Economics of Desertification, Land Degradation and Drought in India

Vol II: Six micro-economic case studies of degradation

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Executive summary of the six case studies on land degradation and desertification (Volume II)

We provide below an executive summary of the six case studies carried out across India in a range of ecosystems and terrain types including rangelands, forests and agro-ecosystems that encompass both montane areas and the plains. These case studies pertain to the major causal reasons of degradation including water erosion, salinity, salt water intrusion in coastal areas, vegetal degradation, sodicity and wind erosion in the States of Madhya Pradesh, Gujarat, Andhra Pradesh, Uttarakhand, Uttar Pradesh and Rajasthan. These studies involving primary surveys were carried out in more than 1000 households and utilized a range of approaches including a systems dynamic approach, travel costs as well as studies on interventions targeted at particular causal mechanisms (the 'preventive approach'). The results of these individual case studies are summarized below.

Modeling the grassland degradation of Banni using system dynamics: An investigation into the ecological and economic causes and impacts of grassland degradation in Banni

The Banni grasslands located in Kachchh district of Guarat, in India were once known as Asia's finest grasslands. In the last few decades however, they have been severely degraded, with grassland productivity falling from 4000 kg/ ha to 620 kg/ ha between 1960 and 1999.The people of Banni, known as Maldharis have been living as nomadic or semi-nomadic pastoralists for hundreds of years, relying mainly on livestock breeding as their source of livelihood. This grassland degradation poses a serious crisis for them. The danger is further exacerbated as the numbers of livestock have increased in the last decade, with the advent of dairies in Banni. This has made the sale of milk and milk products highly profitable. The invasion of the grasslands by the woody species of *Prosopis juliflora is* seen by the Maldharis as one of the primary causes for the degradation of Banni grasslands.

In this study, we present Banni as a complex system and have used system dynamics to model its ecologic-economic interactions resulting from grassland degradation, and to generate future scenarios. We have also carried out an economic valuation of Banni to obtain the present value of its future economic gains under two scenarios, 1) Business As Usual (BAU) and 2) '*Prosopis* removal policy' scenario. Our modeling results, consistent with the Maldharis' perceptions, indicate that *Prosopis* invasion is indeed the major cause for the degradation of Banni, and the economic valuation indicates that *Prosopis* removal is a favourable policy option for sustaining the livestock economy and halting grassland degradation. This study led to several recommendations listed below

- The systems dynamic approach suggests that removal of the invasive tree *Prosopis juliflora* is a favourable policy option for sustaining the livestock economy and halting grassland degradation. The per ha costs of land degradation are estimated at INR 27,645 per hectare, accounting for the difference in total benefits between a business as usual scenario and a *Prosopis* removal scenario. The results indicate that livestock profitability goes up in event of *Prosopis* removal and that in order to sustain livestock as the main occupation of Maldharis the land area under *Prosopis* needs to be cleared, preferably without any delay. A policy level discussion on the need to remove *Prosopis*, as a measure to reduce land degradation is consequently warranted, given that large areas of the country are now under invasive species.

- The economic valuation exercise also indicates that a delay in policy implementation has a huge cost for the economy. This is particularly important for Banni since the livestock sensitivity to grass availability is very high and *Prosopis* density greatly influences grass availability. Hence, a quick policy decision on whether *Prosopis* should be removed or not, based on an assessment of the pros and cons would prove to be beneficial.
- There is a need for additional ecological and economic research on the Banni grasslands. This study needs to be supported with data and information about the micro-dynamics of Banni. The cost of removing *Prosopis* need to be estimated for different regions of Banni depending on the extent of cover and then factored into the analysis. There are information gaps with respect to the grass productivity, fodder availability in different seasons, extent of seasonal livestock migration due to fodder deficit and the role of salinity. In order to strengthen the results of such a modelling exercise, these gaps need to be addressed through research which can then serve as inputs to an integrated systems model which can simulate the behaviour of key policy variables.
- There is also an unresolved issue of entitlement of land ownership in the Banni grasslands. Hence studies on the political ecology of Banni are pertinent, since these factors would also have a bearing on the decision-making processes.
- There is a need to develop decision-support tools which can be used for performing multi-stakeholder exercises to enable consensual decision making, particularly given the current ecological situation of Banni and uncertainty over land rights. Thus, this study serves as a motivation for further research into the dynamics of the Banni grassland and development of decision-support tools for policy planning and consensus development.
- Most importantly, this study highlights the need to focus on initiating studies on the economic impacts of invasive species and their contribution to the economics of land degradation. The contribution and economic costs incurred due to the spread of invasives currently remains largely un-quantified in India.

We would, however, like to emphasise that due to an information gap, lack of data and uncertainty about various models parameters like future rainfall variability or out-migration due to fodder deficits, our model is by no means predictive. The results are only an indication of events that might unfold in Banni in years to come.

Losing the benefits of forests to degradation? A case study from Tehri Garhwal, Uttarakhand

Vegetal degradation has been pegged as the second leading cause of land degradation in India accounting for 8.91% of the total geographical area (TGA) in 2011-13 according to one source (SAC, 2016). Vegetal degradation is the primary cause of degradation in Uttarakhand and has increased from 545610 ha in in 2003-05 to 606616 ha in 2011-13 (SAC, 2016), i.e. from 10.2% to 11.34%. This is also evident from the decrease in dense forests in 77% of the districts of the State (FSI, 2015). The value of Uttarakhand's forests in 2011 was estimated at Rs 1186259 million yielding a per capita figure of Rs 117610 (TERI, 2014). Overexploitation of forest resources contributes to forest degradation in the State, despite their enormous economic value. Physical accounts for the forests of Uttarakhand from 2000-01 to 2010-11, indicate that the demand for fuel wood accounts for the largest share of change followed by diversion of forest land for non-forest use. In 2010-11, fuelwood production was estimated to be 26610 cubic meter stacks while the estimated household consumption was 3013660 cubic meter stacks (TERI, 2014)[1] pointing to grossly unsustainable fuelwood harvests. This huge burden of fuelwood harvests leads to forest degradation impacting the lives of scores of people who depend on these forests for myriad ecosystem services. In this case study, we attempt to determine the value of forests in the Dhanulti and Devalsari area of Tehri Garhwal, Uttarakahand to local communities and to tourists and what their degradation implies in terms of lost revenues from recreation or foregone provisioning services from fuelwood and fodder. In addition, using a mix of primary and secondary data and remote sensing assessments, we determine the costs of forest degradation in Dhanulti and Devalsari from 2001-2015.

A total of 151 households were surveyed to determine their dependence on forests, as well as for a ranking of their perceptions on the value of the forests which was captured using a Analytic Hierarchy Process. A travel cost assessment of 157 tourists to Dhanaulti was also carried out to determine the recreation value provided by the forests of this area. Most of the households (87%) were dependent on fuelwood as their primary fuel source and forests were indisputably the main source of firewood with the most pressure imposed on Reserve Forests. The households collect an average of 1500±130.63 (SE) kg of fuelwood per household per year. The total dry fodder consumption was 1128 kg per ha. The local people valued the forests for their biodiversity, their ecotourism value and their contribution to local livelihoods. In terms of products derived from the forests, the people expectedly ranked fuelwood the highest followed by timber and fodder. A travel cost analysis provided an individual consumer surplus of Rs 918.75 and a total consumer surplus of Rs 24,186 per ha of forest area.

The present value of recreational benefits is Rs 3,13,320 per ha of forest area (discount rate of 4%). The costs of forest degradation for Dhanaulti and Devalsari from 2001-2015 using values obtained from the primary survey for fodder, fuelwood and ecotourism (recreation) and secondary values from Verma (2014) for the remaining ecosystem services are Rs 97.8 million. We calculated an NPV over 25 years using a 4% discount rate as per Verma (2014). The loss in in NPV of forests from 2001-2015 is 0.049 million per ha. The results from this study underline the high costs associated with forest degradation. It also strengthens the conclusion of other studies from Uttarakhand that one of the primary causes of forest degradation in the State is fuelwood collection.

The study also estimated the costs of forest degradation and reclamation for Dhanaulti and Devalsari in 2030. The results indicated that it costs far less to reclaim the area than it does to degrade it. While the costs of degradation for these areas was projected to be Rs 1087.8 million in 2030 (at 2013 prices), the cost of reclamation at Rs 113.4 million is only 10% of the costs of degradation.

Recommendations emerging from this study include

- This study highlights the need to find alternatives to fuelwood consumption in Uttarakhand as a means to reduce forest degradation. Most of the households (87%) were dependent on fuelwood as their primary fuel source and forests were

[1] The study estimated fuel wood consumption based on the NSSO (2009/ 10) data on monthly per household consumption of fuel wood (193.15 kg for rural and 124.71 kg for urban) for Uttarakhand (TEDDY 2011-12, page 295); Conversion factor of 1 cubic meter=725 kg (FAO, 2012) was used and number of households using fuel wood for cooking (Census 2011)

indisputably the main source of firewood with the most pressure imposed on Reserve Forests. Physical accounts for the forests of Uttarakhand from 2000-01 to 2010-11 indicate that the demand for fuel wood accounts for the largest share of change followed by diversion of forest land for non-forest use. In 2010-11, fuelwood production was estimated to be 26610 cubic meter stacks while the estimated household consumption was 3013660 cubic meter stacks (TERI, 2014)[2] pointing to grossly unsustainable fuelwood harvests.

- The local people valued the forests for their biodiversity, their ecotourism value and their contribution to local livelihoods. Enhancing community run ecotourism can contribute significantly to the local economy and help reduce pressure on forests. A significant proportion of the sampled (155) households benefitted from ecotourism (44%) while as many as 48% of households wanted tourism to be developed as the primary activity in the area. Eighty % of households that felt the need to boost ecotourism cited low incomes derived from agriculture and migration as the primary rationale for this. Interestingly, many respondents viewed ecotourism as a means to protect the forest (51%) and reduce dependence on them (49%).They evidently view ecotourism as being less detrimental to forest management. Consequently, the need to focus on low impact ecotourism is one of the major recommendations to emerge from this case study.
- Amongst tourists, 73% wanted to have enhanced sightseeing facilities and improved road conditions. The lack of trained guides was also a big drawback (65%). Several of the indicators suggested that people would like to see improvements in walking trails (53%), bird and butterfly watching facilites as well as local field guides or brochures highlighting biodiversity hotspots (30%), and appropriate signate (34%). Presence of toilets and the need for improved waste disposal were also considered important. Consequently, the overall tourism experience needs to be enhanced for people visiting the forests of Uttarakhand.
- According to our estimates, the costs of reclaiming forests in 2030 works out to only 10% of the costs of forest degradation. It therefore, makes more economic sense to reclaim forests rather than to degrade them. Several measures will need to be taken at the state levels to address the pervasive issue of forest degradation, arguably one of the most important reasons for land degradation

The Role of Farm Bunds in Enhancing Agricultural Productivity and Farm Incomes through Reduced Water Erosion in the Indore district of Madhya Pradesh.

Water erosion is a major contributing factor for land degradation and desertification in India. Madhya Pradesh (MP) is one of the prominent states that is highly vulnerable to water erosion. Under the Integrated Watershed Management Programme (IWMP) farm bunds have been constructed in Madhya Pradesh to control water erosion. This study measures the

[2] The study estimated fuel wood consumption based on the NSSO (2009/ 10) data on monthly per household consumption of fuel wood (193.15 kg for rural and 124.71 kg for urban) for Uttarakhand (TEDDY 2011-12, page 295); Conversion factor of 1 cubic meter=725 kg (FAO, 2012) was used and number of households using fuel wood for cooking (Census 2011)

impact of farm bunds in controlling water erosion in case of Indore district of MP, through a sample of 225 farmers (including 150 farmers with the intervention and 75 farmers without the intervention-the control group). The study finds that the intervention has significant impacts in controlling water erosion in case of soyabean and wheat which are major crops in the study area. In case of these two crops, farmers have been benefitted by these farm bunds in terms of improvement in productivity as well as savings in cost of cultivation. In other words, on average, a farmer with farm bunds has higher productivity (average productivity is 2.82 qnt/ ha for the intervention group vis-à-vis 2.49 qnt for the control group in case of soyabean and average productivity is 6.15 qnt/ ha for the intervention group vis-à-vis 4.77 qnt/ ha for the control for wheat) and lower costs of cultivation (average cost of cultivation is INR 5981 per ha for the intervention group and INR 8051 per ha for the control group in case of soyabean while the average cost of cultivation is INR 4314 per ha for the intervention versus INR 5473 per ha for the control in case of wheat. Therefore, the average profitability per unit of land for an average farmer in the intervention group (INR 2192 per ha for soyabean and INR 3940 per ha for wheat) is higher than that of the control group (INR 524 per ha for soybean and INR 751 per ha for wheat). These savings in average cost of cultivation and gains in average productivity are the cost of land degradation in the absence of water erosion control interventions.

The extent of water erosion in the State of Madhya Pradesh in 2030 is projected to increase linearly to 1138402 ha. Reclaiming these eroded areas in 2030 at the rate of Rs 15,000 per ha will be Rs 17076 million at 2015 prices.

The study suggests that the scope of such an intervention should be expanded to include more farmers. Moreover, farmers who were not part of the intervention were either not aware of the intervention or the plots they owned were not suitable for inclusion. Thus creating awareness about the potential benefits to be derived is critical to programme success as is identifying appropriate measures for those whose plots do not qualify.

The importance of supplementary programmes like skill enhancement, providing proper and necessary agricultural information, creating relevant infrastructure and better access to market as well as financial support are are required as supportive measures. These supportive measures are important to exploit the maximum benefit of the intended programme. Since, agro-climatic conditions and cropping pattern as well as socio-economic conditions of the farmers vary across regions, area-specific flexibility may be incorporated into the overall watershed programme to make it more effective based on requirement of the local farmers. In summary, the recommendations emerging from the study include:

1. Cover maximum number of beneficiaries under the programme
2. Spread awareness about the details and benefits off the programme
3. Provide alternative measure for plots that cannot be covered by the intervention
4. Implement supportive measures to augment the intended programme
5. Incorporate area-specific flexibility

Reclaiming Sodic Land in Mainpuri, Uttar Pradesh – A Case Study

Sodic soil characterized by excessive sodium is considered to be an important impediment to agricultural productivity. Of the total area of the country that is degraded due to sodicity, Uttar Pradesh, Punjab and Haryana are the most severely affected. To treat sodic soils, the Uttar Pradesh Land Reclamation Project implemented by the Uttar Pradesh Bhumi Sudhar

Nigam has been operational since 1993, and is currently in its third phase. UPSLRIIIP is a package intervention to reduce sodicity with four key components – on-farm development, improved drainage systems, agricultural support systems, and an institutional strengthening mechanism for improved market access. This study measured the impact of on-farm interventions to reduce sodicity among the programme beneficiaries by comparing a total sample of 337 households including 205 in the project area and 132 in the control group, before and after the intervention.

The study finds that the intervention has significant impacts in reclaiming sodic soils, which in turn resulted in the enhanced productivity of rice and wheat. The land with highest sodicity which was left barren before the UPSLRIIIP intervention had at least two crops (*Kharif* and *Rabi*) that were cultivated annually. The severity of sodium in the soil was found to have an inverse relationship with percentage change in productivity i.e. higher sodicity resulted in low productivity. The research design allowed estimation of change in productivity in slightly and moderately sodic soils due to the reclamation effort under UPSLRIIIP. The productivity of slightly sodic plots improved by 2.18 t/ ha for rice and 0.82 t/ ha for wheat. For the moderate sodic plots the productivity improved to 1.04 t/ ha. Farmers with sodic plots incurred a loss in net returns from agriculture. In slightly sodic soils this was e. INR -5847/ - per ha which increased in moderately sodic plots to INR -17743/ - per ha, with no income derived from severely sodic plots. The net return of revenue after reclamation increased to INR 1623/ - per ha for slightly sodic, INR755/ - per ha for moderately sodic and INR 870/ - per ha for severely sodic soils. The annual cost of degradation was estimated for control villages as Rs. 223.05 lakhs.

We develop two scenarios for area impacted by salinity/ alkalinity in Uttar Pradesh in 2030. In one scenario, salinity/ alkalinity impacted land is projected to drop to 0 in 2019 itself. Therefore in 2030, Uttar Pradesh would have no alkaline land and all land would be reclaimed by 2019. Hence no costs of reclamation in 2030 would be applicable. However, given that this scenario appears to be a bit optimistic, we generate a second scenario where the degraded area decreases proportionally every eight years.The cost of reclamation norms for alkaline/ saline land is Rs 60000 per ha in 2016 prices[3]. Therefore, the cost of reclaiming lands degraded by salinity/ alkalinity in Scenario 2 in 2030 is Rs 3199 million in 2016 prices.These figures suggest that salinity in Uttar Pradesh is being addressed successfully.There is need for a detailed review of the process by which salinity/ alkalinity in the state is being addressed and an understanding of the reasons for the success of the initiative versus other land degradation causes.

Based on field observations, the results of this study and interaction with experts, summarised below are few recommendations to address the challenges of sodic soil reclamation.

- Successful reclamation of sodic soils in Uttar Pradesh warrants studies to determine the reasons for success and their application to other states impacted by salinity such as Punjab.
- Although, application of gypsum is a feasible approach for overcoming the structural and nutritional constraints in sodic soils, reduced availability and quality of agricultural-grade gypsum has been reported (Sharma et al., 2016). Thus, there is a need to identify other low-cost alternatives to reduce the pressure on limited gypsym reserves.
- In addition, resodification of the previously gypsum-amended sodic lands has also increased. Resodification, refers to the reappearance of sodic patches resulting in

[3] http://agricoop.nic.in/sites/default/files/rps_guidelines%20(2).pdf

stunted crop growth and low yields in a sizeable area of the land. The results of a study conducted by Yadav et al. (2010)[4], to assess the sustainability of sodic land reclamation in Etawah district of Uttar Pradesh using remote sensing and ground truth data, showed that out of the total (3,905 ha) reclaimed area, about 27% had relapsed showing the signs of deterioration after a period of improvement. The study further identifies poor on-farm water management, including factors, such as, nearness to canal, poor drainage system and sallow water tables, to be perilous to resodifiction in Uttar Pradesh. This point towards the need to develop strategies to use marginal quality saline and sodic water in soil reclamation, enhancement of water drainage system and sensitization of farmers to adopt water management practices.

- Lastly, experiments on land reclamation using phytoremediation, through salt-tolerant cultivars in field crops and sodic tolerant fruit crop should be conducted. These cultivars available in different field and horticulture crops also give stable yield with reduced or no amendments, especially in partially reclaimed soils.

Economic benefits of addressing soil and water salinity through sub-surface drainage: A case study from the coastal croplands of Andhra Pradesh

A questionnaire-based survey was conducted among the farmers of the Kalipattanam village of Mogultaru tehsil, West Godavari district of Andhra Pradesh to understand the cost of land degradation in the coastal area owing to waterlogging from saline sea water intrusion to the crop land. Flap gates and sub-surface drainage (SSD) system were installed in selected farmers' land 10 years earlier under the Andhra Pradesh Water Management (APWAM) project. Flap gates were installed to restrict the mixing of saline river water with irrigation water. Farmers with these interventions formed the 'intervention group'. The control group included farmlands outside the APWAM project area but in the same village as the intervention group. Based on the soil salinity of the crop lands in the area, crop lands were classified under five different groups: a) not saline (< 3.0 dS m^{-1}), b) Moderately saline (2.1 to 4.5 dS m^{-1}), c) Saline (4.6 to 6.0 dS m^{-1}), d) Highly saline (6.1 to 8.0 dS m^{-1}) and e) extremely saline (> 8.0 dSm^{-1}).

The study suggests that introduction of flap gate + SSD system has significantly reduced the soil salinity over flap gate only and control area. Each level-increase of salinity reduces the net annual profit of farmers' by INR10045 ha^{-1} and are the costs of land degradation for agricultural productivity in the absence of the intervention. However, there was no significant difference in crop (rice) productivity in the land area under flap gate only and flap gate+SSD area. This suggests that although flap gate + SSD systems reduce the soil salinity level, flap gates are sufficient to improve the productivity of the degraded croplands of the area with comparative lower cost than the flap gate + SSD system. More research is required to ascertain if this is true in a range of local conditions as this can considerably reduce the costs of reclamation.

These interesting results suggest that flap gates may be sufficient to enhance productivity and net annual profits for farmers. This must be kept in mind while initiating other such programmes since this could significantly reduce costs. Moreover, this result needs to be tested in other sites as well to see if it holds true in a range of environmental conditions.

[4] Yadav MS, Yadav PPS, Yaduvanshi M, Verma D and Singh AN (2010) Sustainability assessment of sodic land reclamation using remote sensing and GIS. Journal of Indian Society of Remote Sensing. 38: 269-278.

Given that the results show that flap gates reduce salinity thereby, enhancing rice productivity, it is important to create flap gates in all the crop lands along the Upputeru river to effectively control land degradation as well as enhance rice productivity from salinity reductions.

Moreover, our results suggest the need to restore waterlogged areas. The projected extent of waterlogged areas in the State in 2030 is 148782 ha and the cost of their reclamation is Rs 7439 million at 2013 prices.

The extent of waterlogged areas in the State is projected to increase linearly in 2030 to 148782 ha and the cost of reclamation is Rs 7439 million at 2013 prices.

Foregone agricultural benefits due to wind erosion: The case of shelterbelt plantations in Jaisalmer, Rajasthan.

The western part of Rajasthan is clothed in rolling dunes for almost its whole expanse. Due to the inhospitable climate the people of the area earn their livelihoods primarily with pasture animals and on one crop per year, but sustenance is difficult. The agricultural productivity in the region remains limited due to an unconducive environment, limited choice of crops and aberrant weather conditions. In this study, we determine the costs of wind erosion for agricultural productivity. We do this by ascertaining enhancements in agricultural productivity brought about by shelterbelt interventions that reduce wind erosion. The three main sources of household income are crop production, livestock rearing and off-farm income. All the respondents reported that plantation of shelterbelts have not only helped in anchoring the sand dunes in the area but also proved beneficial in providing fuel wood, livestock fodder and timber, while reducing wind speed. Approximately 84% farmers have received additional benefits such as better ground water availability and improved soil texture for production.

With the presence of shelterbelts the farmers have higher production for two major crops, *Guar* (cluster bean, *Cyamopsis tetragonoloba*) and *Chana* dal (*Cicer arientum*). Input costs are also less for both crops in the intervention areas. For *Guar*, the total cost for shelterbelt farmers is Rs. 1756.39 per hectare as compared to non-shelterbelts *Guar* farmers (Rs 2464.7 per ha). In case of *Chana*, farmers input costs on average are Rs 2000 lower for those with shelterbelts. This increase in revenue coupled with reduced costs has a beneficial impact on the income of the farmers. These results suggest that shelterbelt plantations in the fields act as a boon for the farmers in earning them additional revenues and are required to augment farm incomes through higher agricultural productivity in areas prone to wind-erosion.

The extent of land that is projected to degrade in 2030 shows a linear downward trend (14862424 ha). The cost of reclaiming this degraded land in 2030 is Rs 309323.9 million at 2014/ 2015 prices.

Chapter 1. Approach to the micro-economic assessment

1.1 Introduction

India faces extensive land degradation and desertification that appears to show little sign of improvement despite huge investments in land degradation programmes including watershed management activities. The total area of the country under desertification and land degradation has increased from 81.48 mha in 2003-05 to 82.64 mha in 2011-13 (SAC, 2016). Only salinity/ alkalinity appears to have dipped marginally during this period from 3.8 mha to 3.47 mha (Table 1.1). The leading causes of land degradation in the country are water erosion followed by vegetation degradation and wind erosion. Salinity and alkalinity also contribute to land degradation as does enhanced salinity due to waterlogging and salt water intrusion in coastal areas.

Table 1.1 Cause and extent of land degradation in each category of dryland

Process of Degradation	Area under Desertification (mha)							
	2011-13				2003-05			
	Arid	Semi-Arid	Sub-Humid	Total	Arid	Semi-Arid	Sub-Humid	Total
Vegetation Degradation	2.86	13.48	6.65	22.99	2.81	13.39	6.34	22.54
Water Erosion	3.03	17.51	8.97	29.51	3.12	17.07	8.91	29.1
Wind Erosion	17.63	0.56	0	18.19	17.72	0.57	0	18.29
Salinity/ Alkalinity	2.52	0.86	0.09	3.47	2.52	1.07	0.21	3.8
Water Logging	0.02	0.08	0.31	0.41	0.02	0.08	0.25	0.35
Mass Movement	0.84	0.11	--	0.95	0.76	0.11		0.87
Frost Shattering	2.94	0.46	0.01	3.41	2.74	0.43	0.01	3.18
Man Made	0.04	0.14	0.16	0.34	0.04	0.14	0.14	0.32
Barren	0.25	0.28	0.05	0.58	0.25	0.28	0.05	0.58
Rocky	0.3	0.97	0.02	1.29	0.29	0.97	0.02	1.28
Settlement	0.11	0.93	0.44	1.48	0.07	0.75	0.33	1.15
Grand Total	30.54	35.4	16.7	82.64	30.35	34.85	16.28	81.48

Source: SAC, 2016

As indicated in Vol I, the costs of land degradation and desertification at country level are prohibitively high accounting for Rs 3177390 million or 15.92 % of gross value added from agriculture and forestry[5] (2014/ 15) and 2.5% of GDP. Almost 55% of the costs of land degradation are accounted for by vegetal degradation, followed by land use change (18% and agriculture (16%). Rangeland degradation is significant at 4% of the total costs. In terms of land use change, the largest value is accounted for by wetlands followed by culturable wastelands, and then by pastures and forests.

