
	If yes then how many?
	Name of disability
Q19	Have people in your family fallen ill in the last month? (1) Yes (2) No
	If yes then no. of people for acute illness and no. of people for chronic illness
	If yes, then Type of treatment undertaken? (1) Own medication (2) Advice from local ayurvedic practitioner (3)Visit to medical centre (4)Visit to hospital (5) Other
Q17	**Social Institutions in the village**

	SHG	**Farmer club**	**FPO**	**Any other club**	**Cultural org.**	**Bal panc haya ts**	**Pancha yat**	**Eco club**	**Water shed comm ittee**	**Any other**
Tick which all functional										

** Chronic diseases are medical conditions that are generally progressive. These lifelong conditions, which include heart disease, diabetes, stroke, and asthma, can be managed with simple lifestyle changes. Examples include diabetes, hypertension (high blood pressure), high blood cholesterol, stroke, asthma, and chronic obstructive pulmonary disease (COPD)*

Acute diseases are those diseases that come on abruptly and run a short, severe course, Types of acute diseases include organ failure, breathing difficulties, rapid-spreading infections and tissue death, or necrosis.

Questions for Health Workers/ASHA/Aanganwadi worker of the village.

Q1. Data on MMR and CMR at village level.

Q2. Check the data on weight and height of children from 1-18 months and women of child bearing age (18-39 years). Randomly collect at least 20 data points each for women and children. (20 in each village)

Q3. Check the data on status of anaemia in women of child bearing age. For this randomly select 20 data points.

Migration Survey

Village name :

Block and District name :

Persons conducted with :

1. Have people gone outside the village in search of work from the village from the last 7 years? (Yes/No)

2. If yes then what kind of work?

3. If yes, then how many people go and come back after working away from the village in 2013?

4. When did the people go and when did they come back (referring to the year 2013)?

5. Have there been any number of people that went outside for work and did not return back to the village in the year 2013? (Yes/No)

6. If yes then how many people approximately?

FGD Questionnaire 2013

1. Crops grown in 2013 and their production

2. Cost of inputs for each crop for 2013

3. Percentage of crop that is used for self-consumption for the year 2013 in the villages for 2013

4. Buying price of the crops from market for 2013

5. Selling price of the crops for 2013

6. What is the wage rate for labour for 2013?

7. How many days for each crop required labour for 2013?

8. No. of cows in village in 2013, no. of buffaloes in 2013, no. of goats in 2013, no. of sheep in 2013 , no. of chicken in 2013?

9. Percentage of production used for self-consumption for the year 2013 for each cow, buffalo, goat and sheep and chicken

10. Buying price of each product
11. Selling price of each product
12. Which fodder cultivated in which village in 2013?
13. How much inputs to the fodder when cultivated in Rs.?
14. If fodder purchased in 2013?
15. when and which one?
16. what was the price of the fodder in 2013 when purchased?
17. Which NTFP collected from forest:
    a. quantity of collected NTFP
    b. sell or self?
    c. selling price of crop?
    d. Purchase price from the market?
18. How much percentage of family's dependent on particular source of irrigation (well, borewell, tubewell, river, canal, handpump) for 2013?
19. How much % of land was irrigated in 2013?
    a. and how much rainfed in 2013 in each village?
20. No. of girls below 18 in a village in 2013 and 2018?
21. No. of school going girls for 2013 and 2018?
22. Families of a village in 2013 and 2018?
23. Male population in 2013 and 2018?
24. Female population in 2013 and 2018?

III. Tables, Figures and Maps of the Study Site

Table 27: Details on interventions undertaken by DA in 18 villages of Niwari, Datia and Shivpuri districts

Project intervention	District Name	Village Names	Activities	Programme starting year	Phase of the programmes	Stakeholders involved
Integrated Watershed Management Programme 1& 4	Datia	Chopra, Govind Nagar, Kamhar, Pathari, Salaiya Pamar, Jauri, Kherona, Kheri Devta, Parsonda Baman, Parsonda Gurjar (no development of SHGs)	✓ Construction of water and soil conservation structures- check dams, waste weir, gabion, gully plugs, etc ✓ Distribution of drought resistant seeds ✓ Participatory net planning and Formation of watershed management committees and women self-help groups ✓ Training for monitoring and maintenance of watersheds ✓ Promotion of conversion from mono-cropping to double cropping	2011-2016 and 2012-2017	Completed	Local communities, government departments, CSOs
Promotion of Agri-Horti Based Livelihoods among Schedule Caste Community in Selected	Datia	Chopra, Kamhar, Pathari	✓ Distribution of seeds for vegetable cultivation ✓ Promotion of agro-horti cultivation through trainings ✓ Development and link of micro enterprises	2015-2018	Completed	SC Communities, CSOs

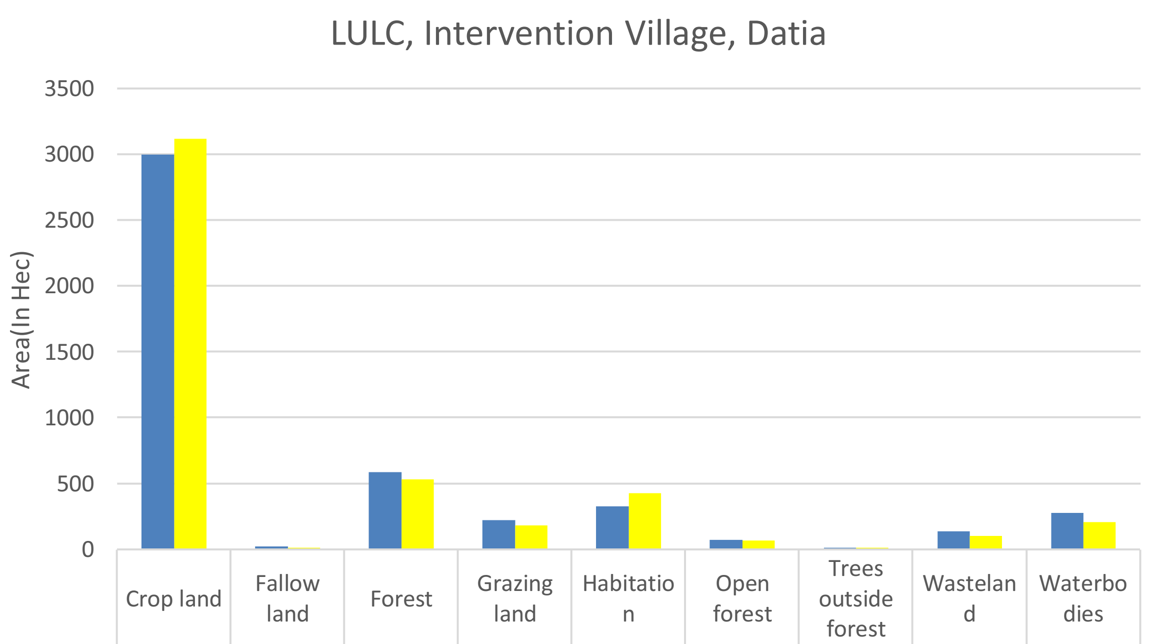
Project intervention	District Name	Village Names	Activities	Programme starting year	Phase of the programmes	Stakeholders involved
Districts of Bundelkhand						
Coca Cola Watershed Programme	Shivpuri	Manpura, Dulhai, Piproniya	✓ Construction of water and soil conservation structures- check dams, waste weir, gabion, gully plugs, etc ✓ Distribution of drought resistant seeds ✓ Participatory net planning and Formation of watershed management committees and FPOs ✓ Training for monitoring and maintenance of watersheds ✓ Promotion of conversion from mono-cropping to double cropping	2016-2018	Completed	Private corporation, local communities, government departments
Tribal Development Fund	Shivpuri	Piproniya	✓ using community radio extensively for dissemination of information on farm linked sustainable livelihood options and improved agripractices ✓ Research and advocacy activities	2013-2020	Completed	CSO
NABARD women	Shivpuri	Manpura, Dulhai,	✓ Creation of social institutions like SHGs	2012-2014	Completed	CSO