While the macro-economic study provides a broad-brush assessment of the costs of land degradation and desertification in India, case studies of the costs of degradation and conversely, the benefits of measures to reduce degradation provide a more nuanced approach to the issue and provide an understanding of the physical, socio-economic and economic factors that might influence the problem at local level. In this volume, we individually address the main causes of land degradation and desertification in the drylands of India through case studies carried out in Gujarat, Uttarakhand, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh and Rajasthan. These case studies encompass major land degradation causal mechanisms, e.g. salinity, water erosion, vegetal degradation, sodicity, waterlogged saline soils and wind erosion. In addition, these case studies cover most ecosystems including rangelands, forests and agricultural lands. For this study, more than 1000 households have been surveyed across the country as well as more than 150 tourists in Uttarakhand. A range of methods have been used in developing the case studies including questionnaire surveys, focus group discussions and consultations with experts across the country and visits to relevant institutions (see Appendix 1.1), and a detailed literature review pertaining to land degradation in India, as well as globally. A systems analytic model has been developed for one case study (Gujarat) that provides detailed predictions based on an analysis of various scenarios. ***The states selected and methodology to be adopted for the study was finalised with MoEFCC in a consultative workshop organised on May 20, 2015.***

The case of Gujarat provides a unique example, both in terms of the approach used and in the issue addressed. While the initial idea was to determine the impacts of salinity on rangelands and agriculture in the Kutch region, on visiting the Banni grasslands, we found that the intervention to reduce salinity in the area had itself become a cause of grassland degradation. This thus provided a unique opportunity to determine the role of a biological invasion in causing land degradation. *Prosopis juliflora*, an exotic species was introduced in various parts of India to control land degradation. In the Banni area it was used as a counter-measure for salinity. However, *P. juliflora*, native to Mexico, like most invasive species lacks predators to keep it in check. Moreover, its adaptability to a range of marginal environments and its ability to coppice, as well as the dispersal of its pods by domestic bovines has enabled its rapid spread across large parts of India and Banni grasslands. The tree also supports little biodiversity and its allelopathic qualities hinder the growth of other native trees, plants and grasses. Dense monocultures of this tree consequently have degraded large parts of the Banni grassland ecosystem and reduced grass availability for the livestock of the Maldharis-traditional pastoralists of the area. This has greatly impacted their livestock economy. We therefore, study the impacts of the invasion of *P. juliflora* on the livestock economy and the grassland ecosystem of Banni. This has enabled us to understand the role of a biological invasion in exacerbating land degradation.

Volume II is divided into seven chapters. This introductory section outlines the broad methodology adopted for the micro-economic assessment studies. This is followed by six case study chapters covering grassland degradation in the saline soils of the Kutch region of Gujarat, a study of forest degradation in the Tehri Garhwal region of Uttarakhand, the

[5] In 2014/ 2015 prices

impacts of water erosion and its mitigation with farm bunds in agro-ecosystems of Madhya Pradesh, the role of flap gates and sub-surface drainage in reducing saline intrusion in the coastal ecosystems of Andhra Pradesh, a study on the reduction of sodicity in the Gangetic Plains of Uttar Pradesh and an analysis of the role of shelterbelts in enhancing agricultural productivity in the wind-eroded deserts of Jaisalmer district, Rajasthan. By encompassing a range of ecosystems, causal mechanisms, implementation programmes, interventions adopted, issues, and methodologies (household surveys, travel costs analysis, analytic hierarchical process, systems modelling approach), we have tried to ensure a snapshot of the range of issues, preventative measures and costs and benefits involved in addressing DLDD in the country. Each case study ends with a scenario development that provides an analysis of the likely costs of reclamation for the particular causal mechanism based on projections for the year 2030.

1.2 Case study selection for the micro-economic studies

A three tier system was proposed for the selection of sites to carry out a micro-economic assessment. This is described below.

1.2.1 Tier 1. Selection of areas within the drylands

The first criterion for site selection was to identify states lying within the drylands. Given the geographical coverage of arid, semi-arid and dry sub-humid areas (the drylands) within the country (Fig 1.1 and Table 1.2), the states selected would have to cover all these three zones. Although the North-East of the country suffers from vegetal degradation, this area, the W. Ghats, patches in the Himalayan belt and some of the Eastern parts of the country lie outside the drylands. Therefore, these areas were excluded for the study. Since this study was initiated before the publication of the latest atlas on land degradation and desertification (SAC, 2016), our selection criteria was based on the ICAR-NAAS (2010) harmonised atlas as well as figures provided by SAC (2007). The process followed is described in subsequent sections.

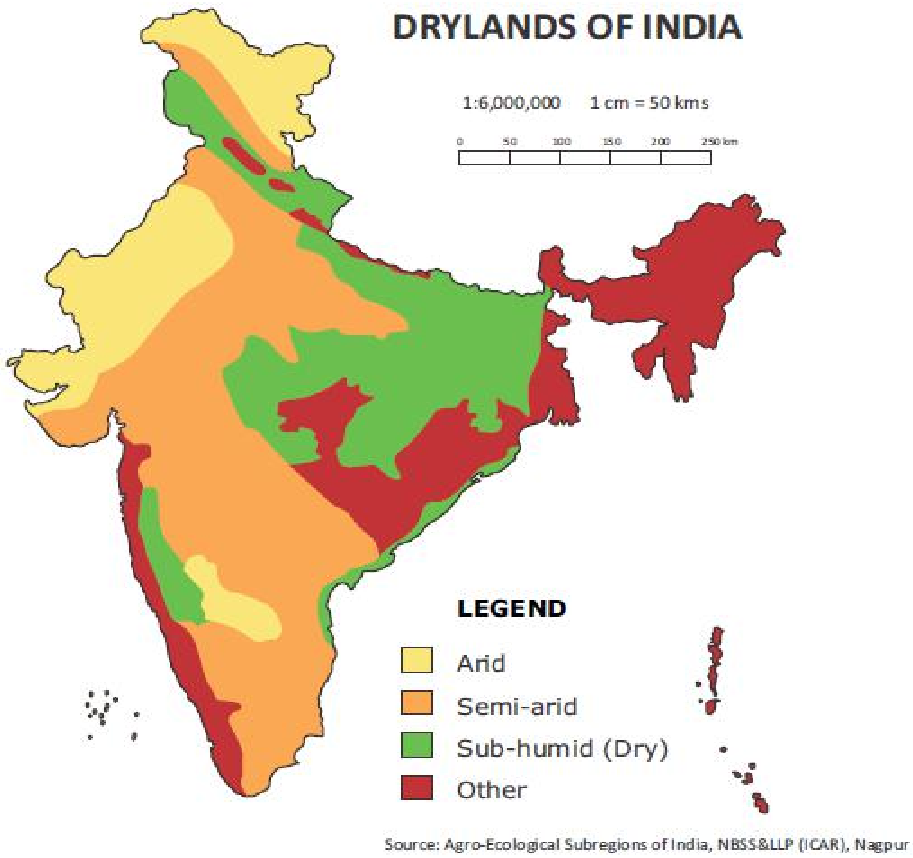

Figure 1.1 The Drylands of India

Source: Agro-ecological subregions of India, NBSSLLP (ICAR), Nagpur (2016)

Table 1.2 Distribution of Desertification in India

Zone	Area (mha)
Arid	30.54
Semi-arid	35.4
Dry sub-humid	16.70
Total	**82.64**

Source: SAC, 2016

1.2.2 Tier 2. Selection of States

The second tier for site selection included:

1. States that were affected by the major processes of land degradation (water, wind, salinity/ alkalinity, vegetal). See Table 1.3, and 1.4.

2. Those states most impacted by desertification
3. Sites that include anthropogenic and natural causes of desertification
4. Sites that ensure geographical representation of the country (north, south, central India and mountainous regions)

The highest levels of vegetal degradation occurred in North-East India but given that these lie outside the arid, semi-arid and dry sub-humid region, we instead selected Uttarakhand which shows significant vegetal degradation (See Fig 1.2). Moreover, it represents a mountainous region of the country. Gujarat was selected due to high levels of degradation resulting from salinisation while Rajasthan is most impacted by wind erosion (Fig. 1.2).

Table 1.3 Degradation and desertification status of India (harmonised figures)

Process of degradation/desertification	Area (mha)	% of geographical area
Water and Wind erosion	94.87	28.86
Acid soil	17.93	5.45
Alkali/ Sodic soil	3.7	1.13
Saline soil	2.73	0.83
Waterlogged Areas	0.91	0.28
Mining/ Industrial	0.26	0.08
Total	**120.4**	**36.63**

Source: ICAR and NAAS (2010)

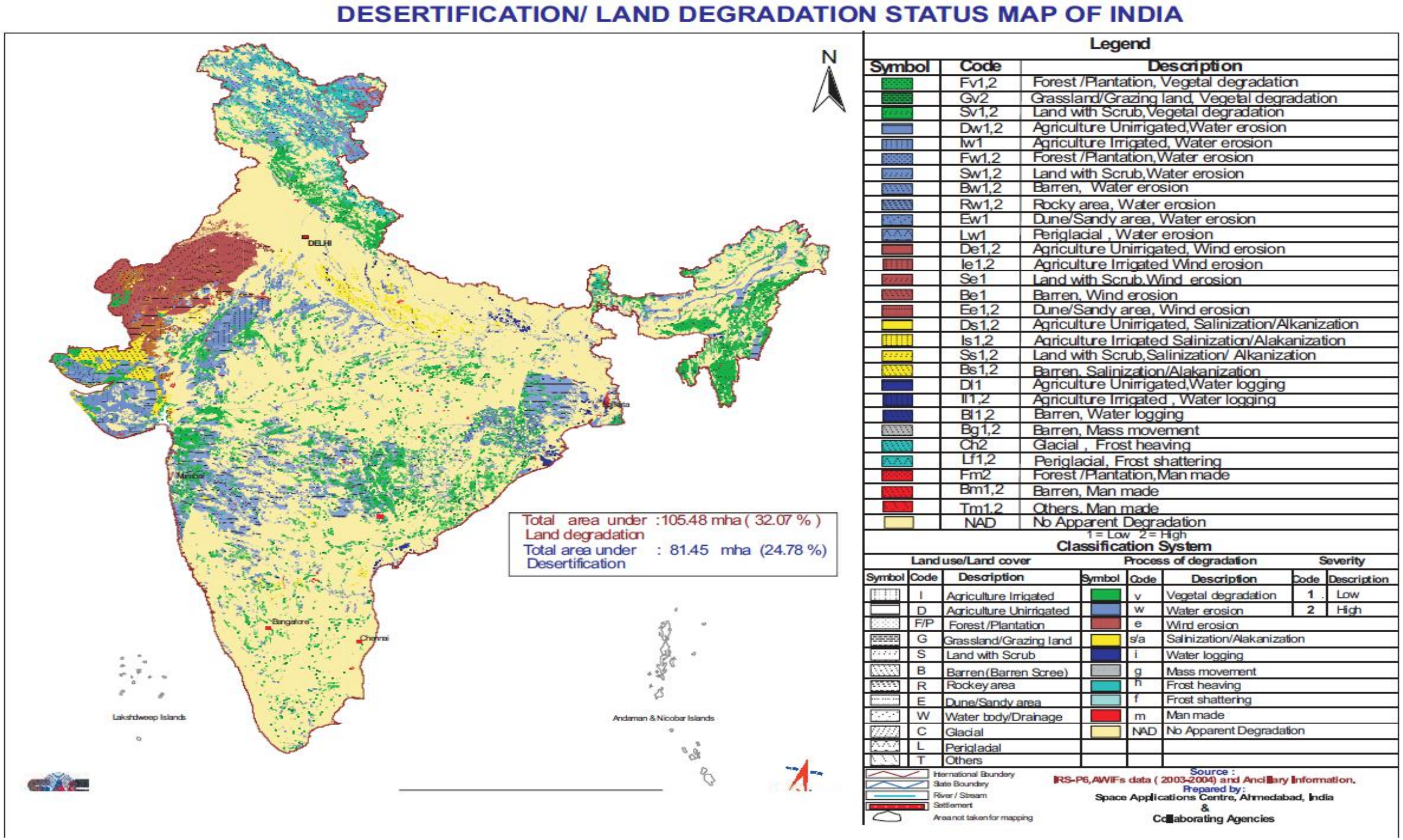

Figure 1.2 Desertification/Land degradation status map of India

Source: SAC (2007)

Based on the first three criteria, the following states were shortlisted (Table 3) according to statistics provided in the harmonized atlas (ICAR, 2010).

Table 1.4 Shortlisted states selected for this DLDD study based on various criteria

State	Area (mha)	% of TGA (of State)	% of total degraded area of the country	Dryland category
Rajasthan	20.46	6.23	16.96	Arid
UP	14.58	4.43	11.96	Semi-arid & sub-humid
MP	14	4.26	11.71	Semi-arid & sub-humid
Maharashtra	10.05	3.06	8.08	Largely sub-humid
Andhra Pradesh (including Telengana)	9.57	2.91	7.64	Largely semi-arid
Karnataka	8.5	2.59	6.72	Largely semi-arid
Chattisgarh	4.71	1.43	3.97	Others and sub-humid
Tamil Nadu	3.21	0.98	2.49	Semi-arid
Gujarat	3.07	0.93	2.6	Arid & semi-arid
Uttarakhand	1.25	0.38	1.19	Largely sub-humid

Source: ICAR and NAAS (2010)

Based on the four criteria listed above, however, we homed in on six states, Rajasthan, Gujarat, Uttar Pradesh, Andhra Pradesh, Uttarakhand and Madhya Pradesh. These states ensured geographical coverage, accounted for a large share in the major causes of degradation, encompassed mountainous and other areas and covered anthropogenic causes of land degradation.

1.2.3 Tier 3. District selection

The third tier of selection was the district. Selection of district was based on a detailed exercise for each state to determine the most degraded districts as well as land use change in the area. Case studies within these districts were then taken to quantify the economic impacts of degradation and explore options for restoration/ prevention. The detailed process followed for district selection in each state is described in each individual chapter.

Chapter 2. Modeling the Grassland Degradation of Banni using System Dynamics - An investigation into the ecological and economic causes and impacts of grassland degradation in Banni

2.1 Introduction

This is a study on the interactions between the ecology and the economy of the Banni grasslands. An area of approx. 2500 sq. km located in the district of Kachchh (Koladiya, 2016), Gujarat, the Banni grassland was once known as Asia's finest tropical grassland (Bharwada&Mahajan, 2012). However, the grassland has been degrading over the years mainly due to invasion of *Prosopis juliflora*. The grassland productivity has come down from 4000 kg/ hectare in the 1960s to 620 kg/ hectare in 1999 (Bharwada&Mahajan, 2012). While many reasons are attributed to the degradation of the Banni grassland, the evidence is still inconclusive on whether the dominant cause is increasing salinity or spread of *Prosopis juliflora*. However, the most cited reason by the Maldharis (pastoralists of Banni) is the spread of *Prosopis juliflora*. The area under grassland has reduced from 1,42,000 hectares in 1989 to 63,000 hectares in 2009 while the area invaded by *Prosopis juliflora* has increased to 82,000 hectares (Koladiya, 2016). With livestock rearing being the primary occupation of the people of Banni, grassland degradation poses a serious problem for sustaining their pastoral economy.

2.1.1 Kachchh

Kachchh (Kutch) is the largest district in India with a geographical area of 45652 Km^2.[6] The district gets its name from the word "kachua" due to its likeness to a tortoise, with the central portion elevated from which the land gently slopes downwards in all four directions (Fig 2.1). The district covers about 23% of the total area of Gujarat State but is home to only 3.5% of the State's population, with a population density of only 46 people per sq. km (as against the State average of 308) (Directorate Of Census Operations, 2011). This may be attributed to the severe aridity and hostile terrain of the region. The Great Rann in the north and the Little Rann in the east of the district, which together constitute about 50% of the district's geographical area, are saline deserts for the greater part of the year and characterized by the near absence of any vegetation. At the same time, Kachchh is an ancient region with a mix of cultures, ecosystems, and geological formations as a result of which it is known for its rich diversity.[7] It is endowed with some unique biodiversity areas- the

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[6] List of districts by geographical area (Census 2001) as reported by Indiastat.com (http://www.indiastat.com/table/geographicaldata/15/geographicalarea/51/16900/data.aspx) accessed on 4 Feb 2016

[7] Archaeological records and excavations reveal that the region was first inhabited by the people of Harappan civilization during 3000-1500 BC. There was a great hiatus in the history of the region between 1400 BC and 500 AD. It is documented that much later, a series of migrations took place from Sindh to Kachchh, and in this process, Sama Rajputs, later known as Jadejas, came to this land and ruled here till the time of India's independence. The tribes inhabiting the modern Kachchh belong to Sandh, Banni, Rabari (Desi, Dhebaria and Vagadiya), Banjara, Magwar, Samma, Jat, Mutwa and Ahir communities, whose main professions include

Flamingo City between Khadir and Pachcham islands is a breeding ground for migratory flamingos and the Wild Ass Sanctuary of the Little Rann is the only home for the last surviving population of the Indian Wild Ass. Banni itself is a great biodiversity hotspot and a birder's paradise, with over 260 species of birds (Koladiya, 2016).

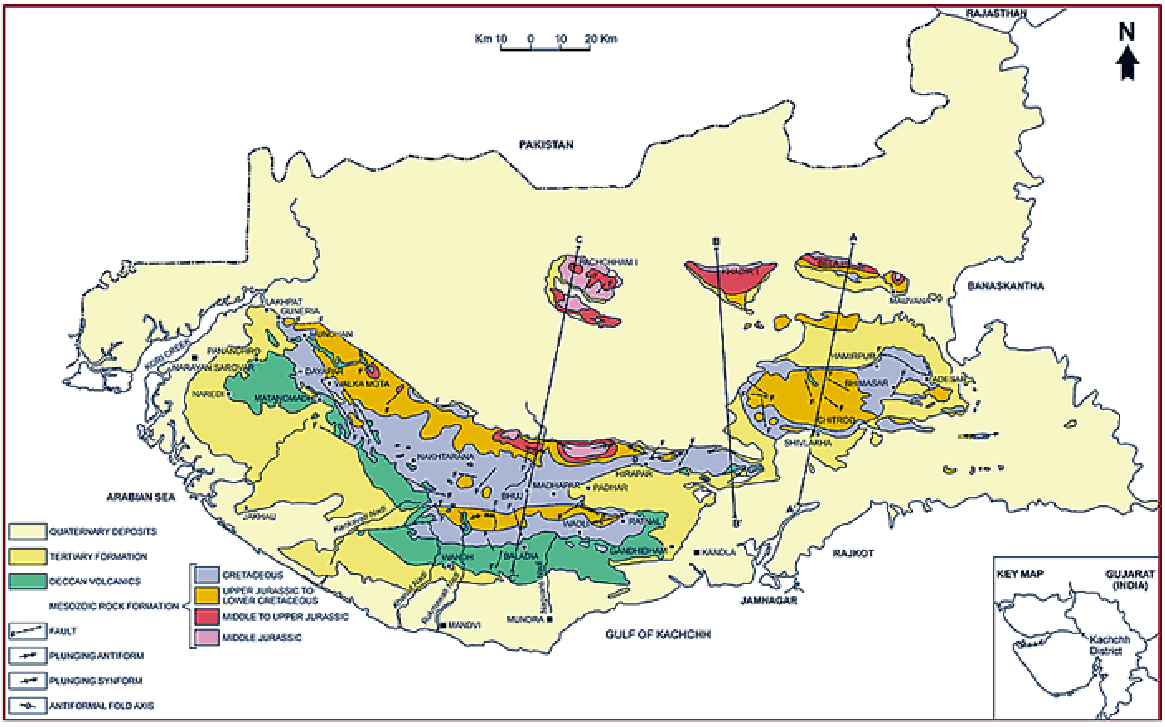

Figure 2.1 Geological Map of Kachchh district.

Source: Geological Survey of India: http://www.portal.gsi.gov.in/portal/page?_pageid=127,693641&_dad=portal&_schema=PORTAL

Gujarat accounts for over half of the country's exclusively saline soils and about 21% of the country's exclusively sodic soils. Exclusively saline soils also make up about 48% of the State's degraded area, followed by exclusive water erosion (31%) and while exclusively sodic soils (17%). A further disaggregated analysis shows that close to 35% of the exclusively saline affected land falls in the Kachchh district. Literature suggests that the primary seasons for this are as follows Low and irregular rainfall leading to naturally arid conditions. (Kulkarni, 1985)

- Saline geographical formation
- Weak land management
- Excessive lifting of underground water by farmers for irrigation

Livestock rearing is an important occupation for arid district, Kachchh. The total livestock population in Kachchh increased from 94,097 in 1962 to 1,707,279 in 2007, an 18 times increase in a span of 45 years (Gavali, 2011). In terms of the composition of livestock, while cattle accounted for major share (49.1%) in the total livestock in 1962, followed by goat

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agriculture, animal husbandry, handloom, and construction. Geological Survey of India http://www.portal.gsi.gov.in/portal/page?_pageid=127,693641&_dad=portal&_schema=PORTAL

(21.4%), sheep (19.3%) and buffalo (8.6%), the subsequent years have seen a decline in the population of cattle (35% in 2007) but a steady rise in the population of buffaloes (37% in 2007) (Gavali, 2011). The composition of total livestock reported in Census- 2007 included cattle (34%), buffalo (37%), sheep (8.5%), goats (20%) and others (0.6%). The population of cows, buffaloes and goats registered an increase (7.4 %, 22.9 % and 2.2% respectively) over the previous Census-2003 while that of sheep registered a fall (2.9 %). Changes in species composition are generally indicative of increased stress among the species which are less drought resistant and are uneconomic to maintain. The increase in the population of sheep (except between 2003 and 2007) and goat is an indicator of desertification (Ramchandani, n.d.). Other factors that have contributed to the changing livestock composition is the susceptibility of Kankrej cattle to *Prosopis juliflora*, decline in grazing land, less inclination towards pastoralism by the young generation and promotion of dairy industry in Kachchh (Gavali, 2011).

2.1.2 Banni Grasslands

Banni grassland is located on the northern border of Bhuj taluka (23° 19’ 23° 52’ N latitude and 68° 56’ to 70° 32’ E longitude) of Kachchh district in Gujarat State (ref. fig 2) (Mehta et. al, 2014). The mainstay of Banni’s economy is livestock rearing.

The Banni grassland is divided into three areas, 1) Ugamani Banni - East Banni, 2) Vachali Banni - Central Banni, 3) Aathamani Banni or Jat Patti - West Banni (Bharwada&Mahajan, 2012). There exist 13 different estimates of its geographic area ranging from 1800 sq km to 3800 sq km (Bharwada&Mahajan, 2012). But the recent estimates have converged to the figure of 2500 sq km (Koladiya, 2016). For this study total Banni area is taken as 2500 sq km.

The livestock breeders of Banni are called Maldharis. There are many pastoral communities in Banni like Raysipotra, Halepotra, Pirpotra, Hingorja, Sumra, Mutva, Node etc. who have migrated several generations ago from Sindh, Marwar and Baluchistan (Bharwada&Mahajan, 2012). During our interviews some of the pastoralists also mentioned Saudi Arabia and Afghanistan. The other community in Banni is the Meghwals. Their main occupation has been leather tanning and shoe making including making artifacts from leather (Bharwada&Mahajan, 2012).

Brief History of Banni Grassland

The Banni grassland was once known as Asia’s finest tropical grassland. Its geographic area spread beyond Indian borders into the geographic areas of Pakistan.

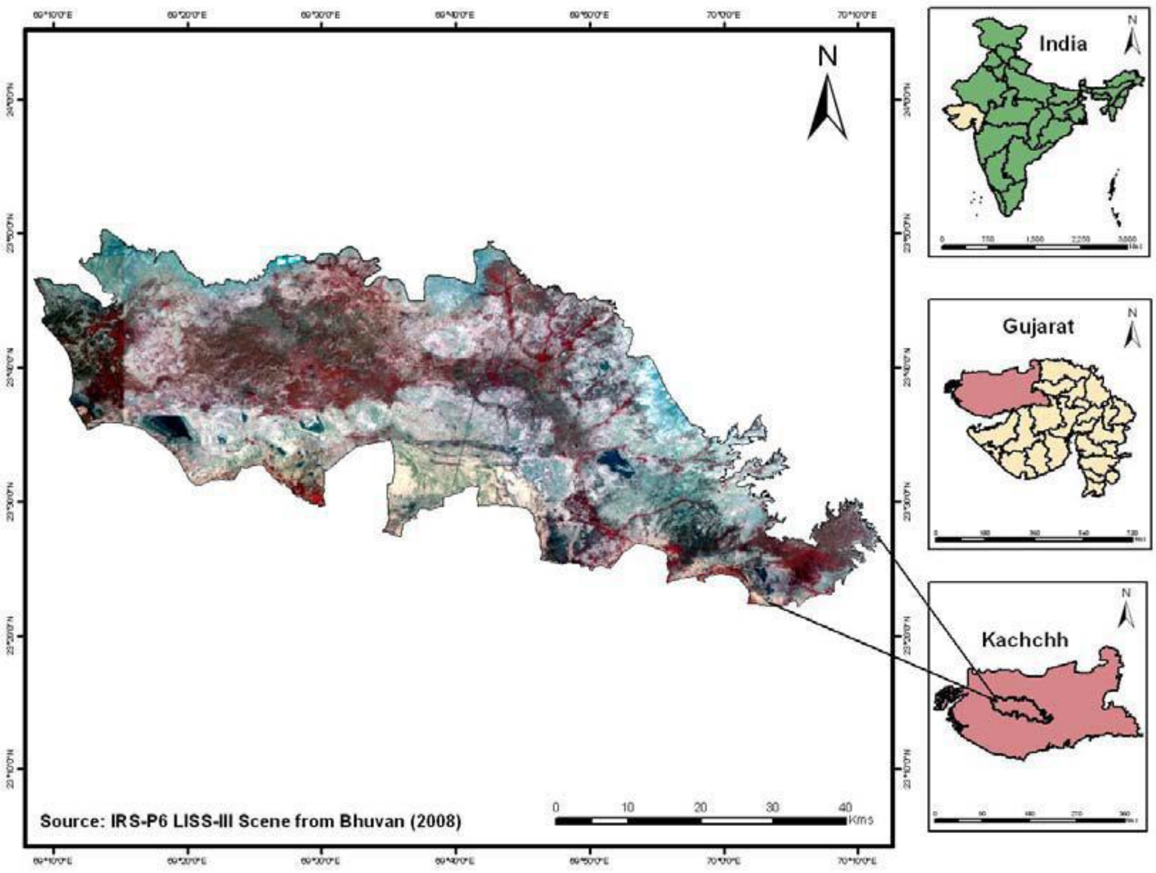

Figure 2.2 Map of Banni Grassland . Source: (Mehta et. al, 2014)

The entire Banni area is largely a flat land which often results in seasonal water flooding during the monsoon. Banni grassland is also sometimes referred to as a seasonal wetland (Mehta et. al, 2014). The Government forest department reports about 254 small and large wetlands in Banni (Bharwada&Mahajan, 2012). It was first declared as a protected forest in May 1955, under the Indian Forest Act, 1927 (Mehta et. al, 2014). The climatic condition falls under arid and semi-arid zone (Mehta et. al, 2014) with an average annual rainfall of around 300-353 mm (Bharwada&Mahajan, 2012) (Geevan, 2003).