Project intervention	District Name	Village Names	Activities	Programme starting year	Phase of the programmes	Stakeholders involved
SHG		Piproniya	✓ Training of local communities			
Integrated Watershed Management Programme 9	Niwari	Patharam, Uboura, Chachawali, Dhamna, Bamhori Sheetal	✓ Construction of water and soil conservation structures- check dams, waste weir, gabion, gully plugs, etc ✓ Distribution of drought resistant seeds ✓ Participatory net planning and Formation of watershed management committees and women self help groups ✓ Training for monitoring and maintenance of watersheds ✓ Promotion of conversion from mono-cropping to double cropping	2011-2018	Completed	CSOs, government departments, local communities
Tejaswini- SHG	Niwari	Patharam, Uboura, Chachawali, Dhamna, Bamhori Sheetal	✓ Creation of social institutions like SHGs ✓ Training of local communities	2008-2014	Completed	CSOs, local communities

Table 28: Ecosystem Service categories

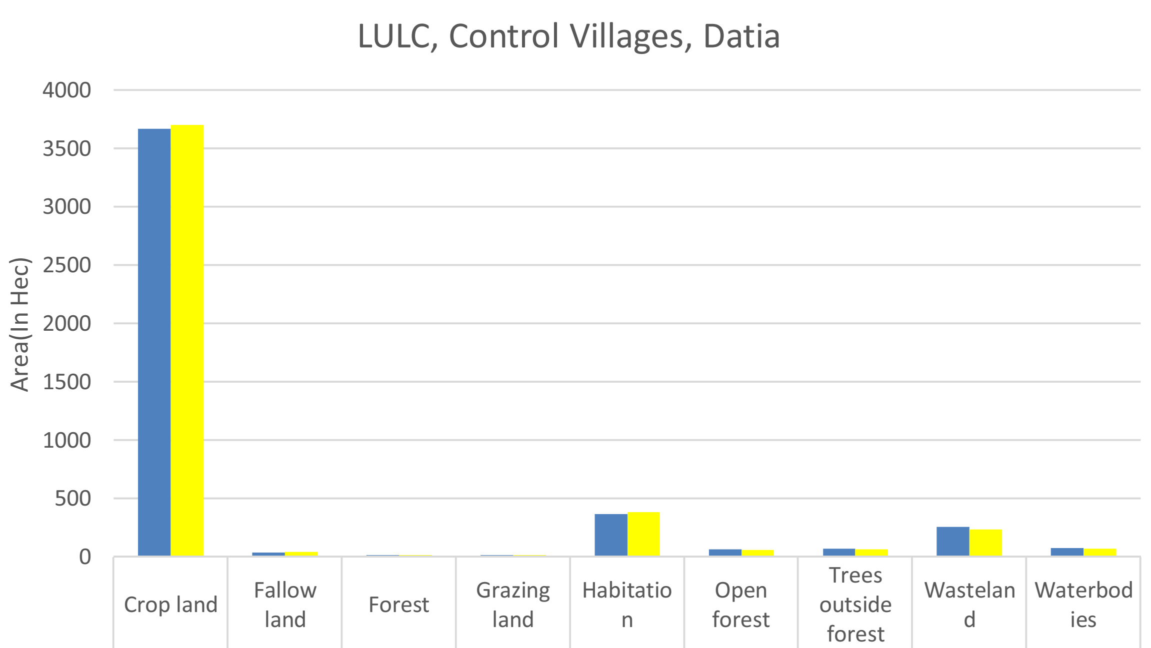
Ecosystem Service categories	Examples of Ecosystem Services
Provisioning services	Fresh water
	food
	fiber
	Fuel
	Natural medicines
	Genetic resources
	Ornamental resources
	Clay, mineral, aggregate harvesting
Regulatory services	Air quality regulation
	Climate regulation
	Water purification and waste treatment
	Regulation of water flow
	Natural hazard regulation (flood, drought, storm, fire etc)
	Pest regulation
	disease regulation
	Erosion control
	Water purification
	Pollination
	Carbon sequestration and storage
	Salinity regulation
Cultural and Recreational Services	Culture
	Recreation and tourism
	Aesthetic value
	Spiritual and religious value (temples)
	Social relations
	Education
Supporting services	Soil formation
	Primary production (accumulation of energy and nutrients)
	Nutrient cycling
	Habitat support for species
	Water cycling

Source: IUCN ecosystem assessment tool (2007)



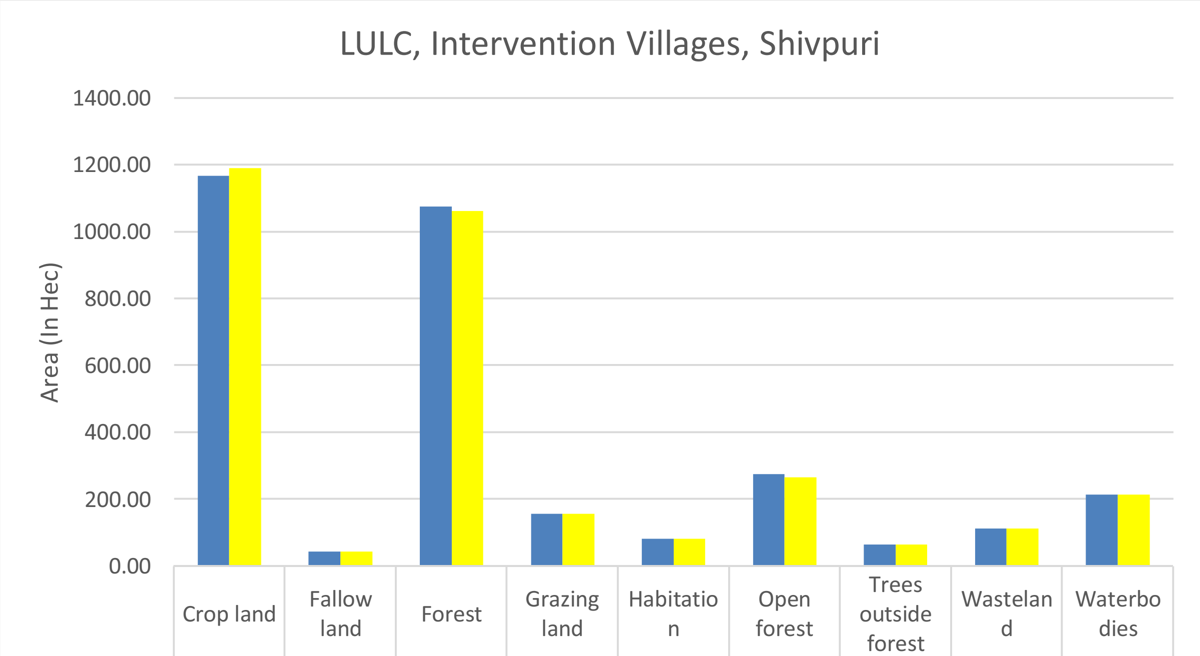
	Crop land	Fallow land	Forest	Grazing land	Habitation	Open forest	Trees outside forest	Wasteland	Waterbodies
2013	2996.6813	21.873318	585.87902	224.78634	328.87241	74.87755	15.598025	138.62124	278.688
2018	3115.8477	12.213742	532.50147	185.14522	425.73186	68.278138	14.927104	102.77573	208.52317