Prosopis juliflora

Prosopis juliflora is a species native to South America, the Caribbean and Mexico. It was first introduced along the Banni and Great Run of Kutch border in 1961 covering an area of 31,550 hectare by the Forest Department in order to control the Rann's ingression (Bharwada&Mahajan, 2012). In the last 55 years the spread of *Prosopis* has led to the loss of native vegetation in Banni, including the grasslands. It is today cited as one of the dominant causes for grassland degradation. Its spread is aided in the summer when grasses are in short supply and thus *Prosopis juliflora* pods become a ready feed for grazing animals. Seeds rejected with the fecal matter quickly germinate and take root as they get both manure and moisture. The open grazing system of Banni further accelerates its rapid spread (Bharwada&Mahajan, 2012). Due to *Prosopis'* allelopathic properties it has led to loss of indigenous plants and reduction in area under grasslands (Bharwada&Mahajan, 2012). The pastoralists of Banni cite the spread of *Prosopis* as the main reason for grassland degradation and opine that if *Prosopis* were to be removed the grasslands would recover. In Banni it is locally called *Gando Baval*, which means 'mad *Ácacia*.

Dairy

Banni was not traditionally a dairy-farming economy. It is only recently after the introduction of dairy, in 2009-2010 for milk collection that the pastoralists of Banni started selling milk. Traditionally they were breeders of livestock and were involved in the trade of bullocks and *Kankrej* cattle. *Banni* buffalo and *Kankrej* cattle are the dominant livestock of Banni that drives the milk economy. The introduction of dairy has led to a revival of buffalo breeding in Banni. Also registration of Banni buffalo as the 11th buffalo breed in India in 2011 has motivated the Maldharis, especially the young generation, to continue and strengthen their pastoral occupation (Bharwada&Mahajan, 2012). In case of the Kankrej cattle consuming the pods of *Prosopis* causes the dislocation of their jaws eventually leading to their death (Bharwada&Mahajan, 2012). Thus, the population of Kankrej cattle has been falling due to spread of *Prosopis*. This has had a negative impact on the bullock trade. The loss in grassland productivity also means that the Maldharis have to purchase more fodder from outside Banni, having a negative impact on the economy of Banni. Discussions with Maldharis revealed that this also spurred them on to migrate out more, to save costs.

Charcoal Making

Charcoal making is practiced by Maldharis to earn income. *Prosopis* wood is harvested for making charcoal. Since the Banni Grassland is classified as a Protected Reserve Forest, it has been illegal to cut *Prosopis* and there has been a ban in place. In 2004 this ban was lifted, leading to a huge increase in charcoal production (Bharwada&Mahajan, 2012). It led to reduction in area under *Prosopis* as Maldharis resorted to removing *Prosopis* trees from the ground for making charcoal. Maldharis recollect that the grasslands had come back as a result of its removal. It is hard to estimate the exact amount by which the production went up but estimates of the increase in number of charcoal-laden vehicles leaving Banni suggest that it could have been as high as ten times (Bharwada&Mahajan, 2012). In 2008, this ban was again imposed. The reasons for this vary. Some suggest that the ban was again imposed because indigenous trees were also being harvested for charcoal. Others suggest that the charcoal traders cartel influenced the re-imposition of the ban since they were unable to exercise control over production and supply of charcoal which resulted in a loss for them (Bharwada&Mahajan, 2012). The ban persists but charcoal making continues in Banni.

Objective and problem definition

Banni's ecological and economic system is highly dynamic. The study focuses on the grassland degradation of Banni from 1992-2014 and simulates future scenarios up to 2030 under different policy options. The ecological conditions, mainly land use and land change affect the economic decisions of the Maldharis. Since Banni is a complex dynamic system, the research methodology relies on use of system dynamics modeling for developing base case and policy runs on the future of Banni.

Further, an economic valuation of Banni's economy is carried out by discounting the future earnings of the pastoral economy (milk, livestock sale, dung manure) and the charcoal economy under two scenarios 1) Base case, i.e. keeping things as they stand today and 2) *Prosopis* Removal Policy (PRP) Scenario i.e. under a case where a decision is implemented to remove *Prosopis* from the Banni area.

This study is not intended to provide a forecast or predict the future of Banni. It is an investigation into the dynamics of Banni grasslands and an exploration into future possibilities under different scenarios. It highlights the interdependencies existing between different sectors and between variables of each sector. The model helps in developing a deeper understanding of the complexities of Banni and serves as a tool for policy testing and evaluation. The study highlights the need for further research on the ecological and economic parameters of Banni, and presents a case for the development of a decision support tool to manage the Banni grasslands. An economic valuation of Banni's economy is carried out by discounting the future earnings of the pastoral economy (milk, livestock sale, dung manure) and the charcoal economy under two scenarios 1) Base case, i.e. keeping things as they stand today and 2) *Prosopis* Removal Policy (PRP) scenario i.e. where a decision is implemented to remove *Prosopis* from the Banni area.

2.2 Methodology

2.2.1 Selection of Site

The share of Gujarat in the country-wide area affected by class of degradation was determined from the harmonised atlas (ICAR, 2010). Gujarat accounted for as much as 56.8% of the country-wide area affected by category 7 or exclusively saline soils (Table 2.1) and 20.9% affected by sodic soils. The share of each class of degradation in the total area of Gujarat was found to be 47.8% for saline soils. When the analysis was repeated on a district basis, Kacch contributed 34.72% to the state-wise area affected by salinity (Table 2.2, Fig 2.3) and hence was selected as the case study area.

Table 2.1 Share of Gujarat in the country-wide area affected by degradation and share of class in degraded area of Gujarat

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Share of Gujarat in the country-wide area affected by the class of degradation (%)																		
1.3	0.3	0.0	0.0	0.0	0.0	**56.8**	10.0	0.0	0.0	100.0	0.0	**20.9**	0.0	0.0	0.0	0.0	4.6	0.1
Share of class in total degraded area of Gujarat (%)																		
31.3	1.0	0.0	0.0	0.0	0.0	**47.8**	0.1	0.0	0.0	1.9	0.0	**17.4**	0.0	0.0	0.0	0.0	0.4	0.0

1 Exclusively water erosion (>10 tonnes/ ha/ yr);

2 Water erosion under open forest;

3 Exclusively acid soils (pH <5.5);

4 Acid soils under water erosion;

5 Acid soils under open forest;

6 Exclusively wind erosion;

7 Exclusively saline soils;

8 Eroded saline soils;

9 Acid saline soils;

10 Saline soils under wind erosion;

11 Saline soils under open forest;

12 Waterlogged saline soils;

13 Exclusively sodic soils;

14 Eroded sodic soils;

15 Sodic soils under wind erosion;

16 Sodic soils under open forest;

17 Eroded sodic soils under open forest;

18 Mining/ Industrial waste;

19 Waterlogged area (Permanent)

Source: ICAR (2010)

Table 2.2 Share of district in state-wide degradation by class (%)

	1	2	7	8	11	13	18	19	Total of classes
Ahmedabad	0.00	0.00	10.64	0.00	0.00	17.61	0.00	0.00	8.15
Amreli	2.66	15.63	0.47	0.00	0.00	0.00	8.33	0.00	1.25
Anand	1.84	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.80
Banaskantha	5.62	0.00	3.14	0.00	0.00	7.71	0.00	0.00	4.60
Bharuch	11.64	0.00	1.34	0.00	0.00	0.00	8.33	0.00	4.31
Bhavnagar	0.00	0.00	5.15	0.00	0.00	2.57	0.00	0.00	2.91
Dahod	5.82	9.38	0.00	0.00	0.00	0.00	0.00	0.00	1.92
Dangs	8.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.68
Gandhi nagar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jamnagar	0.92	0.00	12.37	25.00	0.00	0.00	8.33	0.00	6.26
Junagarh	4.29	18.75	1.94	0.00	0.00	0.00	0.00	0.00	2.46
Kachchh	0.00	0.00	34.72	0.00	100.00	2.02	41.67	0.00	19.02
Kheda	3.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.12
Mehsana	0.00	0.00	0.60	0.00	0.00	1.83	0.00	0.00	0.61
Narmada	2.76	9.38	0.00	0.00	0.00	0.00	0.00	0.00	0.96
Navasari	6.74	0.00	0.33	0.00	0.00	0.00	8.33	0.00	2.30
Panchmahal	2.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77
Patan	0.00	0.00	4.21	0.00	0.00	46.42	0.00	0.00	10.13
Porbandar	6.84	0.00	0.67	75.00	0.00	0.00	0.00	0.00	2.56
Rajkot	0.92	0.00	7.09	0.00	0.00	0.00	0.00	0.00	3.68
Sabarkantha	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
Surat	15.93	12.50	1.94	0.00	0.00	0.00	25.00	0.00	6.14
Surendranagar	6.33	0.00	14.85	75.00	0.00	21.83	8.33	0.00	12.91
Vadodara	4.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.31
Valsad	8.38	34.38	0.07	0.00	0.00	0.00	0.00	100.00	3.04

Please note: The categories correspond to the values provided in the Table above.

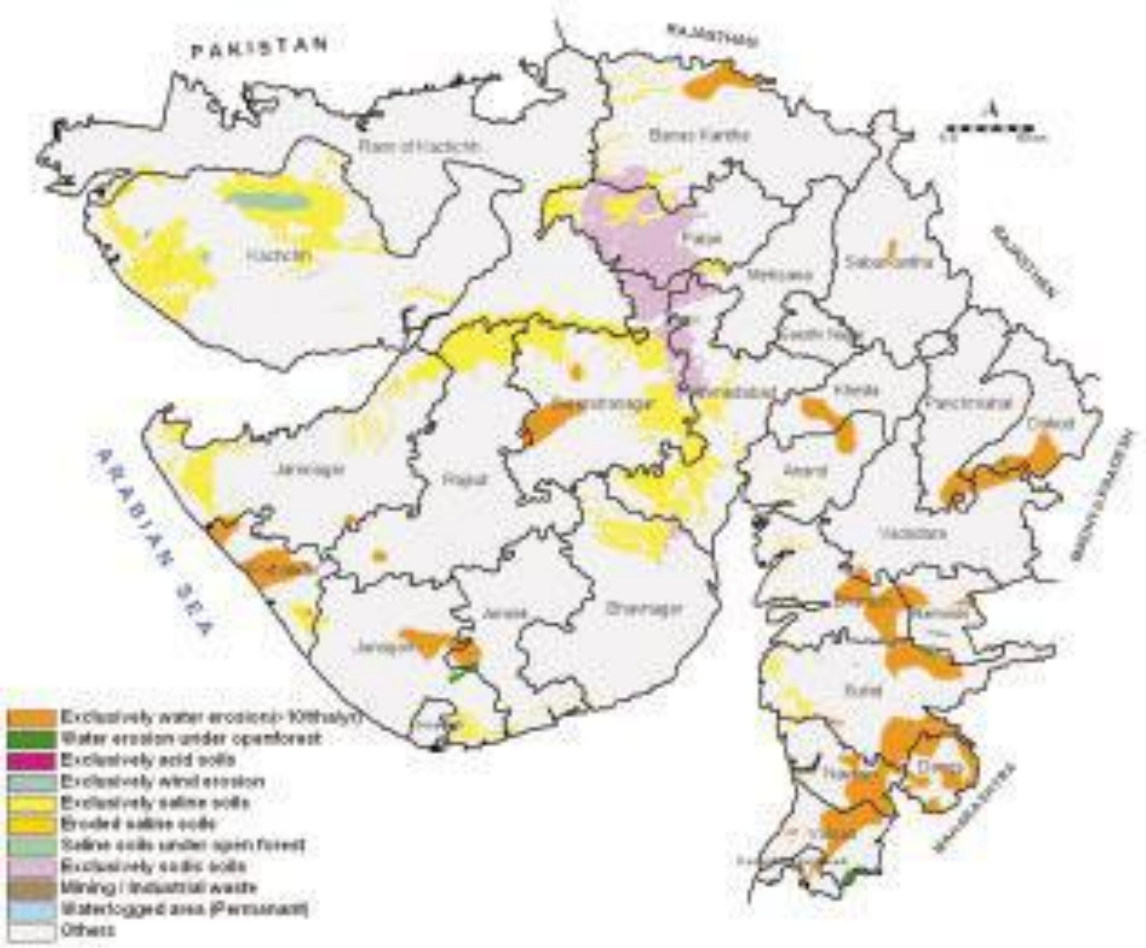

Figure 2.3 Distribution of land degradation classes in Gujarat

Source: ICAR-NAAS (2010)

As mentioned in the first chapter, the case of Gujarat provides a unique example, both in terms of the approach used and in the issue addressed. While the initial idea was to determine the impacts of salinity on rangelands and agriculture in the Kutch region, on visiting the Banni grasslands, we found that the intervention to reduce salinity in the area had itself become a cause of grassland degradation. This thus provided a unique opportunity to determine the impact of a biological invasion on the economics of land degradation. *Prosopis juliflora*, an exotic species was introduced in various parts of India to control land degradation. In the Banni area it was used as a counter-measure for salinity. However, *P. juliflora*, native to Mexico, like most invasive species lacks predators to keep it in check. Moreover, its adaptability to a range of marginal environments and its ability to coppice, as well as the dispersal of its pods by domestic bovines has enabled its rapid spread across large parts of India and Banni grasslands. The tree also supports little biodiversity and its allelopathic qualities hinder the growth of other native trees, plants and grasses. Dense monocultures of this tree consequently have degraded large parts of the Banni grassland ecosystem and reduced grass availability for the livestock of the Maldharis- traditional pastoralists of the area. This has greatly impacted their livestock economy. We therefore, study the impacts of the invasion of *P. juliflora* on the livestock economy and the grassland ecosystem of Banni. This has enabled us to understand the role of biological invasion in exacerbating land degradation.

2.2.2 System Dynamics

Ecological-economic systems are complex and composed of various interconnected, interrelated, interdependent sectors that are closely related by multiple cause and effect relationships and feedback. Such complex systems are well understood using dynamic simulation techniques (Casti, 1997). System Dynamics (SD) is one such approach, suited to understand the non-linear behaviour of complex systems over time using stocks and flows, internal feedback loops, and time delays (MIT, 1997). Pioneered by Jay W. Forrester at MIT (Forrester, 1969), SD is able to unveil the counterintuitive nature of complex systems and uncover relationships between variables that are responsible for the behaviour of the system. Further, being transparent, it provides the reader with the opportunity to go through the model structure and study the linkages (Gallati, 2011).

This system dynamics (SD) model of the Banni grassland is comprised of three sectors: livestock (Buffalo and Kankrej Cattle), grassland & *Prosopis* juliflora and the economy (Pastoral -milk, livestock sale, dung manure and charcoal economy). Impacts of drivers of livestock growth and *Prosopis* growth, their impact on the local environment, and the consequent multiple feedback that could impact the future of these sectors, have been modelled. The model runs are from 1992 to 2030. The key assumptions, model description, simulation results, and insights generated from them are presented below. Equations and parameter values are presented in the Appendix 2.2.

2.2. 3 Key Assumptions

1. 2015 Constant future prices for milk, livestock, feed, charcoal, and dung manure: Forecasting future prices has lot of uncertainty which would add to the complexity of carrying out an economic valuation of Banni grasslands. Hence, here it is assumed to be constant at 2015 prices.
2. No limit on external supply of feed, fodder and water: Today, an external supply of feed and fodder is an integral part of Banni and is assumed to be available for purchase at a cost. Water is available in Banni through pipelines coming in from outside the Banni boundary, and is assumed to be sufficient for the model runs. A modelling exercise of the water resources of Banni would mean modelling the external environment, which has not been done.
3. Exclusion of small ruminants (e.g. sheep, goat etc.)Buffalo and cattle constitute most of the Banni livestock. In 2011 their share was around 92% of the total livestock (Bharwada&Mahajan, 2012). Hence, considering the small proportion of small ruminants and their marginal footprint they are excluded from the study.
4. Rainfall for 2015-2030 is assumed to be same as 1999-2014.Rainfall is highly erratic and drought is a recurring phenomenon in Banni. However, rainfall follows a cyclical pattern, with sub-normal rainfall and heavy rainfall patterns repeating every five years (Bharwada&Mahajan, 2012). Hence we have made this assumption.

2.2.4 Description of the Model Sectors

The model consists of three sectors: Livestock (Buffalo and Kankrej Cattle), grassland & *Prosopis juliflora* and the local economy (Pastoral - milk, livestock sale, dung manure and charcoal deriving from *Prosopis*). These are explained below. All the parameter values and input into the model are provided in Table 2.3 in the next section.

2.2.5 Grassland and *Prosopis juliflora*

The dynamics between grassland area and *Prosopis juliflora* spread are the key factors influencing most of the changes in Banni. *Prosopis juliflora* is the main driver of land use change, as it is highly invasive. Literature suggests that *Prosopis* cover has been increasing at an average rate of 26.73 sq. km. per year (Bharwada&Mahajan, 2012). As the area under *Prosopis* expands it invades the area under grassland.

The total area of Banni is taken as 2500 sq. km i.e. 2,50,000 hectares (1 sq km =100 hectare). (Mukesh H. Koladiya, 2016). Of this, 90% is taken to be total possible productive land area (includes grassland, *Prosopis* dominated area and other vegetation) while 10% is taken to be waste land (wasteland includes saline land, water bodies). In 1992 (the base year), the area of land dominated by *Prosopis* is taken to be 41,180 ha ((Mukesh H. Koladiya, 2016) Pg. 20). The normal spread rate of *Prosopis* is taken to be 8.5% per year (Vineet Vaibhav, 2012). However, this spread rate is enhanced by the presence of livestock, as the seeds are carried by livestock and the passage through the digestive tract facilitates quick germination. (C P Geevan, 2003) (Bharwada&Mahajan, 2012). This has been modelled as a multiplier function in our model, the intensity of impact increasing with livestock population. The details of the function are given in Table 2.3. However, the growth of *Prosopis* is limited by the total land area available, and the equation for the *Prosopis juliflora* growth is:

Increase in *Prosopis juliflora* area = Normal *Prosopis* spread rate*Enhanced spread rate due to livestock presence*Area under *Prosopis**(1-(Area under *Prosopis*/ Total productive land area))

Since Maldharis only use above-ground wood of *Prosopis* for charcoal making it does not reduce the area under *Prosopis* under normal conditions. *Prosopis* area comes down only in periods when the ban on cutting it is removed. This happened between 2004 and 2008, which has been built into the model. The grassland biomass is calculated according to the grassland area (Total productive land less area occupied by *Prosopis*) multiplied by the grassland productivity. The latter is a function of the rainfall in a particular year. Personal interviews revealed that the productivity of the Banni soil is high in a specific bandwidth of rainfall, and lower on both extremes (low and very high rainfall). This bandwidth of 'good rainfall' has been kept as between 250 and 700 mm of rainfall. Rainfall from 2015-2030 is assumed to be the same as from 1999-2014. Rainfall data for 1992-2010 is taken from (Bharwada&Mahajan, 2012), for year 2011-12 it is taken from (Deepa Gavali, 2015) and for 2013-14 is taken from IMD website for Kachchh district (IMD, 2016).

A parameter 'fodder deficit' is defined as the ratio between the fodder available in Banni in a particular year less the fodder requirement in that year divided by the fodder requirement. This ratio is important as it determines the input cost (feed and fodder purchased from outside Banni) for milk-producing Banni buffalo. As the deficit increases, the buffalo input cost increases. Further, this ratio also determines the migration of livestock from Banni in fodder deficit years.

The sector of grassland and *Prosopis* sector dynamics is shown below (Fig 2.4).

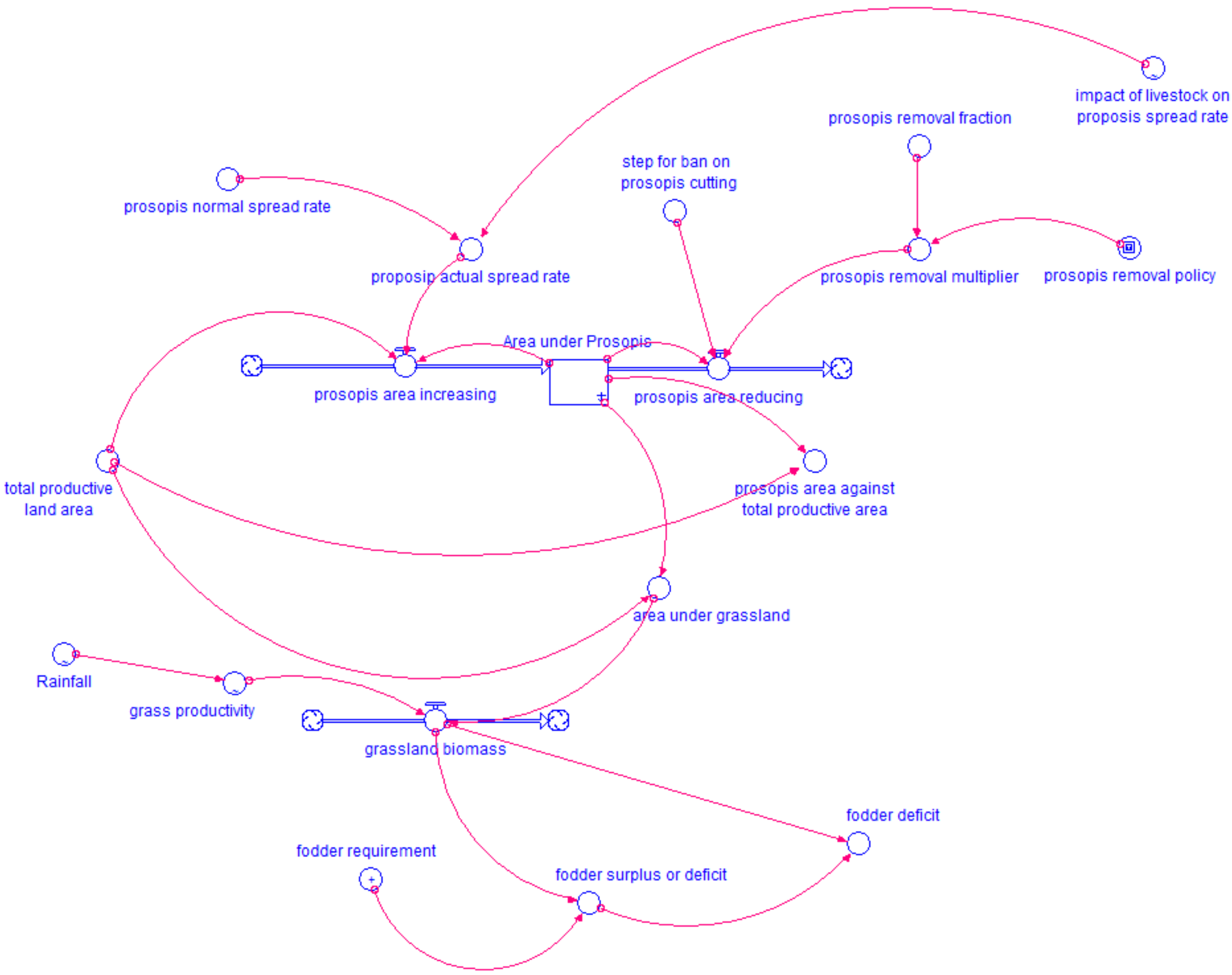

Figure 2. 4 Grassland and *Prosopis juliflora* Dynamics

2.2.6 Livestock Dynamics

This sector consists of populations of the two large ruminants: the Banni buffalo and Kankrej cattle. Small ruminants such as sheep and goats, though present in Banni are excluded due to their relatively smaller footprint on the local grassland (less than 10% of total livestock). For both the livestock (buffalo and cattle), modelling has been done by making ageing chains i.e. breaking down the populations into calves and adults, considering a maturation time and taking differential death rates/ retiring times for both livestock. Calves are born to a certain fraction of the adults every year. Some calves die before they transit into adults according to a calf death rate. There is also a retiring time for the adults after which they stop producing milk and having calves. To manage the frequent droughts in Banni, the Maldharis have adopted two dominant coping mechanisms. One is migrating out of Banni with their livestock for the dry period and the second is by increasing the sale of livestock in dry years. Both of these have been incorporated in the model.