Figure 41



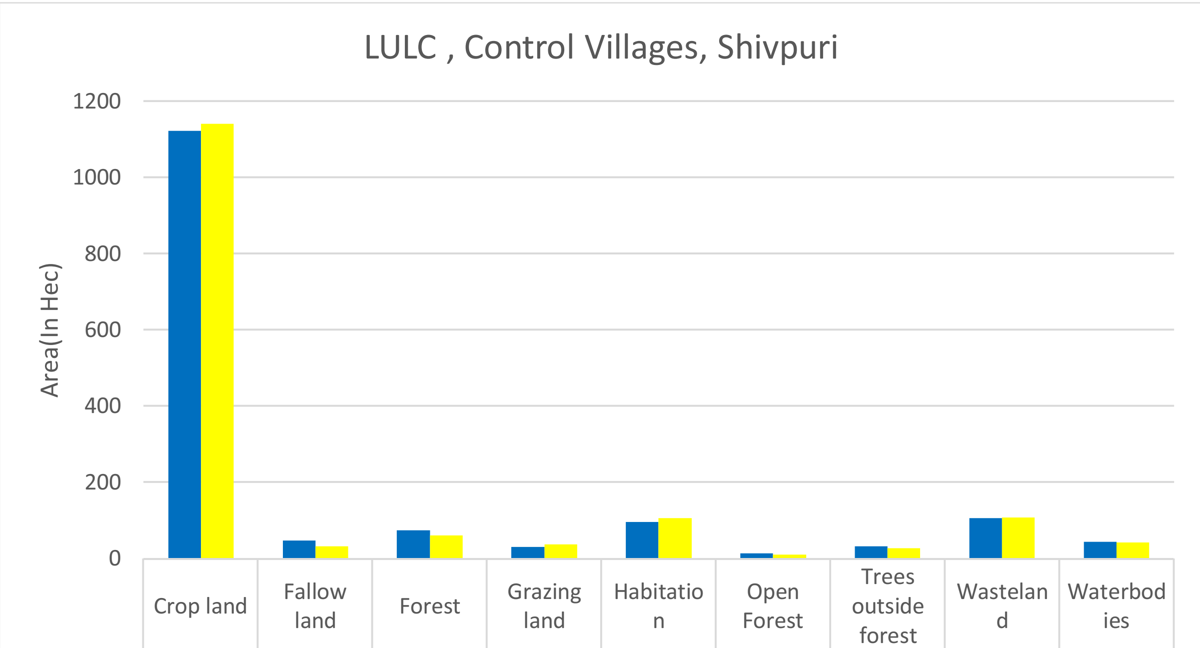
	Crop land	Fallow land	Forest	Grazing land	Habitation	Open forest	Trees outside forest	Wasteland	Waterbodies
2013	3669.8917	40.347371	18.529524	18.943119	368.30518	68.343018	69.102359	260.0279	78.786011
2018	3699.9799	42.500464	16.529524	15.412017	382.5057	60.343018	67.702107	236.51667	70.786759

Figure 42



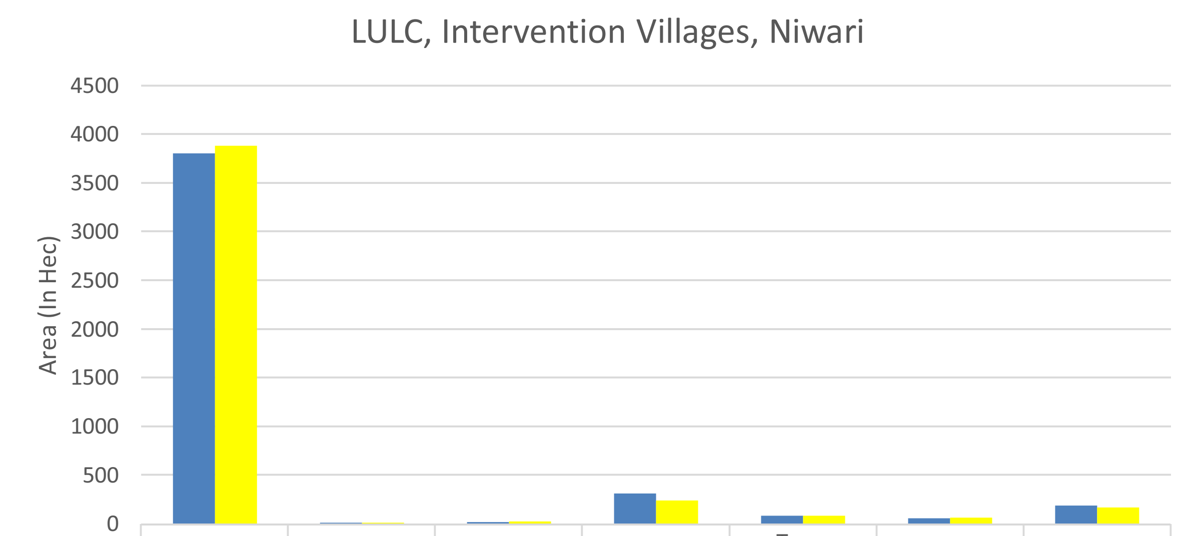
	Crop land	Fallow land	Forest	Grazing land	Habitation	Open forest	Trees outside forest	Wasteland	Waterbodies
2013	1166.89	43.939	1075.64	157.21	82.90	275.45	65.53	113.03	213.85
2018	1189.7903	43.939259	1061.923	157.21	82.895	266.45	65.529357	113.02995	213.85194

Figure 43



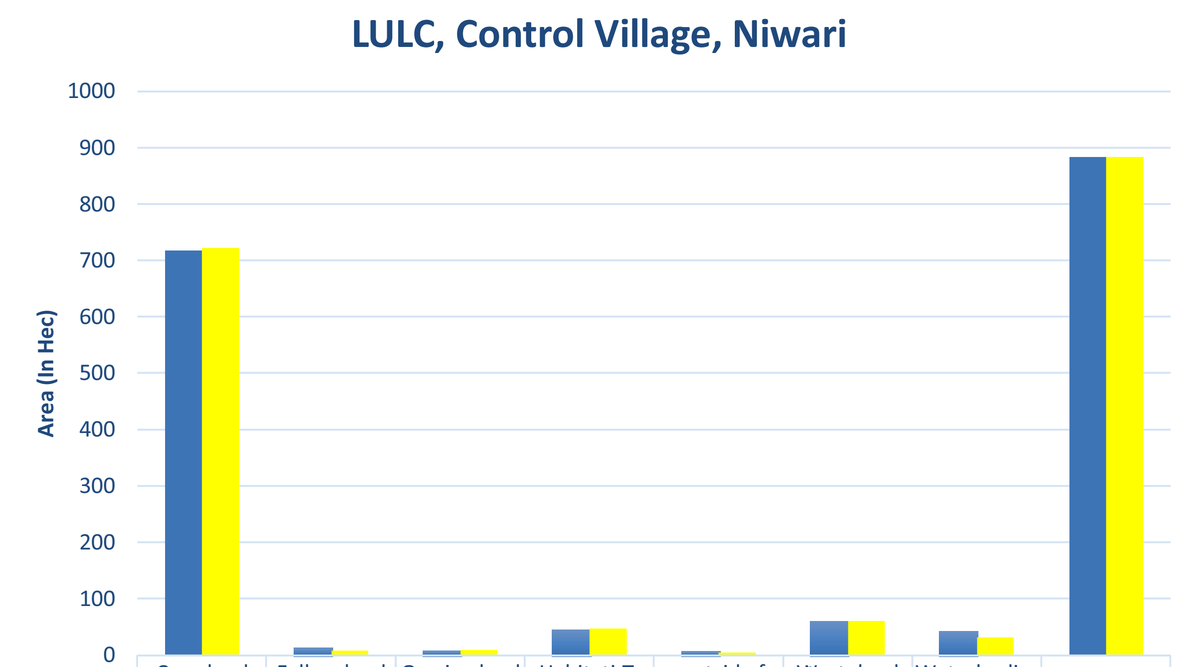
	Crop land	Fallow land	Forest	Grazing land	Habitation	Open Forest	Trees outside forest	Wasteland	Waterbodies
2013	1121.1471	47.908307	73.988651	30.346277	95.666539	13.677038	32.789432	105.70048	43.118487
2018	1141.2189	31.599333	60.868667	36.46539	105.88848	10.848008	27.696762	107.42026	42.307302

Figure 44



	Crop land	Fallow land	Grazing land	Habitation	Trees outside forest	Wasteland	Waterbodies
2013	3802.166305	16.143746	23.063666	311.484031	84.10282	61.432616	189.363575
2018	3885.480742	13.946587	28.103733	240.923591	83.649989	64.981734	170.686233

Figure 45



	Crop land	Fallow land	Grazing land	Habitatio	Trees outside fore	Wasteland	Waterbodies	
2013	718.552182	11.970414	5.759928	43.319221	4.732101	58.717113	40.787825	883.838784
2018	723.046975	8.424673	8.749928	46.816952	4.732101	60.644982	31.422689	883.8383