It is assumed that if the fodder deficit crosses 30% in a certain year, 30% of the livestock leaves Banni, and if it crosses 50%, 50% of livestock leaves Banni. Also, the buffaloes that migrate outside accumulate in a stock of migrated buffaloes which come back when the deficit falls below 10%.

The Banni buffalo ageing chain is composed of two main stocks: Calves and adults. The stock of buffalo calves has one inflow (births), two outflows (calf deaths, maturation to adult buffaloes) and one bi-flow (calf migration).The births are governed by a certain fraction of the adult buffaloes which give birth to a calf every year (approx. 50% of the total adult stock). 50% of the births are female and 50% male. The model considers only females, as males are generally not reared. The fraction of buffalo calve death every year is taken as 20% (after discussions with Maldharis). Maturation time from calf to adult is taken as 3 years. The migration of buffaloes is determined by the fodder deficit in a particular year. It is assumed that if the fodder deficit crosses 30% in a certain year, 30% of the livestock leaves Banni, and if it crosses 50%, 50% of livestock leaves Banni. Also, the buffaloes that migrate outside accumulate in a stock of migrated buffaloes which come back when the deficit falls below 10%. The stock of adult Banni buffaloes has one inflow (calf maturation), three outflows (buffaloes retiring, buffalo sales and stress sales) and one bi-flow (adult buffalo migration).The lifetime is taken as 23 years and sale rate of buffaloes is assumed at 1% per year (based on interviews). A buffalo sale multiplier due to profitability impacts the flow of buffalo stress sales. This sale multiplier depends on the profit per livestock. As the profit per livestock in a year becomes negative, the stress sale multiplier takes effect and increases accordingly.

The Kankrej ageing chain is very similar to the buffalo, having birth fraction, lifetime, maturation time, fodder requirement etc. (Table 2.3) Further, there exists a practice in Banni of purchasing Kankrej calves every year and as the Kankrej calves are very valuable, the stress sale function due to profitability (a function of livestock profitability, as for buffaloes above) is of Kankrej calves and not adults. Another distinguishing feature is that the Kankrej cattle population is negatively affected by *Prosopis*, as the cattle are unable to digest the pods and die on consuming them. These dynamics have been built into the model as well. (Bharwada&Mahajan, 2012). Expert opinions were taken from the NGO Sahjeevan which is active in the area. The livestock sector is shown below (Fig 2.5).

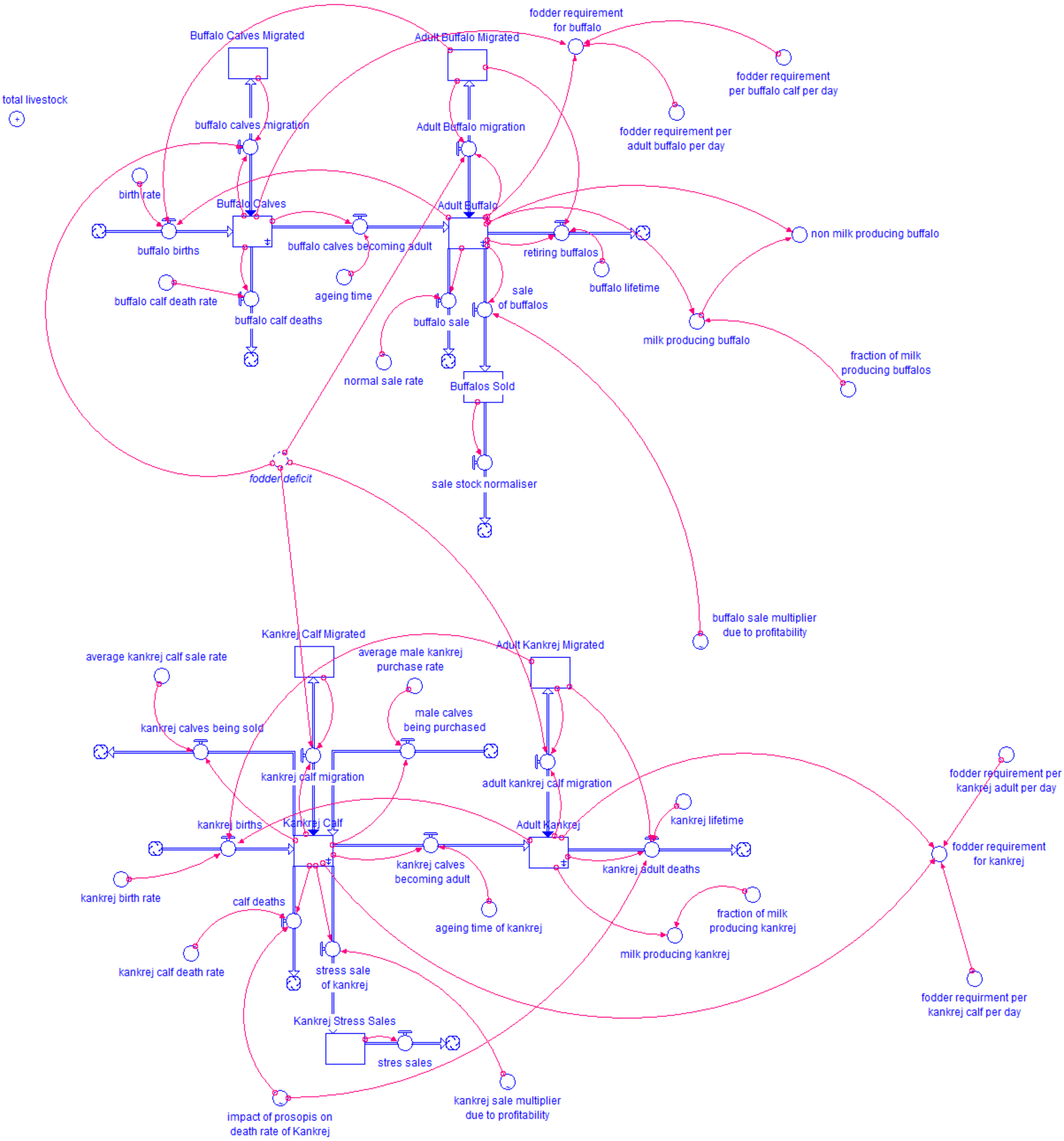

Figure 2.5 Livestock Dynamics

2.2.7 The pastoral and charcoal economy

This sector consists of livestock based income (milk, dung and livestock sale) and charcoal income. Summing the income from livestock, a number for profit per livestock is arrived at. This number governs the stress sales of adult buffaloes and Kankrej calves. As the profit per livestock in a year falls below 0, the stress sale multiplier begins increasing.

Charcoal making is the second biggest source of income for Maldharis after livestock. The extent of charcoal production is divided into three time frames. 1) Before the ban on charcoal production was lifted (i.e. before 2004). Here the charcoal production is assumed to be 2400 sacks of 40 kg each per day for 240 days in a year 2) During the time when the ban was lifted (between 2004 and 2008). Here the charcoal production is assumed to have gone up by 10 times as compared to before the ban (Bharwada&Mahajan, 2012). 3) After the ban was again imposed (i.e. after 2008): Here the charcoal production is taken as 4800 sacks of 40 kg each produced per day for 240 days in a year (derived from discussions with Sahjeevan and personal interviews with Maldharis). It is also assumed that in future, this rate of production would increase to compensate in event of loss of profits from livestock.

The sector diagram is given below:

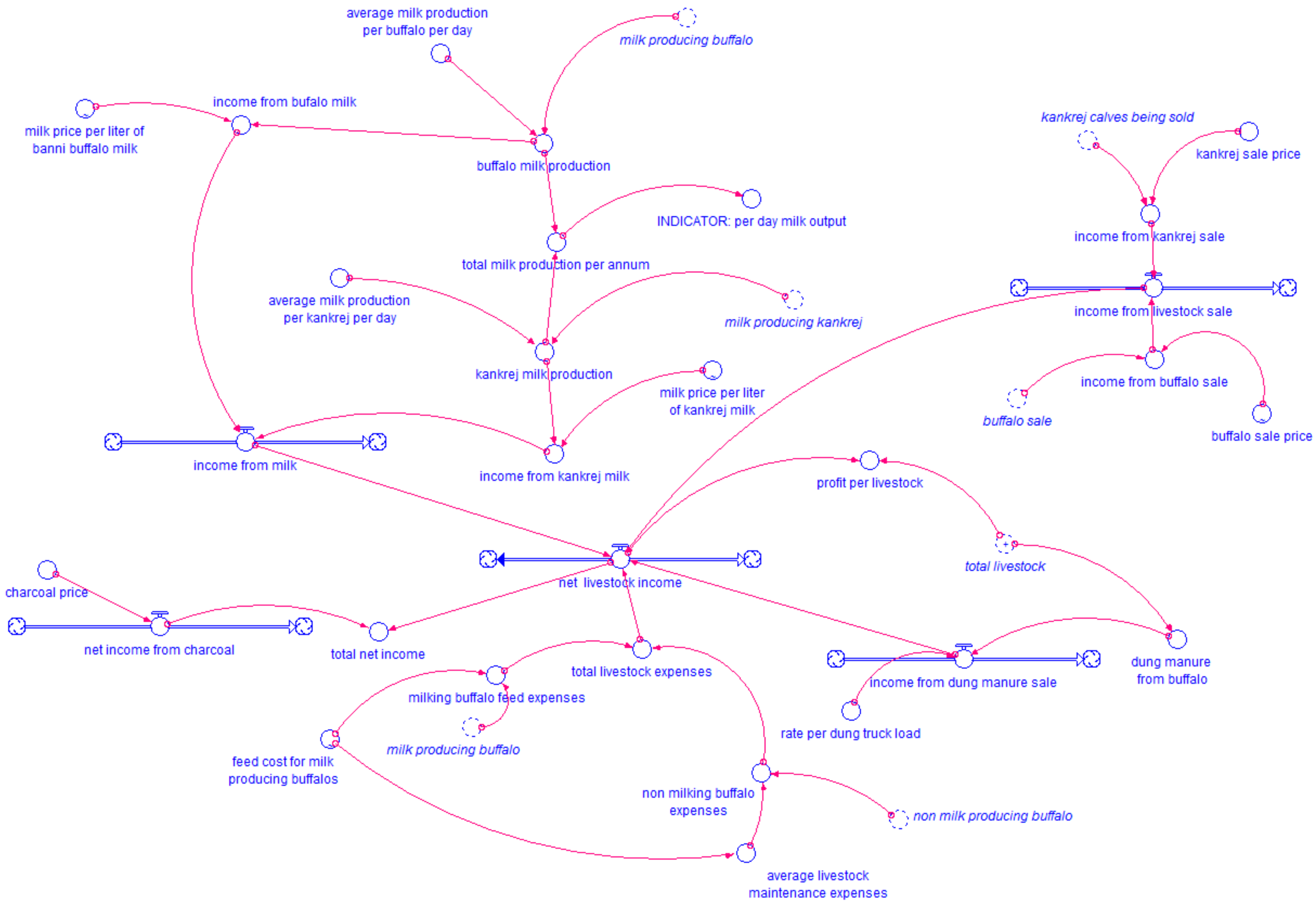

Figure 2.6 Economy sector

Photo 2.1 Interview with Maldharis in Banni.

2.2.8 Key Feedback Dynamics

There are 6 cross-sectorial feedback loops which govern the dynamics of the system. The numerical equations for these can be found in the model equations in Appendix 2.2.

1. **Impact of fodder deficit on livestock input cost**. As the fodder deficit increases so does the livestock input cost since fodder has to be purchased.
2. **Impact of profit per livestock on livestock stress sale rate**. As the profit per livestock becomes negative, the stress sale of livestock goes up (increase in stress sale rate).
3. **Impact of fodder deficit on temporary livestock migration**. If the fodder deficit crosses 30% in a certain year, 30% of the livestock leave Banni, and if it crosses 50%, 50% of livestock leave Banni while if fodder deficit is 10% or lower the livestock migrate back to Banni.
4. **Impact of livestock on *Prosopis* spread rate**. As the livestock population increases it leads to increase in the spread rate of area under *Prosopis*.
5. **Impact of area under *Prosopis* on Kankrej death rate**. As the area under *Prosopis* increases it leads to an increase in Kankrej death rates. However, it has been observed by the Maldharis that Kankrej has adapted to survive in *Prosopis* dense areas. Thus the death multiplier tapers off at high levels of *Prosopis*.

6. **Impact of profit per livestock on charcoal production**. As the profit per livestock becomes negative, charcoal production starts increasing to compensate for the losses.

The behavior of the system is governed by these feedback variables and whether the system grows, declines or oscillates depends on which of these feedbacks are dominant at a particular time of the simulation.

Table 2.3 Parameter values and sources

S No.	Factor	Value taken	Sources &Explanations where necessary
1.	Fraction of adult buffaloes giving birth every year	0.5	Personal Interviews.
2.	Buffalo calf death rate	20% p.a.	Data from personal interview with experts and pastoralists.
3.	Buffalo calf maturation time	3 years	Personal interviews
4.	Normal sale rate	3% p.a.	Personal interviews
5.	Buffalo lifetime	23 years (3 yrs. as calf and 20 as adult)	Personal interviews
6.	Fodder requirement per adult buffalo per day	30 kg	Personal interviews
7.	Fodder requirement per buffalo calf per day	7.5 kg	Personal interviews
8.	Fraction of milk producing buffalos	50%	Personal interviews
9.	Kankrej birth rate	50% of adult Kankrej cattle give birth every year	Personal interviews
10.	Kankrej calf death rate	20% p.a.	Personal interviews
11.	Average Kankrej calf sale rate	60% p.a.	Personal interviews
12.	Average male Kankrej purchase rate	25% p.a.	Personal interviews
13.	Kankrej calf maturation time	3 years	Personal interviews
14.	Kankrej lifetime	12 years as adult and 3 years as calf	Personal interviews
15.	Fraction of milk producing Kankrej	50% p.a.	Personal interviews

S No.	Factor	Value taken	Sources &Explanations where necessary
16.	Fodder requirement per Kankrej adult per day	15 kg	Personal interviews
17.	Fodder requirement per Kankrej calf per day	5 kg	Personal interviews
18.	Buffalo sale multiplier due to profitability	Increases from 0 to 30% with profit per livestock falling from 0 to -5000.	Parameterized using sensitivity runs
19.	Kankrej sale multiplier due to profitability	Increases from 0 to 20% with profit per livestock falling from 0 to -5000.	Parameterized using sensitivity runs
20.	Impact of *Prosopis* on death rate of Kankrej	Increases from 0 to 20% and tapers off as *Prosopis* density doubles	Parameterized using sensitivity runs
21.	Rainfall	Rainfall from 2015-2030 assumed to be the same as from 1999-2014.	Rainfall data for 1999-2010 taken from Let it be Banni", pg. 143, for year 2011-12 taken from, Vegetation dynamics in Banni grasslands under the influence of changing climate, GES 2015, pg 5 and for 2013-14 taken from IMD website for Kachchh district from http:/ / hydro.imd.gov.in/ hydromet web/ (S(lmae0jvse31sb045m2gxd5i1))/ DistrictRaifall.aspx
22.	The total productive area of Banni	225000 hectares	Birds of Banni, GUIDE 2016 Pg 20
23.	Normal spread rate of *Prosopis*	8.5%	Vaibhava et. al, 2012
24.	Impact of livestock on *Prosopis* spread	Increasing from 1 to 2 when livestock population increases from 25000 to 100000	Parameterized using sensitivity runs
25.	Charcoal production	4800 sacks of 40 kgeach produced per day	Sahjeevan
26.	Impact of profit per livestock on charcoal production	As profit per livestock falls below 0, this	Parameterized using sensitivity runs

S No.	Factor	Value taken	Sources &Explanations where necessary
		function begins to increase from 1 and goes up till 2 at a loss of INR 5000 per livestock	
27.	Average milk production per buffalo per day	12 litres	Personal interviews. Milk production per buffalo ranges from 8 liters to 20 liters a day. Average taken as 12 litres a day.
28.	Milk price per litre of Banni buffalo milk	Graphical function varying from Rs.19 per litre in 1992 to Rs. 40 per litre in 2015. Kept at 2015 prices in future.	Historical milk prices taken at 2015 constant values. 2015 milk price taken from personal interviews with dairy industry. 2010 milk price taken from Let it be Banni", pg 71 footnote. 2000 milk price taken from Ecological Economic Analysis of Grassland Systems: Resource Dynamics and Management Challenges-Kachchh District (Gujarat), pg 56, table 6.9 1992 milk prices are assumed.
29.	Average milk production per Kankrej per day	9 liters	Personal interviews. Milk production per Kankrej cattle ranges from 6 to 14 litres a day. Average taken as 9 litres a day.
30.	Milk price per litre of Kankrej cattle milk	Graphical function varying from Rs.10 per litre in 1992 to Rs. 18 per litre in 2015. Kept constant at 2015 prices in future.	Historical milk prices taken at 2015 constant values. Current prices for 2015 taken from personal interview, while earlier prices are re-calculated to reflect 2015 constant values.
31.	Charcoal Price	Rs. 5/ kg taken constant	Sahjeevan, Personal interviews
32.	Price of Dung	Rs 1500 per truck load	Let it be Banni pg 74
33.	Quantity of Dung sold	One truck load every 15 days- one truck load from 100 livestock	Let it be Banni pg 74

S No.	Factor	Value taken	Sources &Explanations where necessary
34.	Kankrej sale price	Rs 10000	Average price varies from Rs 12000 to Rs 30000 for a pair of bullock. Taken as average Rs. 10000 per Kankrej. Let it be Banni, pg 65
35.	Buffalo sale price	Varying from Rs 38000 in 1992 to Rs75000 in 2015 (post breed registration). Constant at Rs 75000 in future.	Current Buffalo price for year 2015 range from INR 50,000 to INR 3,00,000. Mode sale price taken as INR 75,000 and then normalized for the past years taking into consideration the rise in price due to Buffalo registration in year 2011.
36.	Input cost for milk producing buffaloes	Graphical function of fodder deficit. Varies from 10000 at 0 fodder deficit to 140000 at 100% fodder deficit	At 50% fodder deficit the cost of feed for milk producing buffalo is estimated to be Rs. 70,000/ - per annum. The numbers are adjusted to reflect fall and increase in fodder deficit and its corresponding impact on feed cost due to increase in supply. This table could be changed to do sensitivity or policy runs in the interface.
37.	Feed cost for non-milk producing buffaloes	One-third of No. 36.	Personal interviews

Photo 2.2 Interacting with Sahjeevan Experts at RAMBLE, Hodka, in Banni.

2.3 Results

2.3.1 Base Run: Business as usual scenario

The business as usual scenario i.e. base run simulation indicates that the total livestock in Banni will fall from 2015 to 2030 (Figure 2.7). The primary reason for this is reducing area under grassland. Two consecutive years of poor rainfall (2019-2020) are the reasons for the steep fall in livestock numbers in year 2020- similar to what was observed in year 2004. Maldharis use temporary migration as a coping mechanism for dealing with fodder scarcity that occurs in poor rainfall years. Thus, livestock variability could be higher in periods of fodder scarcity. However, rainfall is impossible to predict accurately, and our simulation assumes that the rainfall pattern observed between 1999 and 2014 would reoccur in 2015 to 2030, given the cyclical nature of rainfall patterns in the area. The exact dynamics during this period will of course depend on the nature of rainfall.

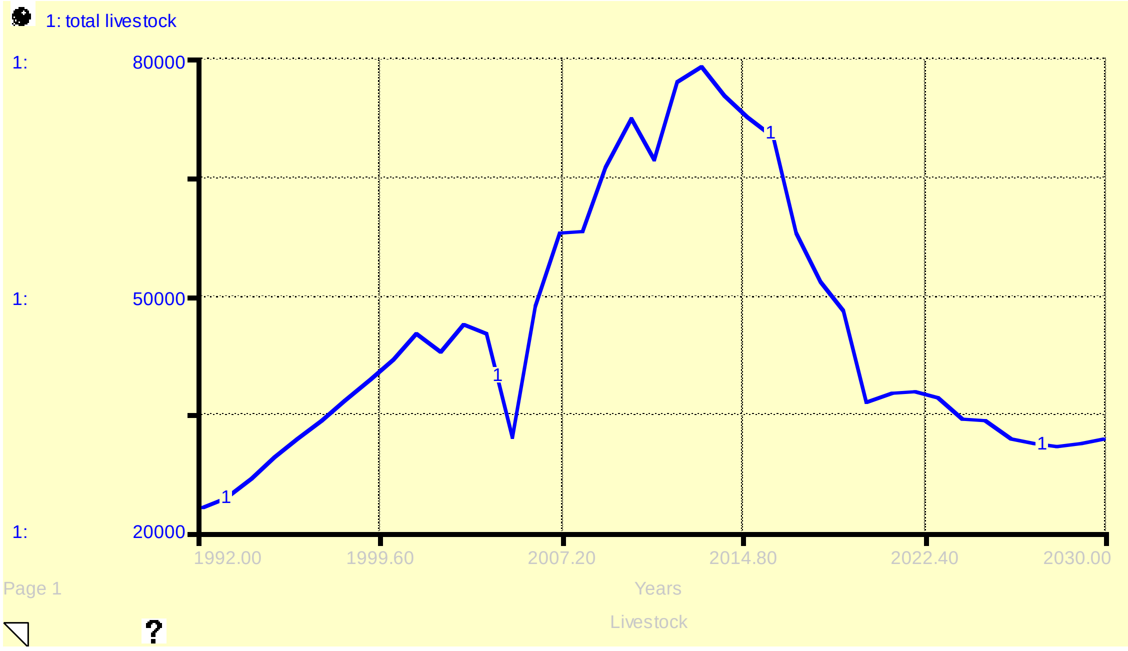

Figure 2.7 Base Case Livestock Population: 1992-2030

The shrinking area under grassland due to *Prosopis* spread is a cause of concern for Banni. If current conditions persist then by year 2030 the area under grassland will reduce to 22,000 hectares from 78,000 hectares in 2015, a reduction of 70%. The primary reason for reduction in grasslands is the increase in spread of area under *Prosopis juliflora*. The model runs suggest that that the area under *Prosopis juliflora* will reach 2, 00,000 hectares by year 2030. (Figure 2.8)

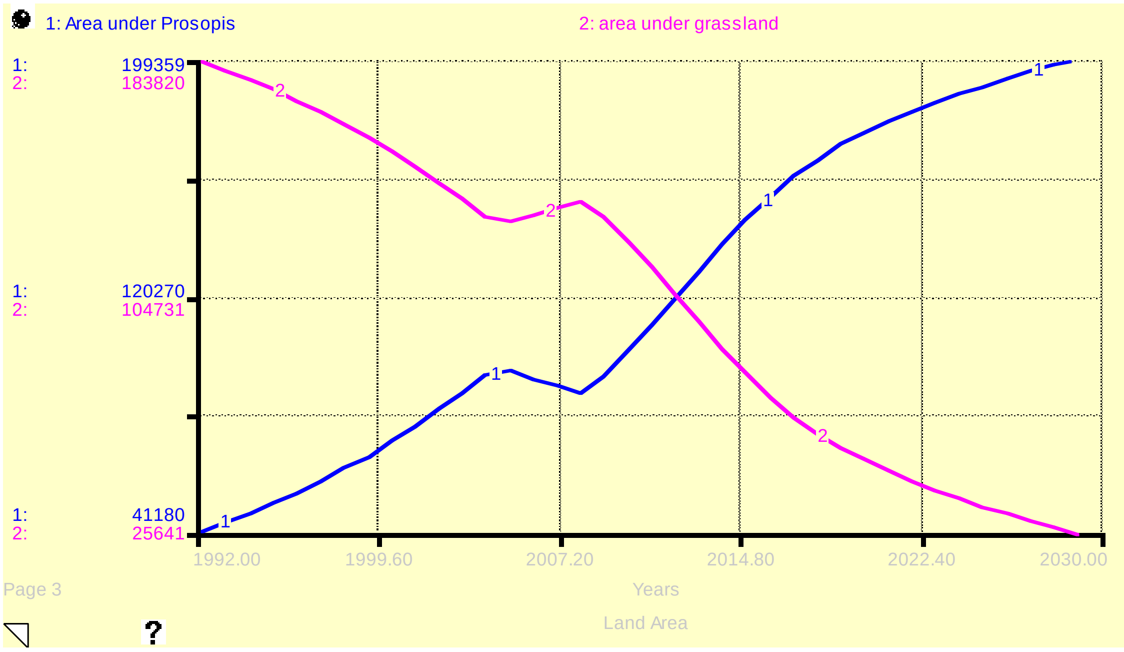

Figure 2.8 Base Case Land Use Change. All figures in hectares: 1992-2030

The period 2004-2008 shows a dip in area under *Prosopis* and an increase in area under grassland. This is due to the lifting of the ban on charcoal-making which caused an escalation in removal of *Prosopis*. Because of this, the grasses recovered, increasing the area under grassland. After the ban was again imposed, it led to growth in area under *Prosopis* while the grasslands continued to shrink.

Our base case simulation runs indicate that the net livestock income is projected to fall in future years and become negative for year 2020 due to two continuous low rainfall years- 2019-20 (Figure 2.9). The decline in net livestock income is mainly due to falling livestock population and increase in livestock input costs, mainly feed and fodder (due to an increased fodder deficit). These input costs spike due to fodder deficit which increases in the later years due to reducing area under grassland. The input costs are projected to go up mainly because of external increase in inputs of feed to reduce the fodder deficit.