Figure 46

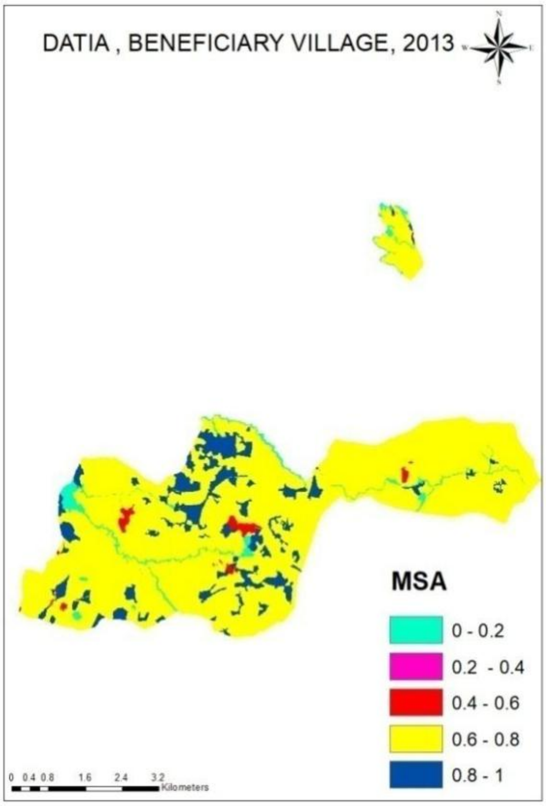


Figure 47: MSA_LU of Datia Intervention cluster 1 in 2013

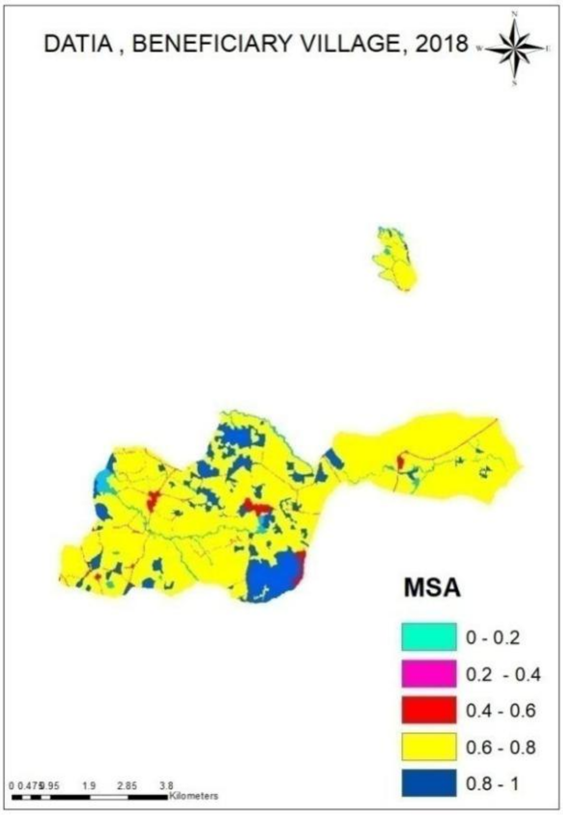


Figure 48: MSA_LU of Datia Intervention cluster 1 in 2018

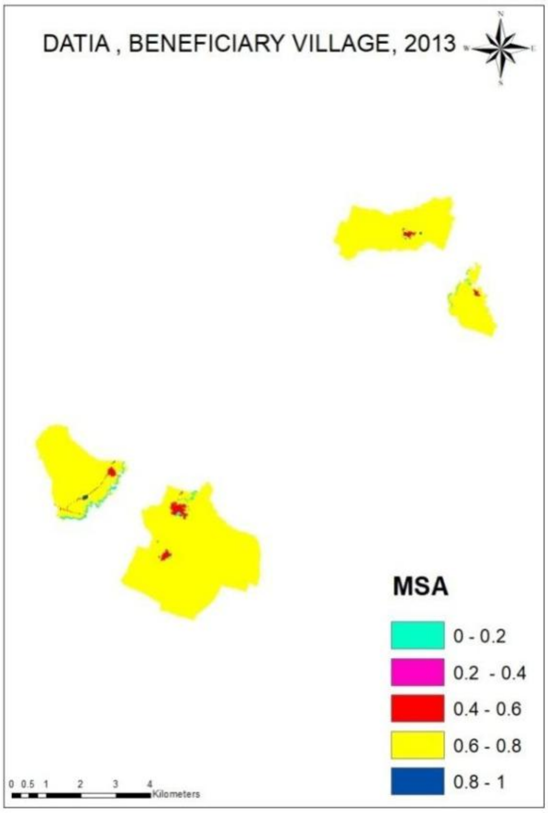


Figure 49: MSA_LU of Datia Intervention cluster 2 in 2013

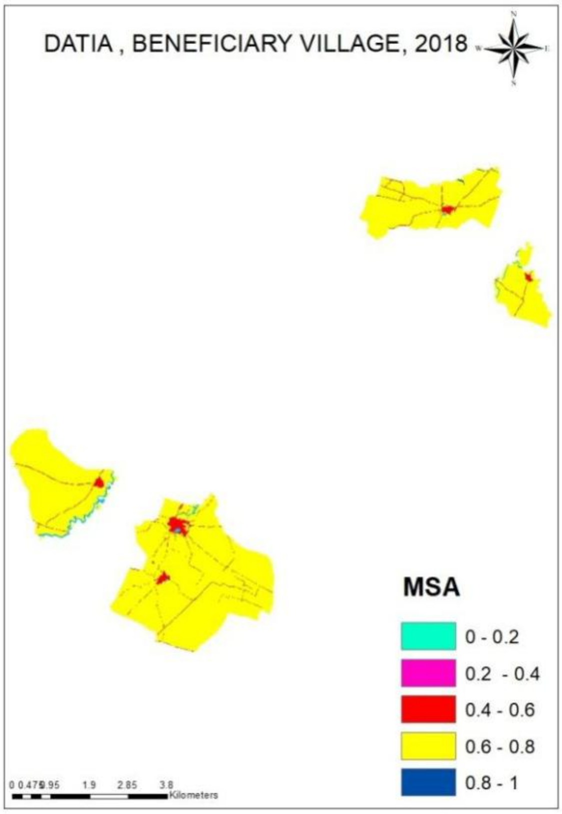


Figure 50: MSA_LU of Datia Intervention cluster 2 in 2018

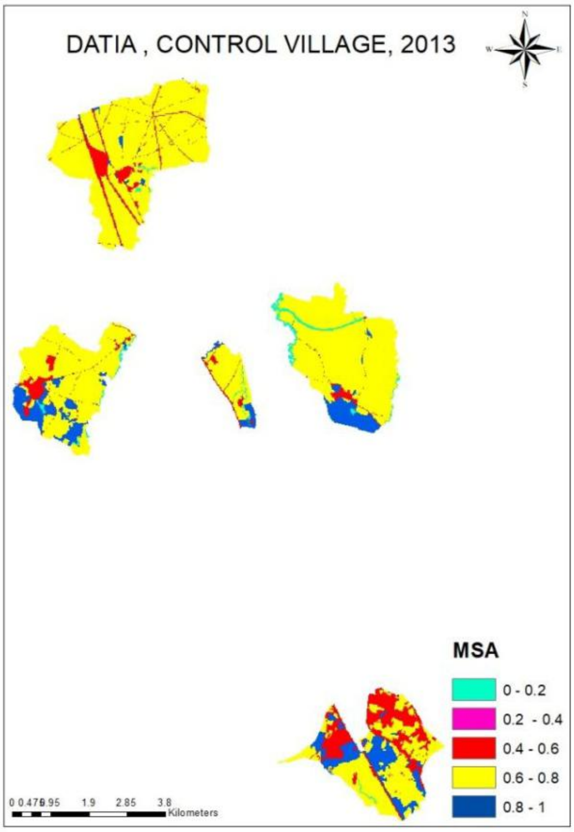


Figure 51: MSA_LU of Datia Control cluster 1 in 2013

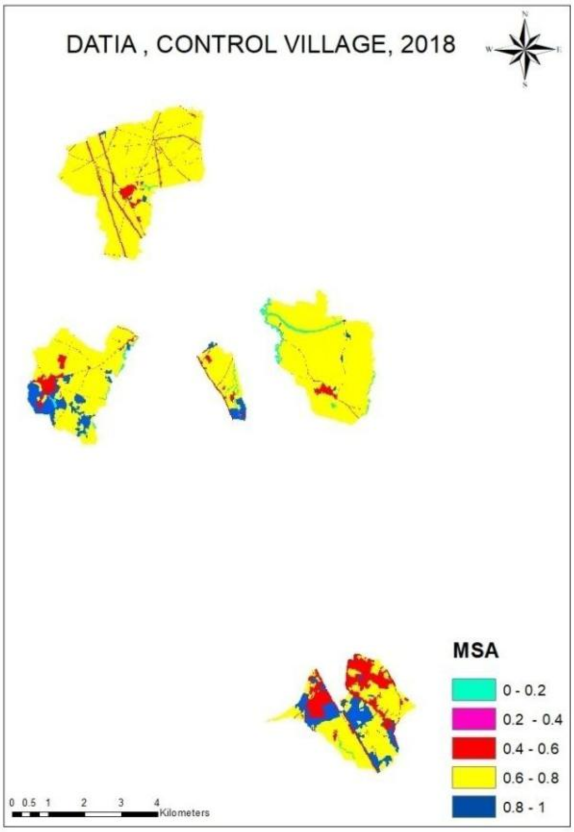


Figure 52: MSA_LU of Datia Control cluster 1 in 2018

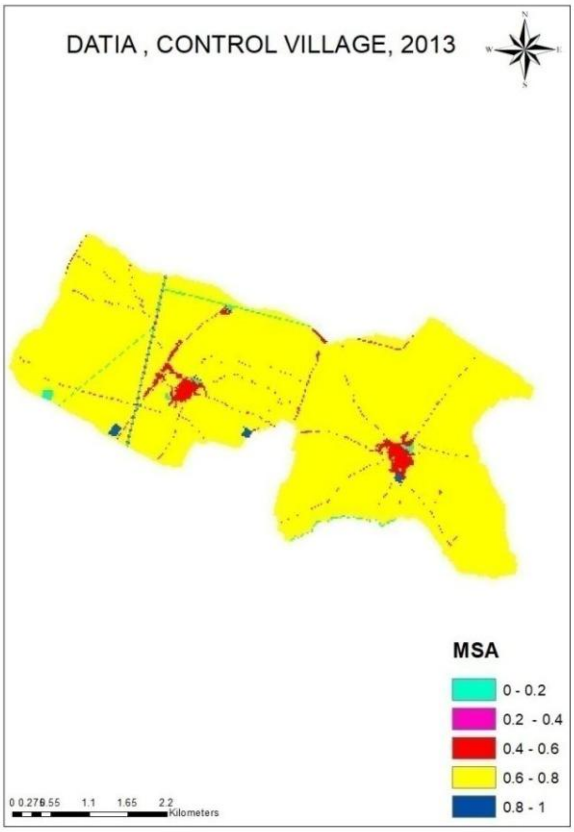


Figure 53: MSA_LU of Datia Control cluster 2 in 2013

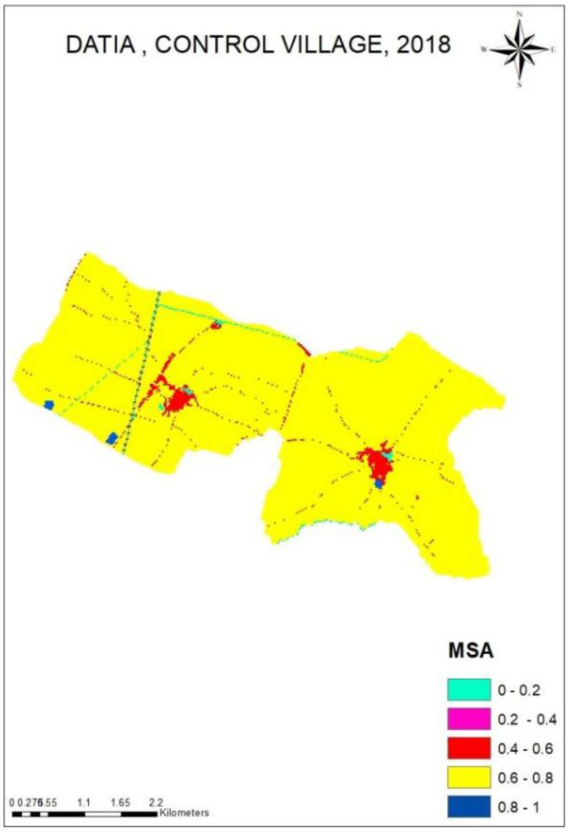


Figure 54: MSA_LU of Datia Control cluster 2 in 2018

Table 29: Data Sources for AGB, BGB and SOC of different LULC categories

Land use type	Above Ground Biomass (AGB)	Source	Below Ground Biomass (BGB)	Source	Soil Organic Carbon (SOC)	Source
Moderately dense tropical dry deciduous forest *	59.16	http://fsi.nic.in/carbon-reports (converted 000 tonnes to tonnes per hectare)	23.23	http://fsi.nic.in/carbon-reports (converted 000 tonnes to tonnes per hectare)	53.12	http://fsi.nic.in/carbon-reports (converted 000 tonnes to tonnes per hectare)
Open tropical dry deciduous forest *	12.82	http://fsi.nic.in/carbon-reports (converted 000 tonnes to tonnes per hectare)	5.03	http://fsi.nic.in/carbon-reports (converted 000 tonnes to tonnes per hectare)	29.91	http://fsi.nic.in/carbon-reports (converted 000 tonnes to tonnes per hectare)
Grazing Land	0.99	total biomass 2.19 given from which AGB was calculated. The agb value was then multiplied with default BCF used in 2013 as 0.47.	0.26	BGB=agb*0.26 (https://www.ijcmas.com/8-7-2019/Atul%20Singh,%20et%20al.pdf)	4.79	default emission factor taken from http://www.fao.org/faostat/en/#data/GC/metadata for cropland and grassland respectively
Trees outside forest	18.04	http://fsi.nic.in/carbon-reports (converted 000 tonnes to tonnes per hectare)	3.71	http://fsi.nic.in/carbon-reports (converted 000 tonnes to tonnes per hectare)	53.98	http://fsi.nic.in/carbon-reports (converted 000 tonnes to tonnes per hectare)
Wheat SC	4.7047	https://www.researchtrend.net/ijtas/pdf/7%20MOHIT%20KUMAR.pdf at 0-15 cm soil	0.329	https://www.researchtrend.net/ijtas/pdf/7%20MOHIT%20KUMAR.pdf at 0-15 cm soil	26.171	https://www.researchtrend.net/ijtas/pdf/7%20MOHIT%20KUMAR.pdf at 0-15 cm soil and SOC% * 20= t/ha SOC-

Land use type	Above Ground Biomass (AGB)	Source	Below Ground Biomass (BGB)	Source	Soil Organic Carbon (SOC)	Source
						https://www.researchgate.net/post/How_does_one_convert_Soil_Organic_Carbon_SOC_from_to_Kg_Ha
paddy SC	4.653	https://www.researchgate.net/publication/230058609_Carbon_stock_assessment_and_soil_carbon_management_in_agricultural_land-uses_in_Thailand/link/5a12a106458515cc5aa9e74a/download	1.3959	https://www.researchgate.net/publication/230058609_Carbon_stock_assessment_and_soil_carbon_management_in_agricultural_land-uses_in_Thailand/link/5a12a106458515cc5aa9e74a/download	20.6	https://pdfs.semanticscholar.org/ff88/8a00ed1142d9e184f3813ccb7704278c602a.pdf
sugarcane SC	13.658	https://www.researchgate.net/publication/230058609_Carbon_stock_assessment_and_soil_carbon_management_in_agricultural_land-uses_in_Thailand/link/5a12a106458515cc5aa9e74a/download	4.0984	https://www.researchgate.net/publication/230058609_Carbon_stock_assessment_and_soil_carbon_management_in_agricultural_land-uses_in_Thailand/link/5a12a106458515cc5aa9e74a/download	10.2	https://www.researchgate.net/publication/230058609_Carbon_stock_assessment_and_soil_carbon_management_in_agricultural_land-uses_in_Thailand/link/5a12a106458515cc5aa9e74a/download
wheat-mustard	63	default value from ipcc guidelines for AGB at the time of harvest https://www.ipcc-nggip.iges.or.jp/public/200	16.38	default value from ipcc guidelines for AGB at the time of harvest https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cr	19.1565	default emission factor taken from http://www.fao.org/faostat/en/#data/GC/metadatafor cropland and grassland respectively