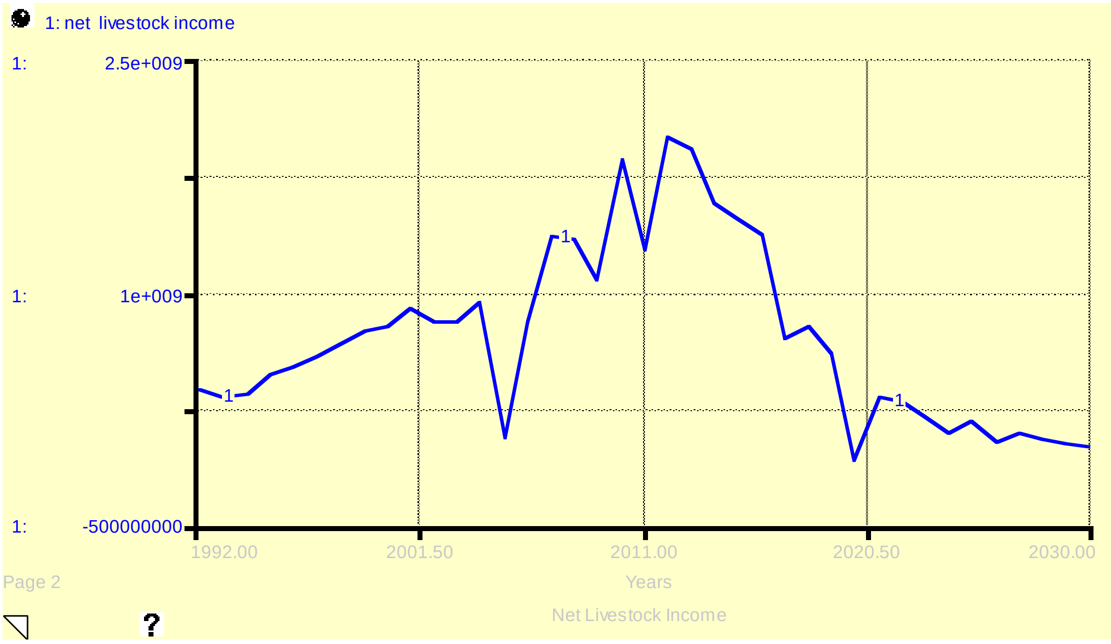

Figure 2.9 Base Case Net Livestock Income: 1992-2003

Grassland biomass depends on the extent of rainfall and grassland productivity. The variation in rainfall greatly influences the extent of grassland productivity and ultimately how much grass grows in that particular year. As can be seen in figure (Fig 2.10) the fodder deficit is expected to spike and rise in future years. This is mainly due to reducing grassland area coupled with some low rainfall years which lead to low grass production. The future trend indicates increase in fodder deficit.

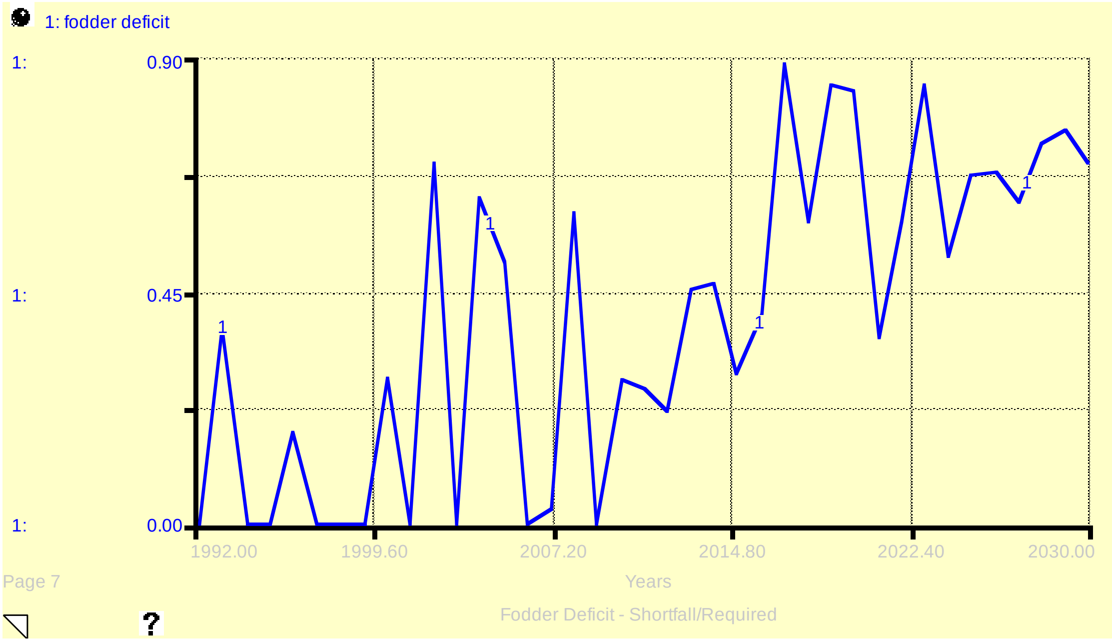

Figure 2.10 Fodder Deficit – Base Case

The base case future runs present a sorry picture for the livestock economy of Banni. If the current spread of *Prosopis* continues then the area under grassland could reduce to the point that livestock rearing becomes uneconomical for the Maldharis of Banni. This could be detrimental since livestock forms more than 95% of the income of Banni. Moreover, the loss of these fragile grasslands would have numerous other impacts-for biodiversity, for biodiversity-based ecotourism and possibly for bird migration as well. Also, since it is a low rainfall region finding alternative livelihoods which can compensate for livestock income loss could be very difficult if not impossible.

hoto 2.3 Maldhari showing Banni grass. On the right kept on floor is the grass they buy during fodder deficit.

2.3.2 Policy testing scenarios: A *Prosopis* removal policy

Against this backdrop, we have modelled the impacts of a hypothetical *Prosopis* removal policy (PRP) either decided by the community or by government order. The *Prosopis* area removal rate is kept at 20% per annum and the policy becomes active from year 2016 and takes full effect after a delay of 3 years. In this scenario the livestock population is estimated to increase and reach close to 1.4 lacs by 2030 (Figure 2.11). The dominant cause for the rise in livestock population is the increased fodder availability due to increase in area under grassland (due to removal of *Prosopis* juliflora). Also removal of *Prosopis* reduces the death multiplier on Kankrej which would leads to an increase in Kankrej population.

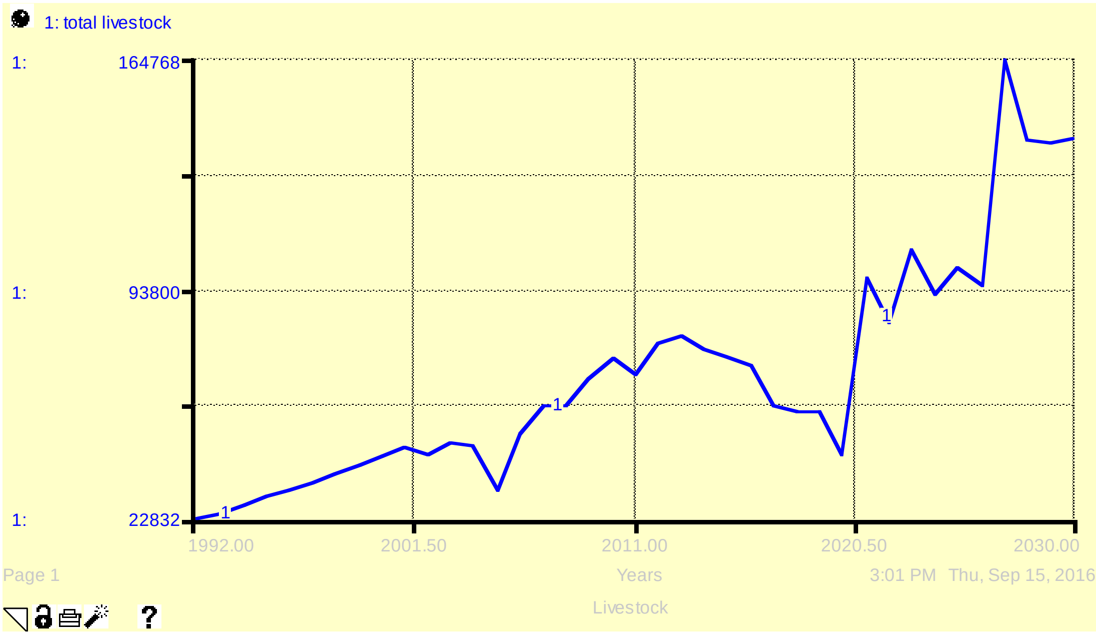

Figure 2.11 Total Livestock under a hypothetical *Prosopis* removal policy

It is projected that the area under grassland would go up to 1,68,000 hectares by 2030 while the area under *Prosopis* would reduce to 56,000 hectares and continue to fall. This would increase the grass availability leading to an increase in Banni's livestock carrying capacity (Figure 2.11).

A key assumption is that grassland area currently occupied by *Prosopis* still has grass seeds and that in event of complete removal of *Prosopis* the grasses would start growing almost immediately. This was observed to happen in 2004-2008, and nearly all the Maldharis we interviewed believe that this is indeed the case. Moreover, scientific evidence also supports this observation.

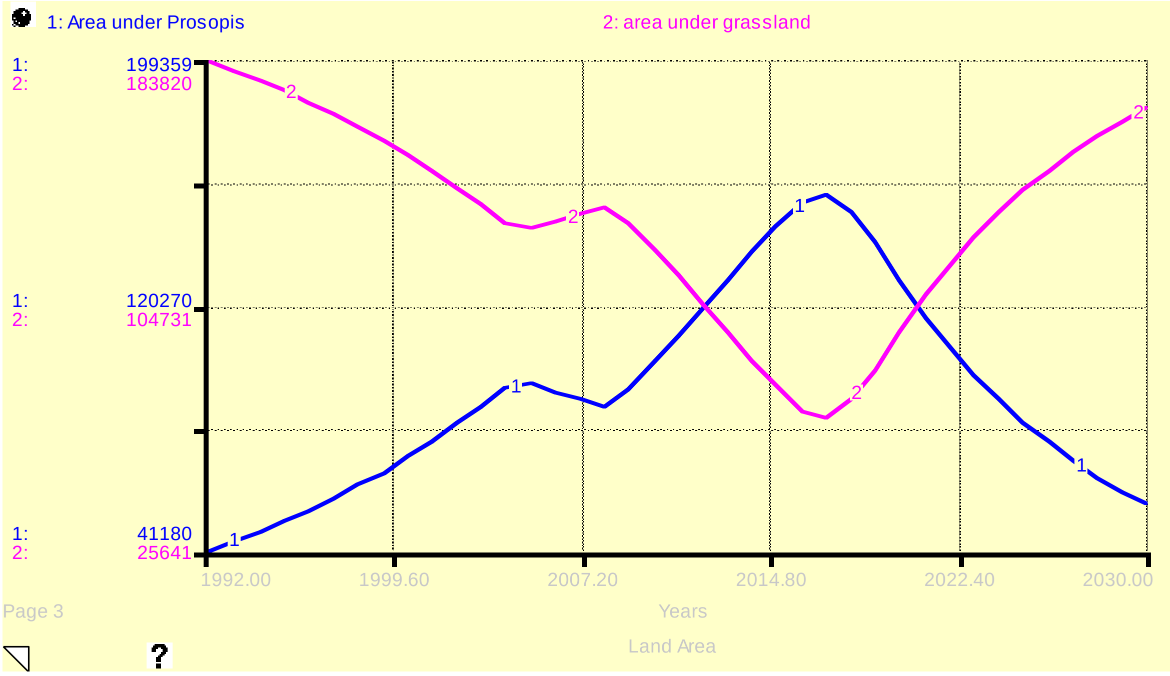

Figure 2.12 Land Use Change under *Prosopis* Removal Policy

Under the PRP scenario the net livestock income is projected to increase after a steep dip in year 2020. This increase is mainly attributable to increase in area under grassland and subsequent rise in availability of fodder. This leads to rise in livestock population due to increased livestock carrying capacity while the input costs remain low. Increased livestock leads to increase in milk output, dung income and income from livestock sale; all leading to increases in net livestock income (Figure 2.13).

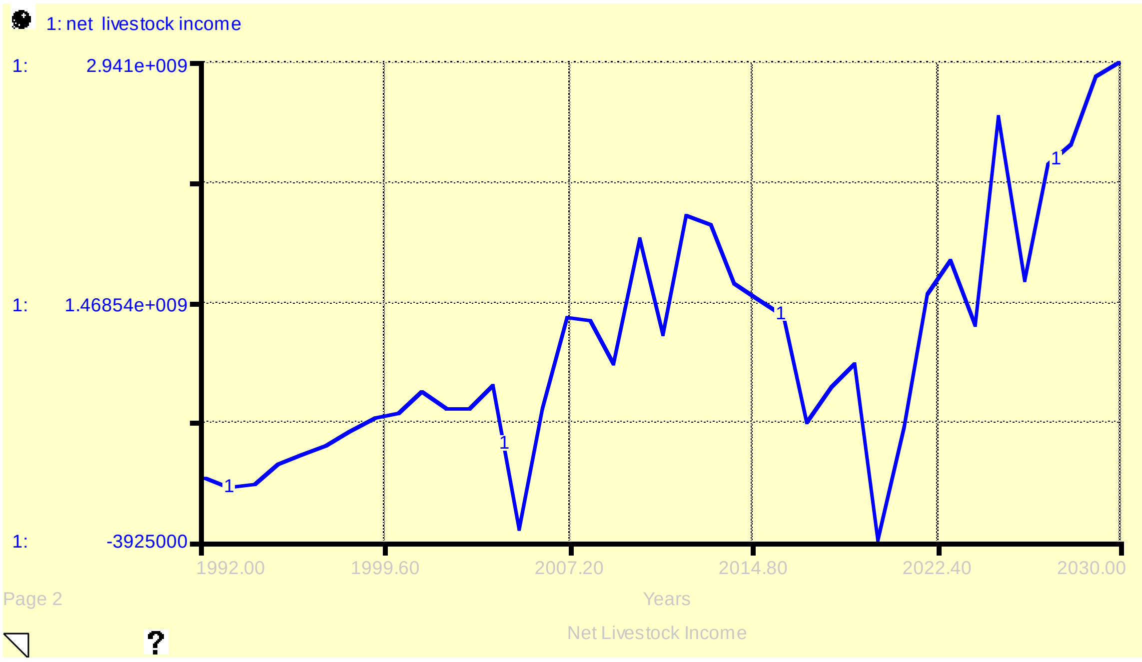

Figure 2.13 Net Livestock Income under *Prosopis* Removal Policy

Comparing the Scenarios

The previous two scenarios are superimposed on each other to give a comparative picture.

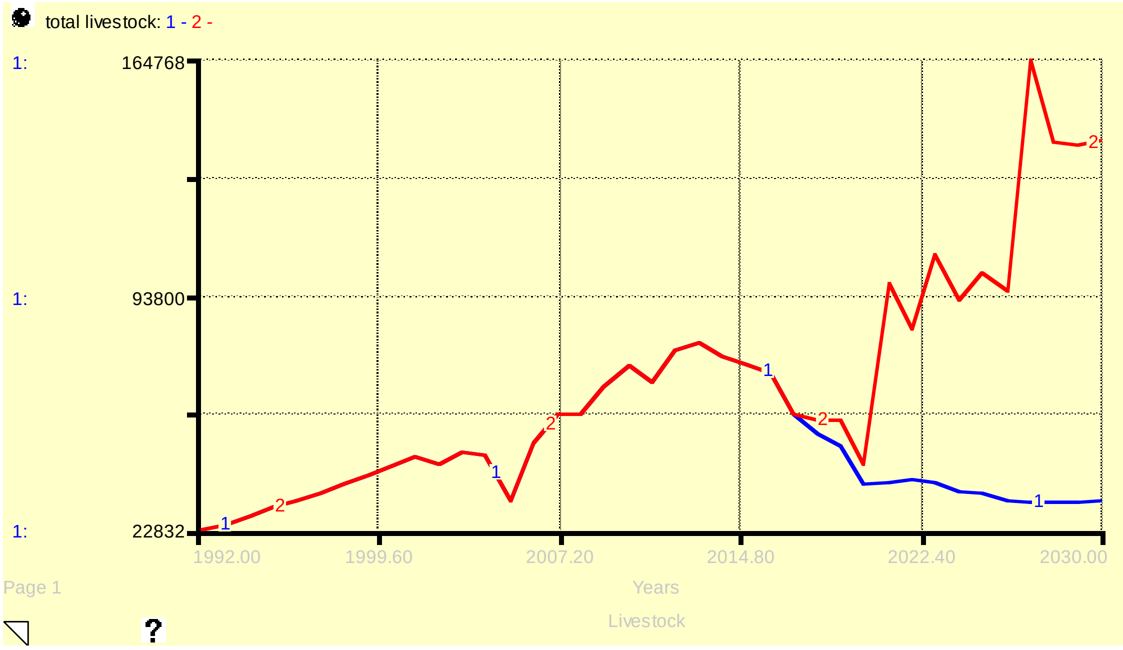

Figure 2.14 Total Livestock Population Projections

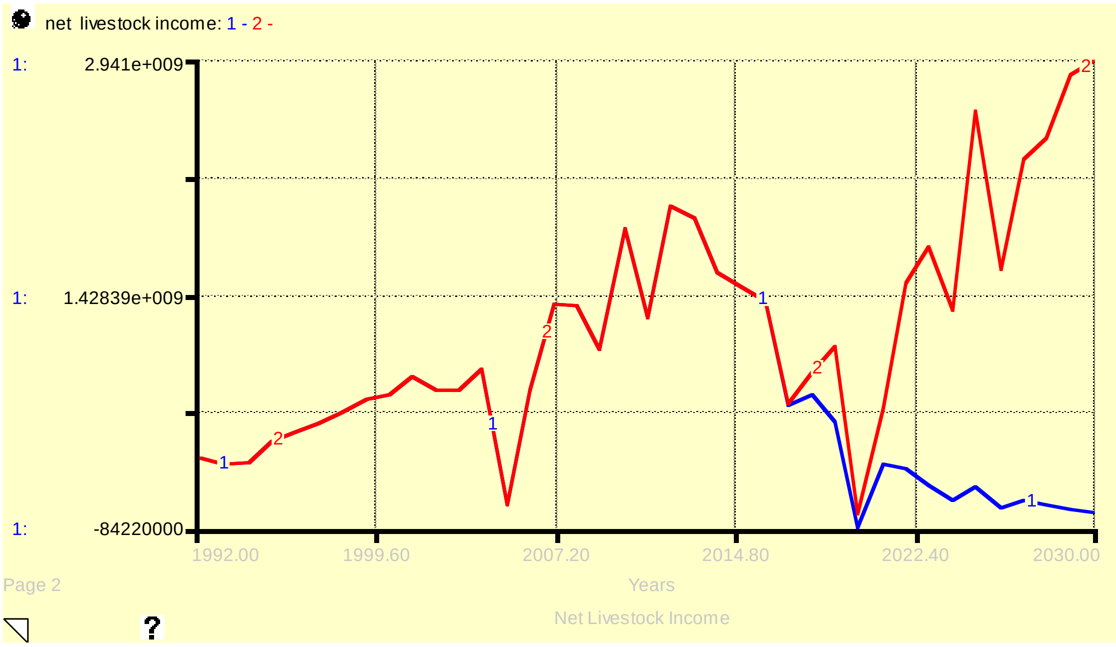

Figure 2.15 Net Livestock Income Projections (INR)

As can be seen *Prosopis* removal has a positive impact on the livestock numbers in Banni, due to grassland regeneration. The net livestock income levels also increase.

In the following section we perform a discounted valuation of future livestock earnings under Base case and PRP scenario from year 2015-2030 using a discount rate of 10%. The difference between the two can be assumed to be the partial costs of grassland degradation induced by *Prosopis* spread in the Banni[8].

2.3.3 Economic Valuation of Income Flows from 2015 to 2030

As per the base run model results the total net income of Banni for 2015 is around INR 150 crores. Milk income contributes more than 95% of the total pastoral income of Banni and more than 85% to the total income of Banni. Charcoal income contributes around 14% of the total income of Banni.

This includes net income from 1) milk, 2) dung, 3) livestock sale, 4) charcoal production. The net livestock income, under the base case, is projected to continuously decline and almost collapse to reach INR 5 crores by year 2030. The sum of present value of livestock and total net income from 2015-2030 comes to INR 485 crores and INR 705 crores respectively. If PRP is in place then the PV (Present Value) increases to INR 1,176 crores and INR 1,389 crores. This indicates that *Prosopis* removal has a big positive multiplier impact on the economy of Banni. Although, there would be a loss of charcoal-based income due to removal of *Prosopis* (it is assumed that the *Prosopis* removed is not used for charcoal making) the net impact remains positive.

Table 2.4 Economic Analysis of Grassland Degradation

Sr. No.	Present Values (10% Discount Rate)	Net Livestock income	Net Total Income
1)	Base Case	INR 4,856,619,264	INR 7,059,788,063
2)	*Prosopis* Removal Policy (PRP) @20% p.a.	INR 11,767,944,967	INR 13,896,972,557
3)	Policy Multiplier (PRP÷Base Case)	2.4	2
4)	Difference i.e. costs of grassland degradation (No. 2 minus No. 1)	INR 6,911,325,703	INR 6,837,184,494
5)	Per ha costs of grassland degradation (No. 4÷2,50,000 ha)	INR 27,645	INR 27,348

One more policy run is done to test the impact of a five year delay in the decision to remove *Prosopis* and the impact this would have on the PVs.

Table 2.5 Economic impact of PRP Policy Delay

Sr. No.	Present Values (10% Discount Rate)	Net Livestock income	Net Total Income
1)	PRP with 5 year delay	INR 7,794,137,768	INR 9,993,125,470
	Loss due to delay	-51%	-39%

The costs of delaying the implementation of *Prosopis* removal policy are substantial. The PV for net livestock income comes down by 50% while the total net income comes down by 40%

[8] We assume that these are the partial costs, because we do not include other costs such as of loss of biodiversity, loss in tourism incomes and other ecosystem services provided by the grasslands.

due to the delay in policy implementation. This indicates that PRP is a time sensitive policy decision and any delays would result in economic losses for Banni apart from other negative ecological impacts.

2.4 Conclusion and Recommendations

The general perceptions of the people of Banni, on the reason for grassland degradation in Banni, point to the growth of area under *Prosopis*. It is also widely believed that if the *Prosopis juliflora* is completely removed then the grasses would come back. Maldharis have repeatedly indicated their preference to remain as livestock breeders and pastoralists because they consider it to be their traditional, profitable occupation. Our model results are consistent with these perceptions and claims. The economic valuation indicates that *Prosopis* removal is a favorable policy option for sustaining their livestock economy and halting grassland degradation. The per ha costs of land degradation are estimated at INR 27,645 per hectare, accounting for the difference in total benefits between a business as usual scenario and a *Prosopis* removal scenario.The results indicate that livestock profitability goes up in event of *Prosopis* removal and that in order to sustain livestock as the main occupation of Maldharis the land area under *Prosopis* needs to be cleared, preferably without any delay. However, our results cannot verify their claims because the model presents a simplified representation of Banni. ***A policy level discussion on the need to remove Prosopis, as a measure to reduce land degradation is consequently warranted, given that large areas of the country are now under invasive species.***

The model provides a glimpse into the future possibilities that exist for Maldharis and the landscape of Banni based on the use of plausible assumptions and parameters. Rainfall is a key variable that determines grass productivity, so variation in rainfall could also change the income dynamics. The economic valuation exercise also indicates that a delay in policy implementation has a huge cost for the economy. This is particularly important for Banni since the livestock sensitivity to grass availability is very high and *Prosopis* density greatly influences the grass availability. ***Hence, a quick policy decision on whether Prosopis should be removed or not, based on an assessment of the pros and cons would prove to be beneficial.***

There is a need for additional ecological and economic research on the Banni grasslands.This study needs to be supported with data and information about the micro-dynamics of Banni. The cost of removing *Prosopis* need to be estimated for different regions of Banni depending on the extent of cover and then factored into the analysis.There are information gaps with respect to the grass productivity, fodder availability in different seasons, extent of seasonal livestock migration due to fodder deficit and the role of salinity. In order to strengthen the results of such a modelling exercise, these gaps need to be addressed through research which can then serve as inputs to an integrated systems model which can simulate the behaviour of key policy variables.

There is also an unresolved issue of entitlement of land ownership. ***This makes studying the political ecology of Banni pertinent, since these factors would also have a bearing on the decision-making processes***.

Most importantly, this study highlights the need to focus on initiating studies on the economic impacts of invasive species and their contribution to the economics of land degradation. The contribution and economic costs incurred due to the spread of invasives currently remains largely un-quantified in India.

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Chapter 3. Losing the benefits of forests to degradation? A case study from Tehri Garhwal, Uttarakhand

3.1 Introduction

Forest degradation is widespread in India with severe consequences for millions of forest-dependent communities. Vegetal degradation has been pegged as the second leading cause of land degradation in India accounting for 8.91% of the total geographical area (TGA) in 2011-13 according to one source (SAC, 2016) or as much as 10.4 % of the TGA if open forests and scrub forests are considered (FSI, 2015, see Chapter 4, Volume I of this report). Forest loss and degradation deprive people of innumerable goods and services such as hydrological services, carbon sequestration and storage, pollination services for agriculture, recreation and tourism values or basic provisioning services. Consequently, their degradation places a huge burden on the exchequer although failure to capture their full market value, underestimates this loss. In the country study, we estimate that forest degradation accounts for 55% of the total costs of land degradation in India amounting to Rs 1441 billion to 1758.6 billion or 1.41% of the GDP and 8.81 % of the gross value added from forestry and agriculture.[9] Here we attempt to determine the value of forests in the Dhanulti and Devalsari area of Tehri Garhwal, Uttarakahand to local communities and to tourists and what their degradation implies in terms of lost revenues from recreation or foregone provisioning services from fuelwood, fodder and Non-Timber Forest Products (NTFPs). In addition, using a mix of primary and secondary data and remote sensing assessments, we determine the costs of forest degradation in Dhanulti and Devalsari from 2001-2015 and project this further to 2030. We then determine the costs of reclaiming these forests in 2030.