Land use type	Above Ground Biomass (AGB)	Source	Below Ground Biomass (BGB)	Source	Soil Organic Carbon (SOC)	Source
		6gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf		opland.pdf		
mustard SC	1.175	https://onlinelibrary.wiley.com/doi/full/10.1002/ldr.2913	0.3055	https://onlinelibrary.wiley.com/doi/full/10.1002/ldr.2913	302.3	https://onlinelibrary.wiley.com/doi/full/10.1002/ldr.2913
Urad SC	0.5687	http://sciencebeingjournal.com/sites/default/files/Total%20Carbon%20Stock%20in%20Agricultural%20System.pdf	0.0376	http://sciencebeingjournal.com/sites/default/files/Total%20Carbon%20Stock%20in%20Agricultural%20System.pdf	12.32	https://www.ijcmas.com/6-7-2017/Raisen%20Pal,%20et%20al.pdf
Mung SC	0.8037	http://sciencebeingjournal.com/sites/default/files/Total%20Carbon%20Stock%20in%20Agricultural%20System.pdf	0.0423	http://sciencebeingjournal.com/sites/default/files/Total%20Carbon%20Stock%20in%20Agricultural%20System.pdf	4	https://pdfs.semanticscholar.org/ff88/8a00ed1142d9e184f3813ccb7704278c602a.pdf- 30 cm soil
groundnut SC	5.7105	https://cdiac.ess-dive.lbl.gov/ftp/Tris_West_US_County_Level_Cropland_C_Estimates/Cropland%20Carbon%20metadata.htm	1.48473		7.6	https://pdfs.semanticscholar.org/ff88/8a00ed1142d9e184f3813ccb7704278c602a.pdf- 30 cm soil
sesame SC	1.2972	https://pdfs.semanticscholar.org/48cf/dda68d860489142c139d60439712028ab450.pdf	0.337272		7.92	https://pdfs.semanticscholar.org/48cf/dda68d860489142c139d60439712028ab450.pdf

Land use type	Above Ground Biomass (AGB)	Source	Below Ground Biomass (BGB)	Source	Soil Organic Carbon (SOC)	Source
maize SC	3.0691	http://sciencebeingjournal.com/sites/default/files/Total%20Carbon%20Stock%20in%20Agricultural%20System.pdf	0.423	http://sciencebeingjournal.com/sites/default/files/Total%20Carbon%20Stock%20in%20Agricultural%20System.pdf	63.1	https://www.researchgate.net/publication/277602825_Projection_of_corn_production_and_stover-harvesting_impacts_on_soil_organic_carbon_dynamics_in_the_US_Temperate_Prairies/link/5575bd5608aeacff1ffe0440/download
Jowar/ sorghum SC	1.2991	for AGB and for SOC with 34.2 g/kg TOC https://sci-hub.tw/https://www.researchgate.net/publication/270474122_Soil_Organic_Matter_and_Physical_Attributes_Affected_by_Crop_Rotation_Under_No-till	0.337761		45.14	for AGB and for SOC with 34.2 g/kg TOC https://sci-hub.tw/https://www.researchgate.net/publication/270474122_Soil_Organic_Matter_and_Physical_Attributes_Affected_by_Crop_Rotation_Under_No-till
chana and peas	63	default value from ipcc guidelines for AGB at the time of harvest https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf	16.38	default value from ipcc guidelines for AGB at the time of harvest https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf	19.1565	default emission factor taken from http://www.fao.org/faostat/en/#data/GC/metadata for cropland and grassland respectively
Masoor SC	1.17	https://www.researchgate.net/publication/314361248_Biomass_carbon_stock_un	0.3042		2.4	https://www.researchgate.net/publication/270094928_Soil_organic_carbon_The_value_to_soil_prop

Land use type	Above Ground Biomass (AGB)	Source	Below Ground Biomass (BGB)	Source	Soil Organic Carbon (SOC)	Source
		der_different_production_systems_in_the_mid_hills_of_Indian_Himalaya				erties
Vegetables	63	default value from ipcc guidelines for AGB at the time of harvest https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf	16.38		19.1565	default emission factor taken from http://www.fao.org/faostat/en/#data/GC/metadata for cropland and grassland respectively
Soyabean SC	1.645	https://sci-hub.tw/10.1016/j.soilbio.2014.04.005	0.4277		3.6	https://sci-hub.tw/10.1016/j.soilbio.2014.04.005
Millet SC	3.2712	https://sci-hub.tw/https://www.researchgate.net/publication/270474122_Soil_Organic_Matter_and_Physical_Attributes_Affected_by_Crop_Rotation_Under_No-till	0.850512		49.02	https://sci-hub.tw/https://www.researchgate.net/publication/270474122_Soil_Organic_Matter_and_Physical_Attributes_Affected_by_Crop_Rotation_Under_No-till

Table 30: Details of Benefit Cost Analysis

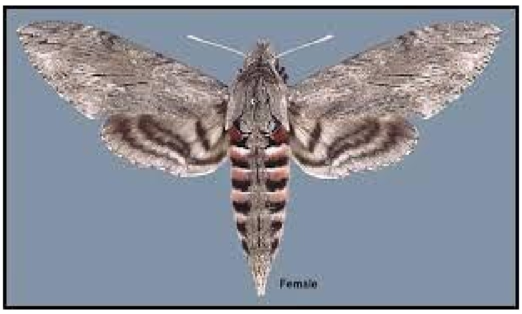
BCR	NPV (000)	Datia	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2040
123.7	₹39,366	Costs	10,696	9,830	8,863	8,333	7,939	7,372	96	60								
	₹2,018,757	Crop Benefit								227,255	227,255	227,255	227,255	227,255	227,255	227,255	227,255	227,255
	₹2,113,875	Livestock Benefit								237,963	237,963	237,963	237,963	237,963	237,963	237,963	237,963	237,963
IRR	-₹50,037	Forestry Benefit								-5,633	-5,633	-5,633	-5,633	-5,633	-5,633	-5,633	-5,633	-5,633
	₹50,068	Biodiversity Ben.								5,636	5,636	5,636	5,636	5,636	5,636	5,636	5,636	5,636
	₹738,095	Carbon Benefits								811,905								
89%	₹4,831,392	Net Benefit	-10,696	-9,830	-8,863	-8,333	-7,939	-7,372	-96	1,277,066	465,221	465,221	465,221	465,221	465,221	465,221	465,221	465,221
BCR	NPV (000)	Shivpuri	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2040
148.0	₹15,475	Costs	0	268	323	304	73	9,813	9,575	9130.95	59.71	55.46						
	₹419,428	Crop Benefit								47,216	47,216	47,216	47,216	47,216	47,216	47,216	47,216	47,216
	₹1,812,766	Livestock Benefit								204,066	204,066	204,066	204,066	204,066	204,066	204,066	204,066	204,066
IRR	-₹197,135	Forestry Benefit								-22,192	-22,192	-22,192	-22,192	-22,192	-22,192	-22,192	-22,192	-22,192
	₹203,792	Biodiversity Ben.								22,941	22,941	22,941	22,941	22,941	22,941	22,941	22,941	22,941
	₹52,160	Carbon Benefits								57,376								
201%	₹2,275,537	Net Benefit	0	-268	-323	-304	-73	-9,813	-9,575	300,276	251,972	251,976	252,032	252,032	252,032	252,032	252,032	252,032
BCR	NPV (000)	Niwari	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2040
68.9	₹19,214	Costs	4,524	4,139	3,732	3,509	3,162	3,013	2,940	2,804	0.00	0.00						
	₹563,179	Crop Benefit								63,398	63,398	63,398	63,398	63,398	63,398	63,398	63,398	63,398
	₹517,967	Livestock Benefit								58,308	58,308	58,308	58,308	58,308	58,308	58,308	58,308	58,308
IRR	₹0	Forestry Benefit								0	0	0	0	0	0	0	0	0
	₹16,800	Biodiversity Ben.								1,891	1,891	1,891	1,891	1,891	1,891	1,891	1,891	1,891
	₹226,031	Carbon Benefits								248,635								
78%	₹1,304,764	Net Benefit	-4,524	-4,139	-3,732	-3,509	-3,162	-3,013	-2,940	369,429	123,598	123,598	123,598	123,598	123,598	123,598	123,598	123,598