Uttarakhand is a treasure trove of forest wealth and biodiversity, apart from a rich heritage of cultural diversity, traditions and community management practices that are closely linked to the State's considerable forest reserves. These forests provide important provisioning services like firewood, fodder, timber, medicinal plants and other non-timber forest products (NTFPs). But the forest ecosystems of Uttarakhand also provide several intangible services which help to sustain life including several regulating services like climate moderation, hydrological regulation, seed dispersal, and pollination, supporting services such as nutrient cycling as well as cultural, recreational and aesthetic services (LEAD India, 2007). Consequently, a large proportion of the population of the state relies on forests and biodiversity, either directly for subsistence or livelihood needs or indirectly through various industries including tourism.

Forests account for 46.73% of the state's geographical area (FSI, 2015). Although, forest cover had stabilized from 2001 to 2013, the latest figures indicate a dip in forest cover by 268 km^2 (FSI 2015) (Fig.3.1). Forest degradation also continues to be a problem for the State given the enormous dependence on the forests for fuelwood, fodder and other NTFPs. This is evident from the decrease in dense forests in 10 districts, i.e. almost 77% of the districts. Moreover, the overall decrease in dense forests for the State is a matter of concern (Figure 3.2).

[9] At 2014/ 2015 prices. See Chapter 4 in Volume I where the costs have been estimated.

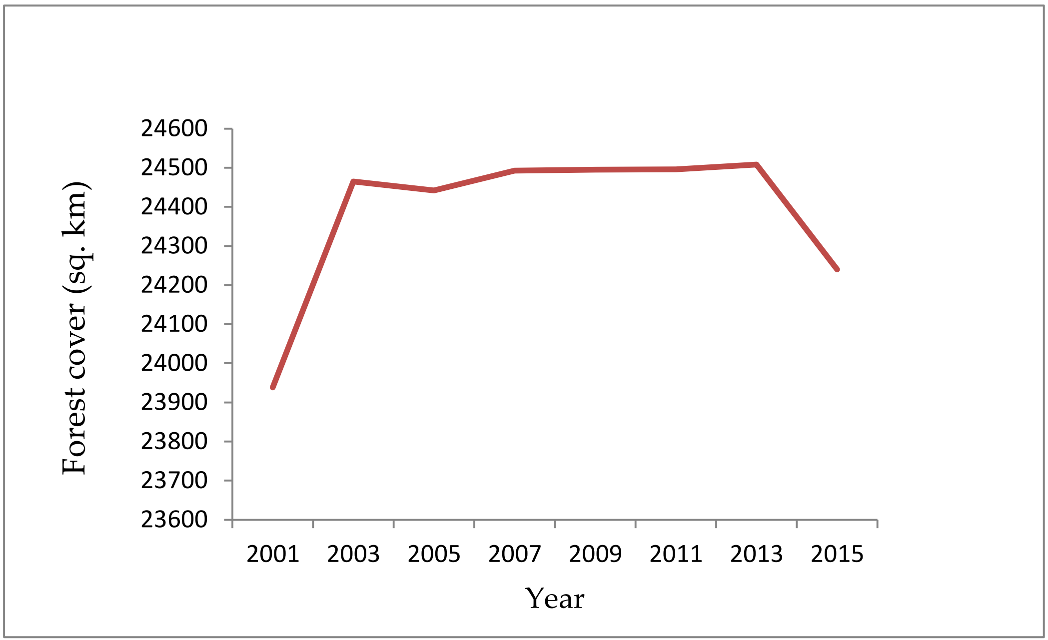

Figure 3.1 Forest cover in Uttarakhand from 2001-2015

Source: State of Forest Reports, FSI (2001-2015)

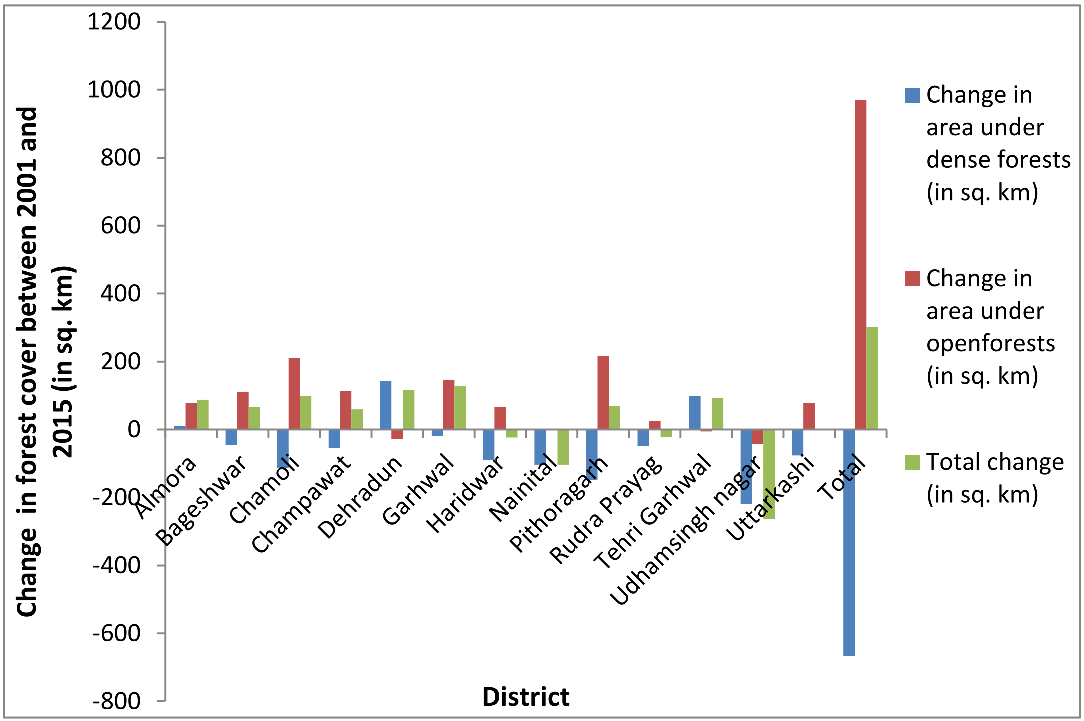

Figure 3.2 District-wise change in forest cover (dense and open forests) between 2001 and 2015

Source: State of Forest Reports, FSI (2001-2015)

Overexploitation of forest resources contributes to forest degradation in the State, despite their enormous economic value. Physical accounts for the forests of Uttarakhand from 2000-01 to 2010-11 indicate that the demand for fuel wood accounts for the largest share of change followed by diversion of forest land for non-forest use. In 2010-11, fuelwood production was estimated to be 26610 cubic meter stacks while the estimated household consumption was 3013660 cubic meter stacks (TERI, 2014)[10] pointing to grossly unsustainable fuelwood harvests. However, timber extraction is a negligible contributor to the changes in forest stock in the state (TERI, 2014). This huge burden of fuelwood harvests leads to forest degradation, rather than deforestation. Ecological studies to assess Uttarakhand's forest status conducted by Baland et al. (2006) using measures of forest quality such as canopy cover, tree lopping and forest regeneration also point to severe degradation in the State. As many as 40% of all forest patches studied fell below the sustainability threshold for canopy cover and the mean percent of trees severely lopped was 50%. Tree stock density, however, appeared quite healthy-only 15% of forest patches fell below the sustainability threshold of 35 square metres per hectare. Interestingly, Baland et al. (2006) conclude, that since, "the nature of degradation does not involve a substantial reduction in forest biomass, this would not be picked up by aerial satellite images." Therefore, official estimates of forest cover changes in Uttarakhand are unlikely to pick up finer-scale forest degradation. These studies point to severe forest degradation due to fuelwood extraction in Uttarakhand. In this study, we carry out a finer scale valuation of forest degradation in the Dhanaulti and Devalsari areas of Tehri Garhwal.

The forests of Dhanaulti, close to Mussoorie in Tehri Garhwal are an important tourism destination for people who come here to trek, to visit religious places, to enjoy the scenic beauty or to bird or butterfly watch. The forests are therefore, of value to tourists. In order to capture this value, travel costs incurred by tourists can be used as a proxy for the value of a site. The Travel Cost Method (TCM) involves the estimation of recreational demand for particular sites based on visitors' 'revealed' - as opposed to 'stated' – preferences, and assumes that a surrogate market for the good (in this case forests) exists (Chopra, 2004). This is certainly likely to be true for the sites surveyed in Uttarakhand which are thickly forested and offer scenic vistas to tourists as well as a rich diversity of birds, butterflies and flora for nature lovers.

In this case study, the value (estimated via the Travel Cost Method) that tourists place on the forests of Dhanaulti and Devalsari are assumed to be the foregone recreational benefits if the forests are degraded. In other words, these will be one of the costs of forest degradation - because it is these biodiverse forests that add value to ecotourism and once degraded or lost, ecotourism may dwindle or cease. However, tourists' valuation of the forests (and forest biodiversity) is insufficient to capture their full value. Local communities for example, derive benefits other than tourism revenue[11], based on their direct dependence on forests for fuelwood, fodder, minor timber and Non-Timber Forest Products (NTFPs). A meta-analysis of 54 studies from developing countries indicated on average income from the forest accounted for 22% of the total household income (Vedeld et al., 2004). Forest products fulfil both subsistence and livelihood needs of forest-based communities. Products derived from forests form a safety net in times of food or resource scarcity. Consequently, this case study, also determines the direct dependence of local communities on the forests for their subsistence and other needs. In addition, their perception of the forests' value is captured

[10] The study estimated fuel wood consumption based on the NSSO (2009/ 10) data on monthly per household consumption of fuel wood (193.15 kg for rural and 124.71 kg for urban) for Uttarakhand (TEDDY 2011-12, page 295); Conversion factor of 1 cubic meter=725 kg (FAO, 2012) was used and number of households using fuel wood for cooking (Census 2011)

[11] as guides, or pony owners or owners or employees of hotels, tea stalls or souvenir stalls

using an Analytic Hierachy Process. The perspectives of other stakeholders such as scientists and conservation biologists who value these forests for their existence value or pharmaceuticals for whom they have bioprospecting potential, however, have not been directly considered in this study[12]. The focus in this study is on determining the tourism and recreational benefits provided by the forests, local community dependence on forests and their perceptions and ranking of forest value. These services are then used to derive the change in the Total Economic Value (TEV) of these forests resulting from their loss and degradation. The change in forest cover was estimated via a remote sensing assessment of land use and land cover change from 2001-2015. In summary, the case study objectives include:

- Change in forest cover in Dhanaulti and Devalsari using a remote sensing assessment;
- Estimation of the dependence of the local communities of Devalsari and Dhanaulti on their forest resources;
- Estimation of travel costs for Dhanaulti to determine the recreational benefits of the area;
- The estimations of forest dependence, recreational benefits and change of forest cover were then combined with the remote sensing assessment of forest change to arrive at a valuation of forest degradation in Dhanaulti and Devalsari.
- Projections of the costs of degradation to 2030 (scenario development) and the costs of reclaiming the forests, and
- Perceptions and ranking of the value of forest resources by local communities.

Photo 3.1 A head-load of fodder

[12] However, some of these values have been considered while establishing the costs of forest loss/ degradation in this area.

3.2 Methodology

3.2.1 Selection of state and district

According to the latest desertification and land degradation atlas of India (SAC, 2016), vegetal degradation is the second leading cause of land degradation and desertification in India (8.91% in 2011-13 and 8.60% in 2003-05). At the time of study initiation only the SAC, (2007) atlas was available according to which the states most impacted by vegetal degradation lay in the North-East of India, outside the drylands. Uttarakhand was also important in terms of vegetal degradation. Therefore, we selected Uttarakhand for our case study of vegetal degradation and because of its mountainous areas (to ensure that our study encompassed a range of topographies, ecosystems and causal mechanisms across the country). Vegetal degradation is the primary cause of degradation in Uttarakhand and has increased from 545610 ha in in 2003-05 to 606616 ha in 2011-13 (SAC, 2016), i.e. from 10.2% to 11.34% (Fig 3.3).

The share of Uttarakhand in the country-wide area affected by class of degradation was determined from the harmonised atlas (ICAR and NAAS, 2010), since this atlas was used as the basis of our selection of study sites across the country. The results are provided in Table 3.1. None of the results indicate that Uttarakhand figures high in terms of degradation status (ICAR and NAAS, 2010), probably because vegetal degradation is not included as a causal mechanism in the harmonised atlas. We then looked at the share of the districts in the state-wise degradation by class (%). According to this, Tehri Garhwal district was the most degraded district of Uttarakhand (ICAR and NAAS, 2010), (Fig 3.3, Table 3.2) and accounted for 41.27% of the state's area for acid soils under open forest. In addition, SAC (2007) indicated that Tehri Garhwal showed high levels of forest degradation (Fig 3.4/ 3.5). Consequently, Tehri Garhwal was selected for an intensive survey of vegetal degradation. Forest Survey of India (2015) data for Tehri Garhwal also indicated decreases in open forest cover from 2001-2015. Moreover, a study conducted by TERI (TERI, 2014) indicated that percentage of area under forest fragmentation in Tehri Garhwal, had increased in the very high, high and medium categories during 2001-2011 from 8.16% to 9.37%, 6.33% to 8.05% and 7.27% to 7.37%, however, fragmentation in the low and very low classes decreased during this period[13]. These figures indicate high levels of forest fragmentation for Tehri Garhwal.

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[13] The mathematical representation of the fragmentation is:

$$Frag = f(n_{\_F}, n_{\_NF})$$

Where, Frag = fragmentation; n = number of patches; F = forest patches; NF = non-forest patches. Pixels having fragmentation index values ranging 0-20 were categorized as very low fragmentation; following low (20-40), medium (40-60), high (60-80) and very high (80-100) fragmentation.

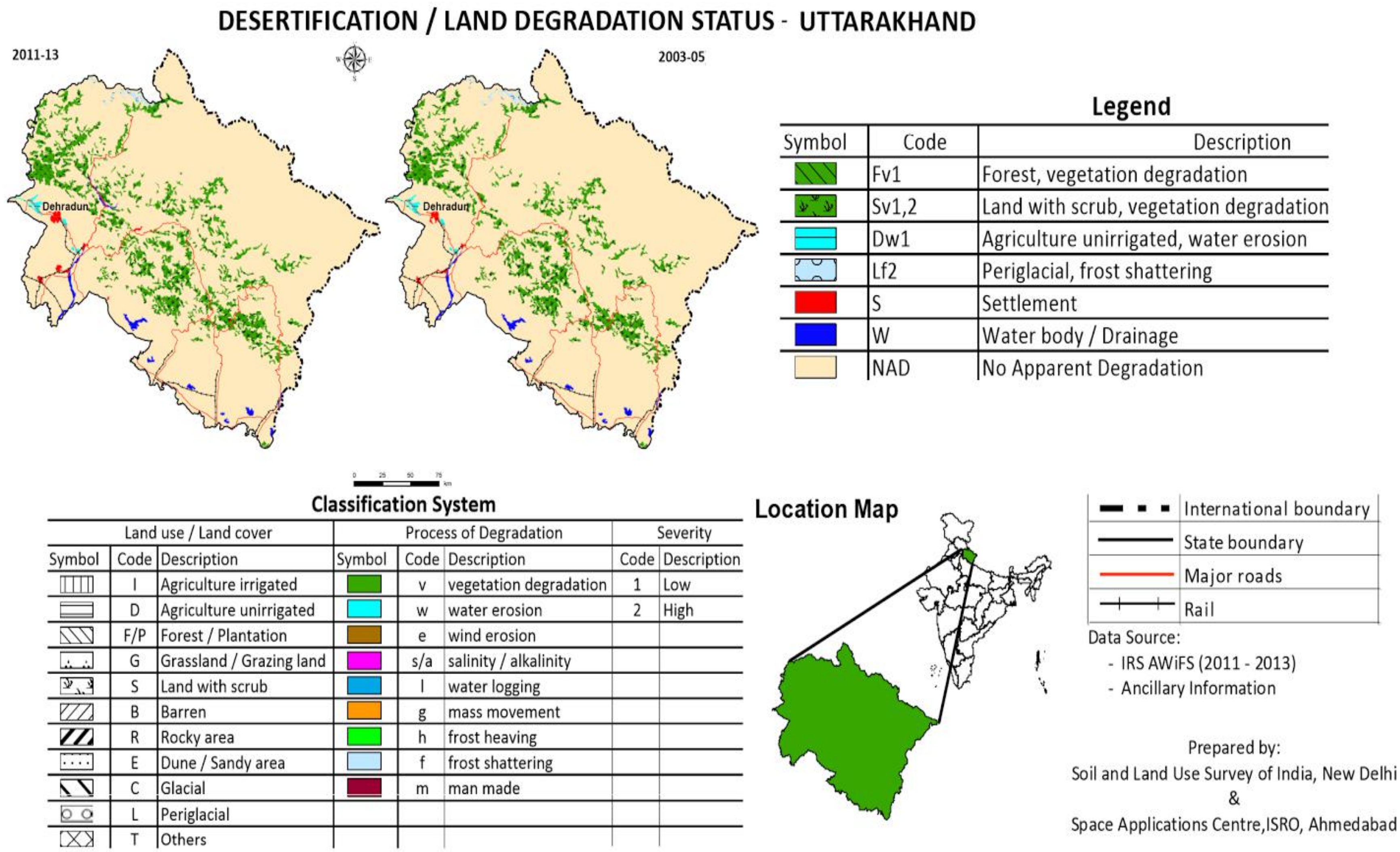

Figure 3.3 Desertification/Land degradation status of Uttarakhand in 2003-05 and 2011-13

Source: SAC (2016)

Table 3.1 Share of Uttarakhand in the country-wide area affected by degradation and share of class in degraded area of Uttarakhand

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Share of UK in the country-wide area affected by each class of degradation (%)																		
1.1	1.9	0.3	**3.3**	**2.8**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.4**	**2.9**
Share of class in total degraded area of UK (%)																		
57.8	12.5	0.9	13.2	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7

1 **Exclusively water erosion (>10 tonnes/ha/yr);**	11 Saline soils under open forest;
2 Water erosion under open forest;	12 Waterlogged saline soils;
3 Exclusively acid soils (pH <5.5);	13 Exclusively sodic soils;
4 Acid soils under water erosion;	14 Eroded sodic soils;
5 Acid soils under open forest;	15 Sodic soils under wind erosion;
6 Exclusively wind erosion;	16 Sodic soils under open forest;
7 Exclusively saline soils;	17 Eroded sodic soils under open forest;
8 Eroded saline soils;	18 Mining/ Industrial waste;
9 Acid saline soils;	19 Waterlogged area (Permanent)
10 Saline soils under wind erosion;	

Source: ICAR-NAAS, 2010

Table 3.2 Share of district in state-wide degradation by class (%)

	1	2	3	4	5	18	19	Total of classes
Almora	3.62	0.00	0.00	0.00	0.00	100.00	8.00	2.30
Bageshwar	1.93	2.22	0.00	0.00	2.02	0.00	12.00	1.88
Chamoli	7.84	6.67	23.08	14.81	10.61	0.00	24.00	9.41
Champawat	0.36	5.00	0.00	0.53	10.10	0.00	4.00	2.37
DehraDun	16.16	5.00	0.00	10.58	7.58	0.00	0.00	12.40
Haridwar	18.21	20.00	0.00	0.00	0.00	0.00	0.00	13.03
Naini Tal	7.12	7.78	0.00	0.53	0.00	0.00	16.00	5.44
Pauri Garhwal	12.42	16.67	46.15	7.94	17.68	0.00	0.00	13.17
Pithoragarh	0.36	0.00	0.00	3.17	0.00	0.00	4.00	0.70
Rudraprayag	0.12	8.89	0.00	0.00	6.06	0.00	0.00	2.02
Tehri Garhwal	6.27	24.44	7.69	41.27	41.41	0.00	0.00	17.91
Udham Singh	21.35	0.56	0.00	0.00	0.00	0.00	32.00	12.96
Uttarkashi	4.22	2.78	23.08	21.16	4.55	0.00	0.00	6.41

1 Exclusively water erosion (>10 tonnes/ha/yr);

2 Water erosion under open forest;

3 Exclusively acid soils (pH <5.5);

4 Acid soils under water erosion;

5 Acid soils under open forest;

18. Mining/Industrial waste

19. Waterlogged areas

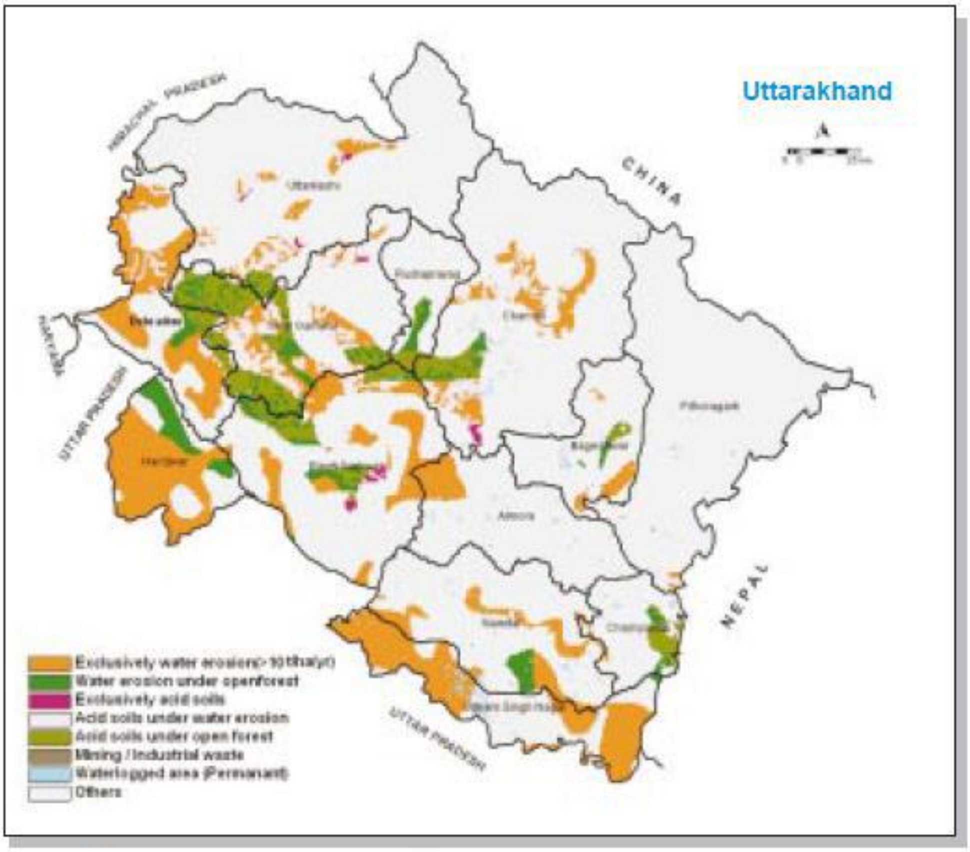

Figure 3.4 Degraded areas of Uttarakhand

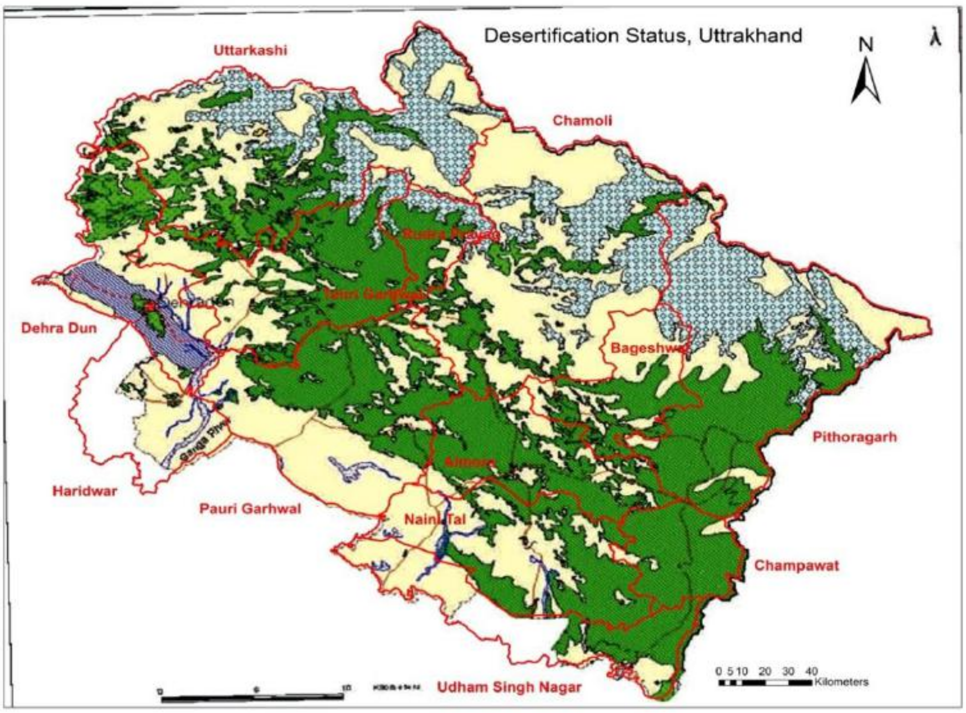

Figure 3.5 Forest degradation status of Uttarakhand including Tehri Garhwal

Source. SAC, 2007

3.2.2 Description of case study sites

Two areas were selected in Tehri Garhwal for household level surveys, travel cost surveys and GIS mapping. These included Devalsari and Dhanaulti micro watersheds. A total of nine villages were surveyed from these areas located in Thatyur block. Details of the villages surveyed and the number of households surveyed in each village are provided in Table 3.3.