Table 31: Pollinator and Non-pollinator species in intervention and control villages in Datia

Names of Species	Village Wise	Season	Where found? Plantation/ crop	Pollinator (P) /Non-pollinator species (NP)
 Apis Cerana Indica	Salaiya Pamar, Kamhar, Pathari, Chopra, Bijapur, Ramnagar, Sarol, Samroli, Uprayen	All seasons (active in summer)	All crops, vegetables, fruits	P
 Apis Dorsata	Salaiya Pamar, Kamhar, Pathari, Chopra, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	All seasons (active in summer)	All crops, vegetables, fruits	P
 Apis Florea	Salaiya Pamar, Kamhar, Pathari, Chopra, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen	All seasons (active in summer)	All crops, vegetables, fruits	P

Names of Species	Village Wise	Season	Where found? Plantation/ crop	Pollinator (P) /Non-pollinator species (NP)
 Apis Mellifera	Salaiya Pamar, Kamhar, Pathari, Chopra, Bijapur, Ramnagar, Sarol, Samroli, Uprayen, Sonagir	All seasons (active in summer)	All crops, vegetables, fruits	P
 Eurema Hecabe	Salaiya Pamar, Kamhar, Pathari, Chopra, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	Rainy season	Kharif crop	P
 Danaus Chrysippus	Salaiya Pamar, Kamhar, Pathari, Chopra, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	Rainy season	Kharif crop	P

Names of Species	Village Wise	Season	Where found? Plantation/ crop	Pollinator (P) /Non-pollinator species (NP)
 Junonia Orithya	Kamhar, Ramnagar, Govindnagar, Sarol, Uprayen, Sonagir	Rainy season	Kharif crop	P
 Ceratina Binghami	Salaiya Pamar, Sonagir, Uprayen	All	Vegetation	P
 Xylocopa Aestuans	Kamhar, Govindnagar, Samroli, Uprayen, Sonagir	kharif	Trees more not in crops	P
 Xylocopa Fenestrata	Salaiya Pamar, Kamhar, Pathari, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	kharif	Trees more not in crops	P

Names of Species	Village Wise	Season	Where found? Plantation/ crop	Pollinator (P) /Non-pollinator species (NP)
 Onthophagus Catta	Salaiya Pamar, Kamhar, Chopra, Bijapur, Ramnagar, Samroli, Sonagir	all	Not on vegetation but on cow dung.	NP
 Onthophagus Bonasus	Salaiya Pamar, Kamhar, Pathari, Chopra, Bijapur, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	rainy	Not on vegetation but on cow dung.	NP
 Lampides Boeticus	Kamhar, Sarol, Uprayen, Sonagir	rainy	Trees and crops	P
 Agrius Convolvuli	Kamhar, Ramnagar, Govindnagar, Uprayein	winter	crops	P

Names of Species	Village Wise	Season	Where found? Plantation/ crop	Pollinator (P) /Non-pollinator species (NP)
 Aulacophora Foveicollis Lucas	Kamhar, Salaiya Pamar, Pathari, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	All year	Rabi crop	NP
 Cyrtopeltis Tenuis	Chopra, Salaiya Pamar, Pathari, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	All year	Rabi crop	NP
 Coccinella Septempunctata	Kamhar, Salaiya Pamar, Pathari, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	rainy	Plants, peanuts	NP
 Menochilus Sexmaculatus	Kamhar, Salaiya Pamar, Chopra, Bijapur, Ramnagar, Sarol, Samroli, Uprayen, Sonagir	rainy	Plants, vegetables	NP

Names of Species	Village Wise	Season	Where found? Plantation/ crop	Pollinator (P) /Non-pollinator species (NP)
 Catopsilia Pomona	Kamhar, Pathari, Salaiya Pamar, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	rainy	Kharif crop	P
 Colotis Vestalis Vestalis	Kamhar, Pathari, Salaiya Pamar, Bijapur, Ramnagar, Sarol, Samroli, Uprayen	rainy	Kharif crop	P
 Spodoptera Exigua	Salaiya Pamar, Bijapur, Ramnagar, Uprayen, Sonagir	winter	Flowers	P
 Cnaphalocrocis Medinalis	Salaiya Pamar, Pathari, Kamhar, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	rainy	Kharif crop	P

Names of Species	Village Wise	Season	Where found? Plantation/ crop	Pollinator (P) /Non-pollinator species (NP)
 Delias Eucharis	Salaiya Pamhar, Pathari, Bijapur, Ramnagar, Govindnagar, Uprayen, Sonagir	rainy	Kharif crop	P
 Pelopidas Mathias	Salaiya Pamhar, Pathari, Ramnagar, Samroli, Uprayen, Sonagir	all	Only plants not on crops	P
 Musca Domestica	Kamhar, Pathari, Salaiya Pamar, Chopra, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	All seasons	All	P
 Camponotus Compressus	Kamhar, Pathari, Salaiya Pamar, Chopra, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	Rainy season	All plants, crops and ground	P

Names of Species	Village Wise	Season	Where found? Plantation/ crop	Pollinator (P) /Non-pollinator species (NP)
 Euploea Core	Salaiya Pamhar, Kamhar, Chopra, Bijapur, Ramnagar, Govindnagar, Uprayen, Sonagir	rainy	all	P
 Rousettus Leschenaultii	Kamhar, Pathari, Salaiya Pamar, Chopra, Bijapur, Sarol, Samroli, Uprayen, Sonagir	All seasons	Habitat areas- mango, imli, guava	P
 Cynopterus Sphinx	Kamhar, Pathari, Salaiya Pamar, Sarol, Samroli, Uprayen, Sonagir	All seasons	Habitat areas- mango, imli, guava	P
 Pteropus Giganteus	Kamhar, Chopra, Salaiya Pamar, Samroli, Uprayen, Sonagir	All seasons	Habitat areas- mango, imli, guava	P

Names of Species	Village Wise	Season	Where found? Plantation/ crop	Pollinator (P) /Non-pollinator species (NP)
 Ropalidia Marginata	Kamhar, Pathari, Salaiya Pamar, Chopra, Bijapur, Ramnagar, Govindnagar, Sarol, Samroli, Uprayen, Sonagir	summer	Fruits	P
 Spialia Galba	Salaiya Pamhar, Ramnagar, Uprayen, Sonagir	rainy	All	P

Source: Primary and secondary data

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