Table 3.3 Details of villages sampled for the household survey

Village	Block	Panchayat	Total # of households in village	Total Population	# of households sampled
Chhanan Gaon	Thatyur	Dhanaulti	99	649	23
Dawali Mhdhe Alu Chak	Thatyur	Dhanaulti	38	263	28
Dhanaulti	Thatyur	Dhanaulti	12409	74083	17
Goth	Thatyur	Dhanaulti	23	126	7
Khaneri Madhe Batwaldhar	Thatyur	Dhanaulti	68	460	31
Lam Kande	Thatyur	Dhanaulti	59	364	21
Nakurchi	Thatyur	Dhanaulti	35	245	4
Bangsil	Thatyur	Devalsari	76	386	11
Odars	Thatyur	Devalsari	12	73	9
			410	2566	151

Dhanaulti[14] is a scenic mountainous area located close to Mussoorie (at a distance of about 24 km), a popular hill resort. Its proximity to Mussoorie, and presence of deodar, rhododendron and oak forests, mountains and pilgrimage spots has made it a popular tourist destination[15]. A recently created community managed eco-park has provided a boost to ecotourism and enhanced revenues for local communities. The 13 ha ecopark is at an altitude of 2280 m a.m.s.l. and lies between 30° 42' N, 78° 24' E (Kala, 2013). The ecopark in a single year (2011-2012 attracted 2.6 million tourists and earned revenues of Rs 3.3 million (Kala, 2013). While an eighteen member elected committee manages the eco-park as many as 25 men and women belonging to local communities are employed in the eco-park. The general body of the committee includes a number of the local business owners-hotels, tea stall, shops, restaurants and dhabas as well as about 70 mule owners. It thus ensures representation of large numbers of the local community. The committee helps in the conservation of adjoining forest areas including prevention of tree cutting, poaching of wildlife and fire prevention and have helped halve plastic waste generation. Dhanulti is also close to the Surkanda Devi temple (a distance of about 8 km), which is dedicated to the goddess Parvati.

[14] Also referred to as Dhanolti

[15] Maps of the study site are available in the section on land use and land cover change (LULC)

The forests include species of Deodar *(Cedrus deodara*), Banj Oak (*Quercus leucotricophora*), Rhododendron (*Rhododendron arboretum)* and *Pinus roxburghii* (Pine). Some of the Van Panchayats[16] upon which the villages of Dhanaulti partially depend are the Lambidhar Van Panchayat dominated by oak and deodar forests and the Kedarkhola Jangal dominated by deodar and pine.

Devalsari lies in the Aglar valley of Tehri Garhwal and is the base camp for a 10 km trek to Nag Tibba, the highest peak in the area (3048 m). It is located at a distance of about 55 km from Mussoorie and is also rich in birds and butterflies, with about 70 butterfly species recorded from the area. Tourists are now venturing to this area to bird and butterfly watch while on a very small scale, the village community are developing ecotourism facilities. We surveyed the Bangsil and Odar villages in Devalsari. The village of Odars in Devalsari depends on the Odarsu Van Panchayat which is dominated by Banj Oak (*Quercus leucotricophora*), the only oak-dominated forest within a radius of 10 km that is strictly managed by the local communities.

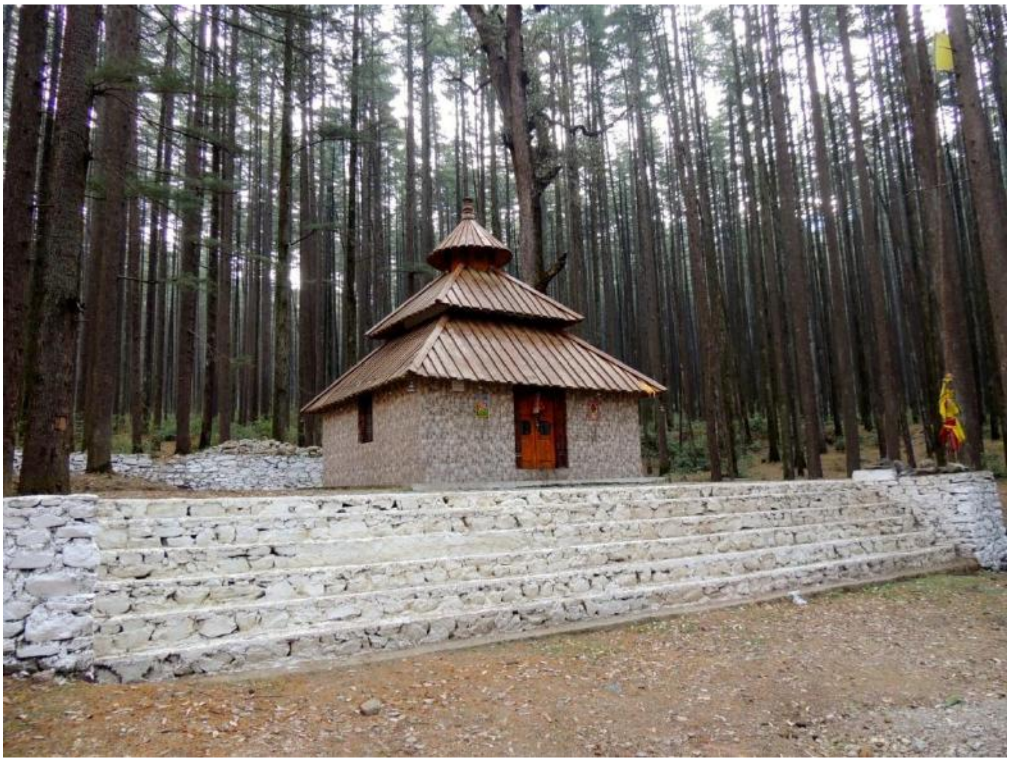

Photo 3.2 A Shiv temple set amongst a grove of deodars in Devalsari

[16] Uttarakhand forests are administratively managed as Van Panchayats, Reserve Forests and Civil-Soyam forests.

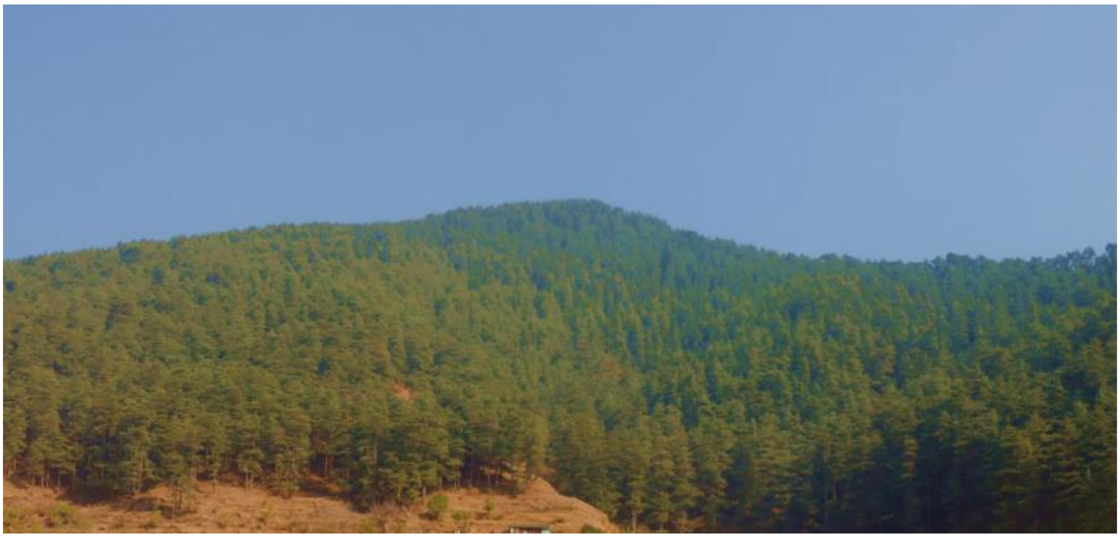

Photo 3.3 A view of the forest from Bangsil, Devalsari

3.2.3 Field surveys

The field survey was carried out in April, 2016. Three discrete surveys were conducted at the study sites. The first survey was a household-level analysis to understand the dependency of local communities on their forest resources. A total of 151 household heads were surveyed using a detailed, structured questionnaire provided in Appendix 3.1. At the household level, household heads or any adult member were interviewed in order to gather information. The household questionnaire consisted of questions seeking information on various aspects relating to forest-based livelihoods. These included: (i) social and demographic profile of the household, (ii) livelihood sources and assets of the household, (iii) access to and dependence on forests and (iv) people's perceptions of forest status and degradation.

Additionally, 150 local households were asked to provide their perceptions on the value of the forests which were captured using an Analytic Hierarchy Process. Details of this questionnaire are in Appendix 3.2. A travel cost assessment of 157 tourists to Dhanaulti was carried out to determine the recreation value provided by the forests of this area. This included questions relating to travel costs incurred, expenditure on various activities, preferred recreational activities, socio-economic questions and attributes of the area that they valued the most. The questionnaire is appended in 3.1

To support the quantitative data collected, informal discussions and focus group discussions were carried out with the local communities, as well as with other stakeholders such as the forest department, collectors of Non-Timber Forest Produce (NTFPs) and community elders.

Photo 3.4 A group discussion in progress

3.2.4 Data analysis

The different data analysis methods are listed below. The relationship between each component of the valuation exercise is explained in Fig. 3.6.

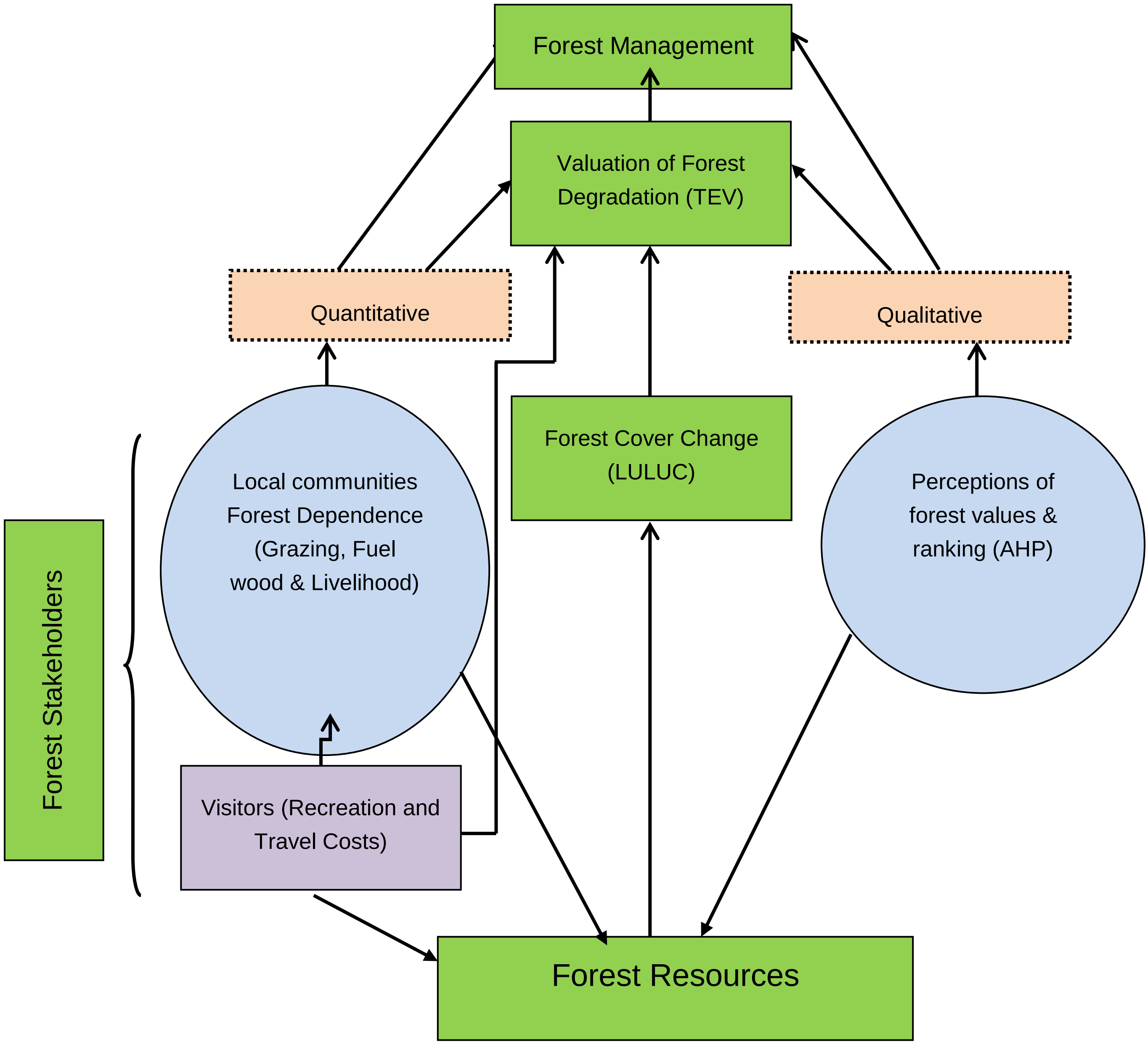

Fig 3.6. Framework of data analysis methods

Analytic Hierarchy Process to assess stakeholder perceptions' on forests

Perceptions of stakeholders on the values of the forests that can help plan appropriate management approaches for the area were captured using an Analytic Hierarchy Process (AHP), which was developed by Saaty (1977, 1980).

According to Hadipur *et al.* (2015), Multi Criteria Decision Making (MCDM) is a procedure that consists in finding the best alternative among a set of feasible alternatives. The AHP method which was first proposed by Saaty (2008) is mostly for solving MCDM problems. It is one of the most widely used MCDM (Lee et al., 2008).

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. This process is particularly useful in group decision making (Saaty and Peniwati 2008). More recently, the AHP has been applied in multi-objective forest management and land-use planning due to its flexibility and effectiveness in analyzing complex decision-making problems (Schmoldt et al 2001; Vacik and Lexer, 2001; Dhar et al., 2008). This interactive method allows stakeholders to express their preferences and thus contribute to decision making and planning (Proctor, 2000; Wolfslehner et al., 2005).

Fundamentally, the AHP works by developing priorities for alternatives and the criteria used to judge the alternatives. These priorities are derived based on pairwise assessments using stakeholder judgment. The software DEFINITE has been used for this exercise. Jansen (1994) provides details of the technique used for this exercise.

Data relating to household-level questionnaires were analysed using SPSS (SPSS Inc.).

Travel Cost Methodology

Two approaches can be used in a travel cost study, one is a zonal travel cost and the second is the individual travel cost. In the context of our case study of Uttrakhand we prefer the Individual Travel Cost Method (ITCM) which is appropriate for sites with high individual visitation rates. Other than that, ITCM has distinct advantages over ZTCM since it accounts for the inherent variation in the data, and can be estimated using a smaller number of observations. Furthermore, ITCM is more flexible and can be applied to a wide range of sites (Khan, 2004) while eliciting relevant information on visitors' characteristics, preferences and behaviour. However, the application of the correct TCM depends on the identification of the dependent variable. Generally, Ordinary Least Squared (OLS) estimation is used to estimate the parameters of the recreational demand equation though truncated count data models in single-site recreational demand models are increasingly being used (Creel and Loomis, 1990; Hellerstein, 1991; Englin and Shonkwiler, 1995; Shrestha et al. 2002; Martinez-Espineira and Amoako-Tuffour, 2005). For this study, we used OLS.

To formulate the travel cost function, we follow Mariwala et al. (2010) and assume that the individual's utility depends on the total number of visits to the site, the quality of the site, and a bundle of other goods.

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We represent the utility maximizing problem of the consumer as:

$$\text{Max } U (X, r, q) \qquad (1)$$

where,

U: utility function of the consumer/ household,

X: bundle of other commodities,

r: number of visits to the site yearly,

subject to two budget constraints (money and time):

$$M + P_w t_w = X + cr \qquad (2)$$

$$t^* = t_w + (t_1 + t_2) r \qquad (3)$$

where

q: an index of quality of the site

M: exogenous income or non-wage income,

p_w: wage rate,

tw: hours of work,

c: monetary cost of a trip,

t*: total discretionary time,

t_1: round-trip travel time, and

t_2: time spent at the site.

Here, equation (2) is the income constraint and equation (3) is the time constraint.

The number of visits will be an increasing function of the site's environmental quality. The time constraint reflects the fact that both travel to the site and time spent on the site take time away from other activities. Thus there is an opportunity cost to the time spent in the recreation activity which is the wage rate.

The full price of the visit is p_r includes the monetary cost of travel to the site, the time cost of travel and the cost of time spent at the site, i.e.,

$p_r = c + p_w (t_1+t_2)$…..(4)

Substituting (3) and (4) in the income constraint (equation 2) we obtain

$M + P_w .t^* = X + p_r.r$………(5)

Maximizing equation (1) subject to the constraint of equation (5) will yield the individual's demand functions for visits:

$r = r (p_r, M, q)$ . . . . (6)

The data on rates of visitation, travel costs, can be used to estimate the coefficient on p_r in a travel cost-visitation function.

The economic valuation of a recreational site involves the estimation of the demand for recreation and calculation of the associated consumer surplus, i.e., the area under the demand curve.

Factors that Determine Recreational Demand

In the ITCM, the number of trips also depends on demographic variables; the most important variables include travel cost, travel time, substitute sites, and site quality

Demographic variables such as age, sex, education, income, employment status also affect recreational demand. Age might be an important determinant of visitation rate-for example younger people might prefer trekking and adventure sports or older people might prefer its scenic value or its biodiversity potential. Sex may be another determinant-with more men or more women visiting for various reasons. With regard to education, people with higher education are likely to appreciate the recreational benefits more (for example in terms of biodiversity value or forest quality). Household income has also been found to correlate positively with participation in outdoor recreation activities. Similarly, better-quality recreational facilities available in the area may attract more tourists to that particular site. In our study, we have included these explanatory variables in the regression analysis. Details are provided in the results.

Value of Consumer Surplus

From the linear functional form of the travel cost model, the consumer surplus is estimated as

CS = $r^2 / -2\beta_1$ where

CS: Consumer surplus

B_1: Curve of the demand function (cost coefficient).

Estimating the present value

The present value benefitsis estimated following Mariwala *et al*. (2010) as;

PVB= $CS/(1+V) + CS/(1+V)^2 + ... + CS/(1+V^n)$

Which is the yearly recreational benefit from Uttarakhand. Assuming a constant annual benefit, this simplifies to:

Present Value Benefits (PVB) = CS / v,

Where v is the discount rate[17].

3.2.5 Land Use and Land Use Change in Dhanaulti and Devalsari

Changes in land use and land cover in the study areas were mapped for three time periods. For this study, Landsat 5 Thematic Mapper (TM) imagery has been used for the year 1989; Landsat 7 Enhanced Thematic Mapper Plus (ETM+) imagery has been used for 2001 and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) imagery has been used for 2015 (Table 3.4). This imagery was used for the preparation of Landuse and landcover (LULC) maps for the Dhanaulti and Devalsari micro watersheds (MWS) of Uttarakhand. The LULC classification has been carried out using a supervised classification technique wherein a maximum likelihood classification algorithm is used for differentiating between various classes based on the spectral signature of various pixels in the image. As a result, five major classes have been identified for this study viz. forest, agriculture, wasteland and water/ sedimentation. In addition, for forests, two density classes have been identified; open and dense forests

Table 3.4 Data used for a LULC classification of two micro watersheds

Satellite	Acquisition date	Path/row
Landsat 5 Thematic Mapper (TM)	05-12-1989	146/ 39
Landsat 7 Enhanced Thematic Mapper Plus (ETM+)	30-12-2001	146/ 39

[17] The series is added to infinity

Satellite	Acquisition date	Path/row
Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	11-11-2015	146/ 39

3.2.6 Calculation of the costs of forest degradation in the area

In order to estimate the costs of forest degradation (shift from a higher forest density class to a lower value), we adapt the Millennium Ecosystem Assessment (MEA, 2005) definition of land degradation to the forestry context in India, and then apply the Total Economic Value (TEV) approach to determine the value of forest degradation (see Nkonya et al. 2016). The following steps were followed:

$$CF_{CD} = \sum_{i,j} a_{i,j}\{F_{jT} - F_{jO}\}$$

Where

- CF_{CD} is the cost of forest degradation due to change in forest density class during periods T (2015) and O (2001)
- a_{ij}= NPV of the attribute/ ecological service i in forest density class j, where i,=1,…10 and j = 1,2 (open, dense)
- F_{jT} is the area under forests of type j in the two time periods considered, T (2015) and O (2001)

For an estimation CF from 2001-2015, we used the figures generated by the primary survey for fodder and fuelwood dependence as well for recreation. Other benefits (timber, NTFP, bamboo, carbon sequestration, soil conservation, water recharge, pollination and seed dispersal) were estimated from Verma et al. (2014) for two categories of forests found in the study areas namely, Montane & Moist Temperate Forest and Subtropical Pine/ Broadleaved Hill Forests and for two categories of forest (dense and open). The estimated values were adjusted for double counting and simultaneous delivery of ecosystem services as suggested by Verma et al. (2013) and the values were averaged for very dense and moderately dense forests to arrive at a value for dense forests. As mentioned in the previous section, the change in forest cover under various density classes (dense and open) was estimated through a remote sensing exercise. Prices were adjusted to 2013-2014 to ensure consistency with the macro-economic study.

3.3 Results

3.3.1 Demographic and socio-economic profile

Respondents' demographics

Most of the respondents were male (83%) and young (i.e. 51% fell in the age group of 21-40 years). As many as 39% of the respondents were in the age group 41 to 60 years while slightly more than 9% were in the oldest age group of 61-80 years and only 1 respondent was under 20 years. Scheduled Castes (18%) and other backward castes (OBC) (40%) formed the majority while the general caste accounted for 42% of the respondents.

Sampled households

The demographic and socio-economic profile of the study villages is discussed in this section. Females constitute 46% of the total population. The literacy rate for the entire population is 75%. A higher percentage of all males are literate (85%) while 63% of all females are literate. The age-wise distribution of gender and literacy is presented in Table 3.5. The most literate population, not surprisingly is amongst those in the age group of 11 to 18 years, the school going population. The sex ratio is highly skewed which starts from birth; for example in the age group under 5 years, girl children comprise only 42% of the population while male children outnumber them at 58%. This skewed situation continues till the age of 61 years, when the percentage of men and women equalises, probably because women tend to have longer life expectancy. Literacy is high amongst women till the age of 31 after which it dips. This is probably attributable to enhanced efforts to promote literacy for women in Uttarakhand in recent years. The older generation of women, however, did not reap its benefits.

Table 3.5 Demographic profile of sample households

Age group (in years)	Percentage of population	Gender		Literacy	
		Percentage of males	Percentage of females	Percentage literate males	Percentage of literate females
< 5	7%	58%	42%	NA	NA
6 - 10	12%	53%	47%	100%	95%
11-18	23%	53%	47%	97%	100%
19- 30	21%	55%	45%	95%	77%
31- 45	25%	54%	46%	90%	51%
46 -60	8%	58%	42%	76%	29%
>61	3%	50%	50%	46%	15%
Total	100%	54%	46%	85%	68%

The entire population of the sampled villages were Hindu although Scheduled Castes (SC) and Other Backward Classes (OBC) comprise the majority of the population (58%) (Fig 3.7).

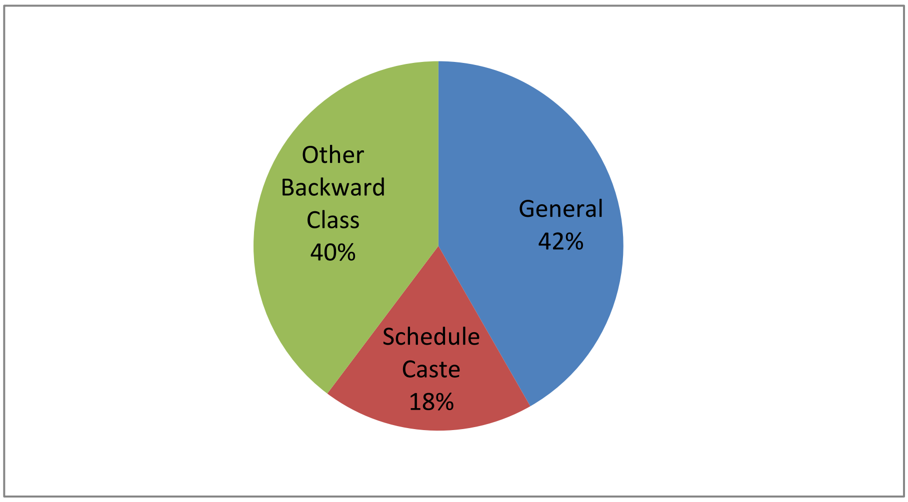

Figure 3.7 Caste composition of the sampled households (in % of households)

The primary occupation profile of the respondents is provided in Fig 3.8. While domestic work carried out by women is the primary occupation listed, this is followed by farming. Eight percent of the population is involved in the sale and collections of NTFPs, indicating that forests are not only a source of subsistence but also provide livelihood benefits.

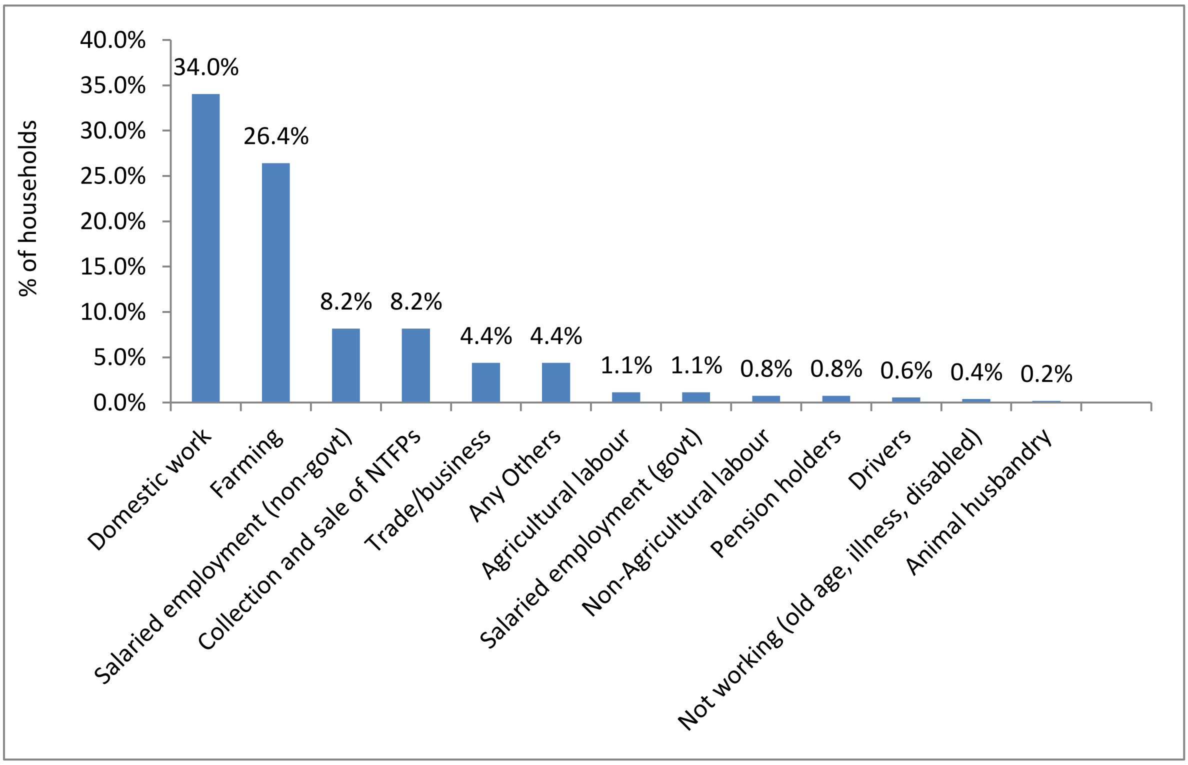

Figure 3.8 Occupation profile of the sampled households

Land is an important economic and social asset in rural societies and ownership patterns reflect the socio-economic profile of the community. Land is not only the source of food for rural households but also plays an important role in enabling access to credit, enhances social status and so on. The average land holding in Uttarakhand is low at 0. 9 ha, putting most people in the category of marginal farmers. In our sample too, 95% of households comprised landless (22%) or marginal farmers (less than 1 ha of land owned) (73.5%). A small percentage (5%) own more than 1 ha (Fig 3.9). Given the landless or marginal nature of farms owned by most of the people of our sample villages, their dependence on biomass and forests for fuel sources and for other sources of livelihood is likely to be high. While 78% of households sampled owned land, farming was the primary occupation for only 26% of the total population.

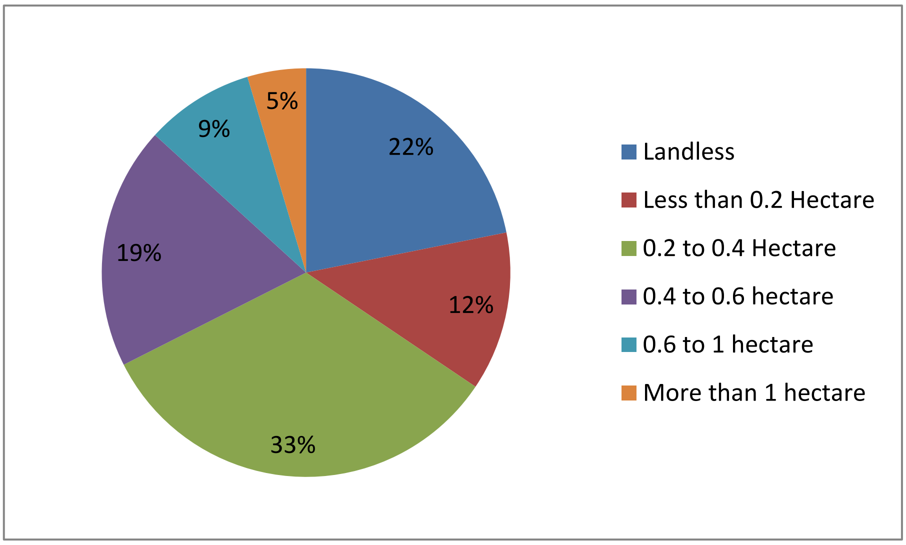

Figure 3.9 Ownership of agricultural land by sample households (in % of households)

Migration to cities for work was relatively high in the sampled population which is also typical of the State as a whole. As many as 34 % of sampled households had one or more migrant member in each household. Of these 46 households, more than 41.3% had members who were employed in the unskilled sector (Fig 3.10) while 32% were employed in the service sector and 4% owned their own businesses. Most of the migrant population included adults over the age of 30 (76 %). While most migrated to other districts in Uttarakhand (46% of the migrant population), 39% migrated outside the State and only 15% migrated within the same district).

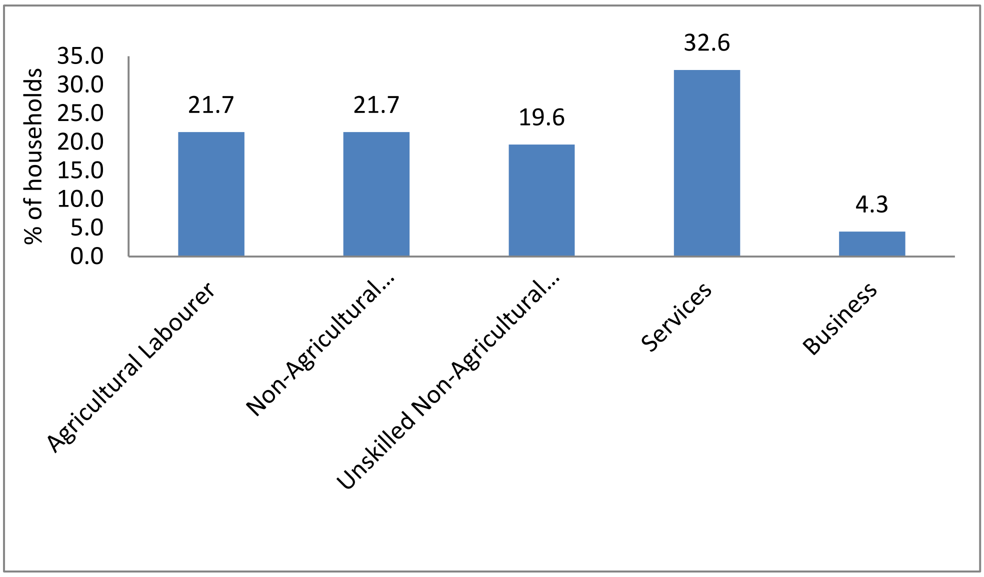

Figure 3.6 Distribution of occupations amongst migrant members of each household (in % of household)

Fragmentation of land holdings and resultant reduced farm sizes was the most frequent reason for outmigration (32.5%) with decreased land productivity and the need for additional incomes tying as the next most important categories (24.7% each). Decreasing wage opportunities accounted for 15.6% of the out-migration (Fig 3.11).

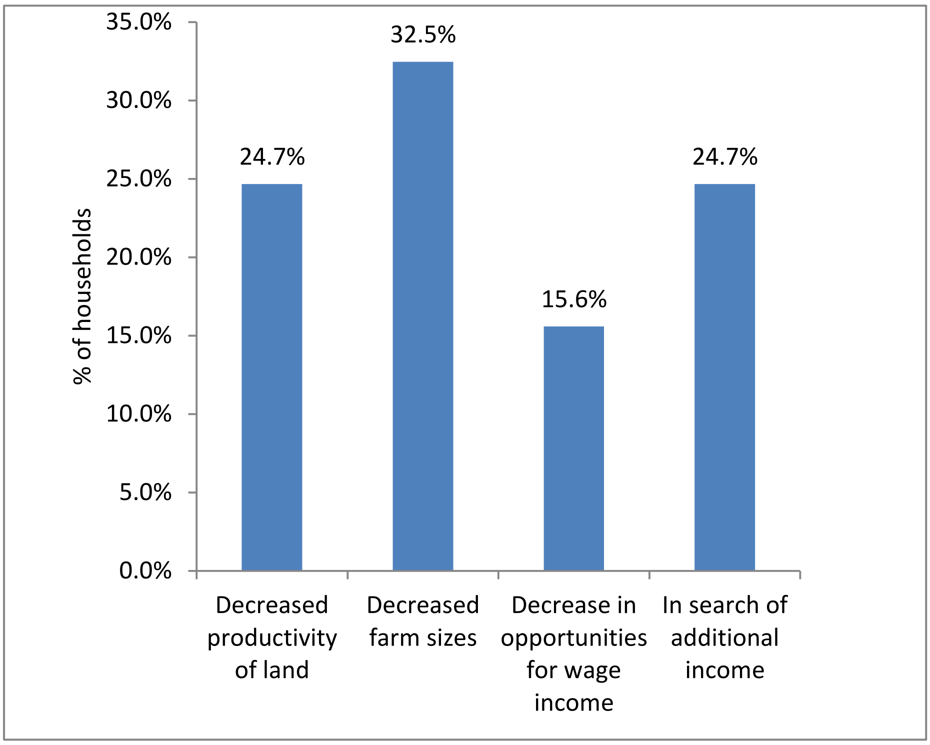

Figure 3.7 Reasons for out-migration (in % of households)

At least 37% of households own livestock. Amongst those that do, only 20% of households rear sheep and 5% own goats while as many as 32% own mules. The ownership pattern of bovines is in Table 3.6. The ownership pattern of mules which are used to ferry tourists, is a possible indication that some of the households are involved in tourism. Of the households owning livestock, stall feeding is predominant (96% of households) (that is fodder is cut from the forests) for bovines but all the goats are left to graze while a larger percentage of sheep also graze in the forest. Figures for open grazing are lower at 50% of households who own livestock. Forty one percent of households both graze their cattle in the forest and collect fodder from the forest.

Table 3.6 Patterns of livestock ownership and their forage patterns

Type of livestock	% of HH that own livestock	% of total households	% carrying out stall feeding	% carrying out open grazing and stall feeding
Cows	34%	13%	79%	21%
Bullocks	20%	7%	45%	45%
Buffaloes	36%	13%	65%	35%

Type of livestock	% of HH that own livestock	% of total households	% carrying out stall feeding	% carrying out open grazing and stall feeding
Calves	27%	10%	87%	13%
Sheep	20%	7%	27%	73%
Goats	5%	2%	0%	100%
Mules	32%	12%	28%	72%

Each household (amongst those who own and graze their livestock) on average graze their livestock for an average of 5.44 days±0.35 (SE), while fodder collection for each household is an average of 47kg ±11.5 (SE) per day. In terms of fodder availability, grass and tree fodder (from the forest) is collected by 44.3% of the households who own livestock, while agricultural residues are used by 30% of the households and commercial fodder by 25.6% of households. The total fodder utilisation in these villages from open grazing and stall feeding is 533, 96,617.88 kg. Therefore, the total green fodder in kg/ ha is 4512 which converts to 1128 kg/ ha of dry fodder. Assuming a price of Rs 5 per kg of dry fodder this provides a value of Rs 5640 per ha. We have utilised this figure to arrive at a value for fodder for the valuation of forest loss from 2001-2015.

Most of the houses are electrified (87.4%), self-owned (99%) and permanent (pucca) (39.1%) or partially pucca (52%), and 94% of all households own a ration card while the majority (78%) have a MNREGA card entitling them to one hundred days of employment a year.

3.3.3 Dependence on forests

In terms of jurisdiction, the forests of Uttarakhand are classified as Reserve Forest (RF), Civil-soyam forest and Van Panchayats (VPs). The state forest department has exclusive control over Reserve Forests, the Civil-soyam forests fall under the jurisdiction of the revenue authorities of the state while Van panchayat forests are under operational control of local communities. In general the vegetation status of Van Panchayats and Reserve Forests are better than Civil-soyam forests. In our study sample, all the households had access to the Reserve Forest, 81.5% had access to Van Panchayats while only 51% of the households had access to Civil-soyam lands (Fig 3.12). Correspondingly similar trends are visible in terms of ranks in which these forests are accessed and this may be partially attributed to distance of these villages from these forests which range from an average of 2.3 km for RFs, 3.02 for VPs and 4.11 for civil-soyam forests (Fig 3.13). Another reason for reduced access to the Van Panchyats could be because of management restrictions imposed by the local communities themselves on their locally managed VPs.

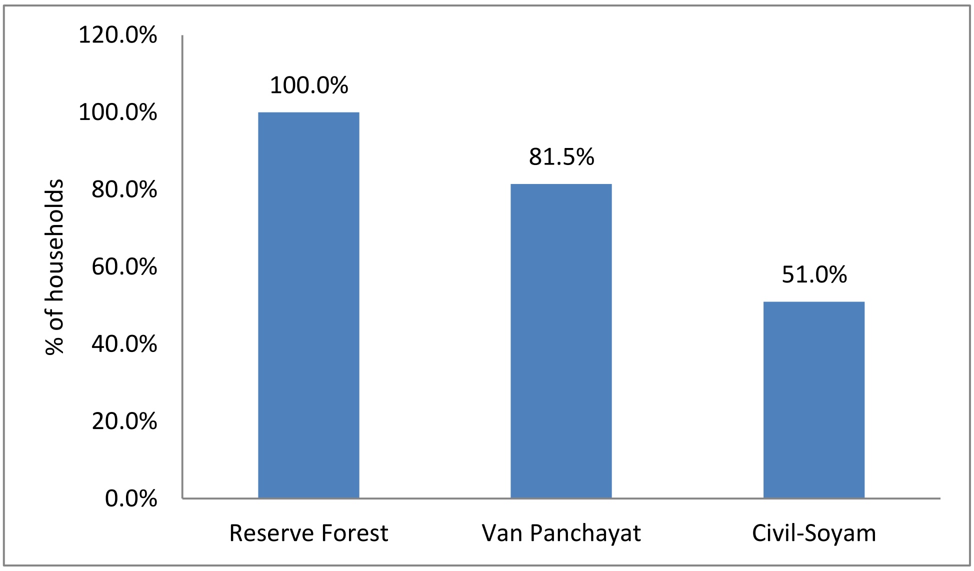

Figure 3.8 Percentage of households with access to different types of forests

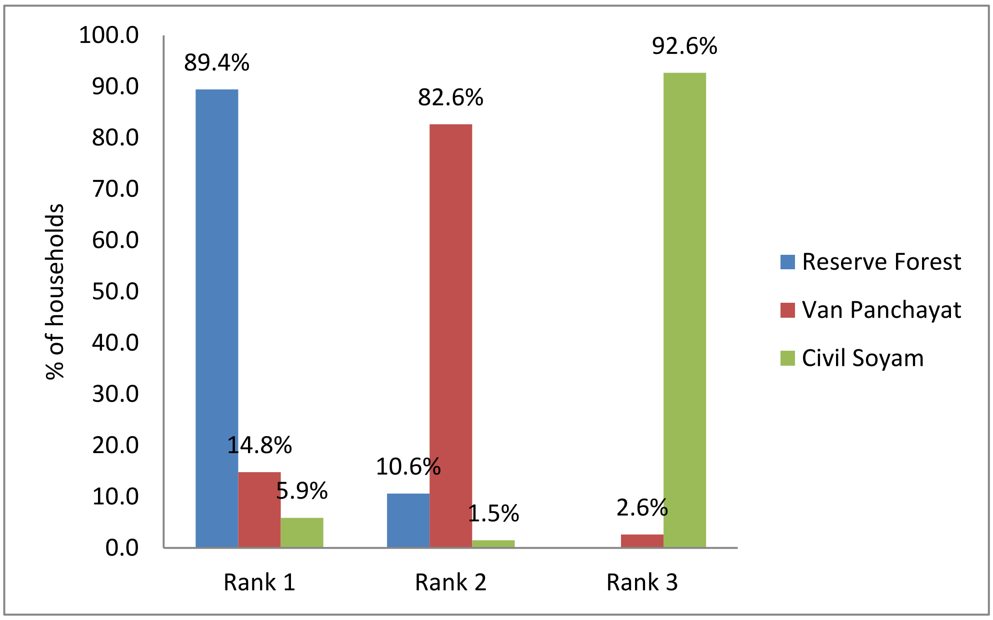

Figure 3.9 Percentage frequency at which the different categories of forest are accessed

The most commonly cited reason for accessing the forests was collection of fuelwood (100% of respondents), while 95% and 75% mentioned collection of small timber and NTFPs from the forest (Fig 3.14). Collection of fodder cited by 42% of households or grazing of animals (28%) is another important activity. The figures strongly indicate that local communities are entirely dependent on the forests for their subsistence and possibly their livelihood needs. Their perception of the forests is very utilitarian in nature; tourism and recreation which are largely leisure activities were the least cited reasons for accessing the forests.

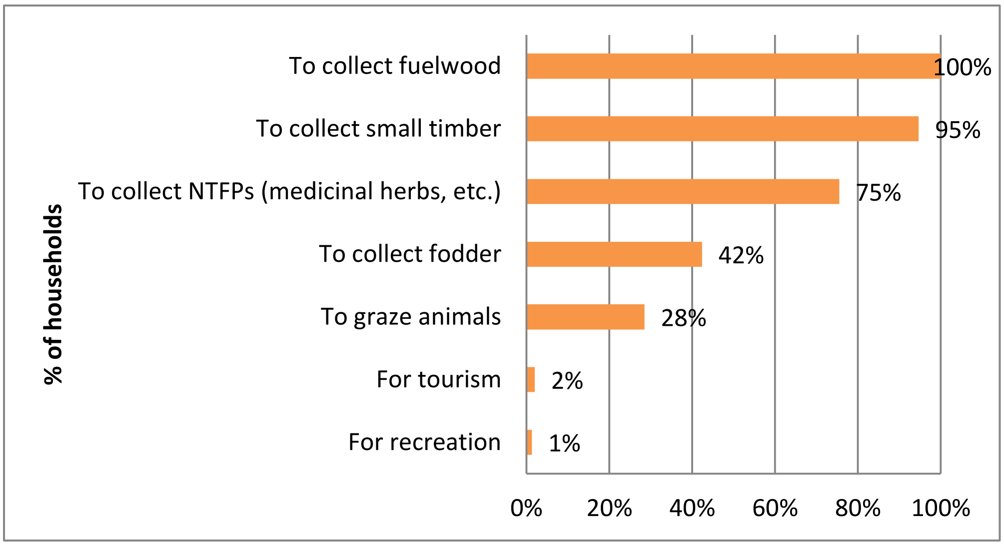

Figure 3.10 Percentage-wise distribution of causal reasons for forest access[18]

Most of the households (87%) are dependent on fuelwood as their primary fuel source while only 32.5% use LPG. A large percentage of households are also dependent on low-grade biomass sources such as dry leaves (74.8%), agricultural residue (32.5%) or dung cakes (6%) (Fig 3.15) signifying a predominantly biomass-based fuel economy.

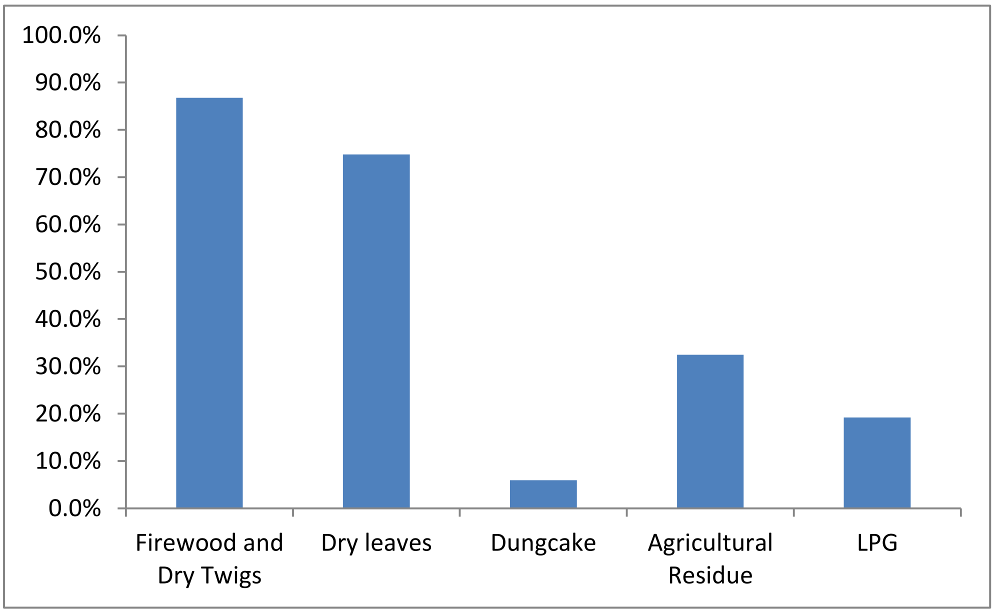

Figure 3.11 Percentage of households dependent on various fuel sources[19]

While fuelwood is an important fuel source for all the households surveyed, in terms of sources of collection, all the households collected firewood from the Reserve Forest, while 35% collected firewood from Van Panchayats and only 4% collected fuelwood from Civil-soyam forests. Village trees and private sources also provided firewood to 18% and 3% of

[18] Multiple responses were possible for this question

[19] Multiple responses were possible in this question

households surveyed respectively, accounting for a much lower percentage of total fuelwood collection. Forests were indisputably the main source of firewood (Fig 3.16) with the most pressure imposed on Reserve Forests. The households collect an average of 1500±130.63 (SE) kg of fuelwood per household per year. This figure appears to be fairly conservative. According to the 68th round of NSSO (National Sample Survey Organization consumer expenditure), in 2011/ 12, the average monthly per household consumption of firewood for Uttarakhand was estimated at 260.71 kg in rural areas and 204.1 kg in urban areas (NSSO, 68th round, 2012), This translates into roughly 3132 kg per household per year for Uttarakhand. However, of this NSSO figure it is not clear how much is collected from forests and how much from other sources. Our figures translate to 14480 tonnes of annual fuelwood collection in all the villages sampled[20]. This translates into fuelwood usage of 1223.46 kg per ha or 1.69 cum/ ha. Using a price of fuelwood of Rs 849 per cum the value of fuelwood per ha is estimated at Rs 1433.

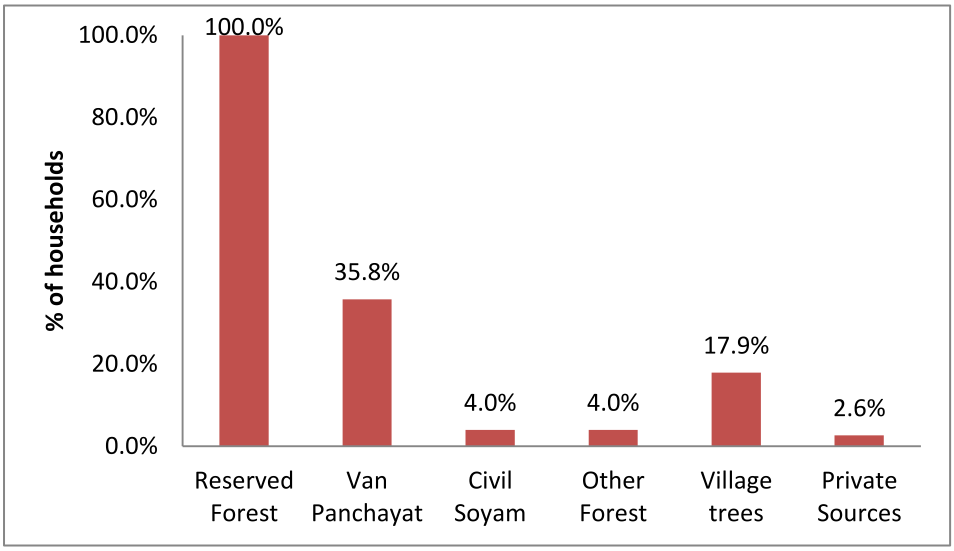

Figure 3.12 Percentage of households collecting firewood from various sources

On average, each household collects firewood 2.6 ±2.3 (SD) times a week with an average quantity of 35.2 kg ± 30 (SD) collected every week. On average it takes 3.4 ±1.4 (SD) hours per visit. Each household sends 1-2 members for fuelwood collection. Greenwood accounts for an average of 14.31% of the total fuelwood collection (14.31 ±6.6 (SD)).Amongst NTFPs collected from the forest, wild vegetables and fruits accounted for the majority of forest products (Fig 3.17).

[20] This is calculated based on population figures of the villages sampled from the 2011 census.

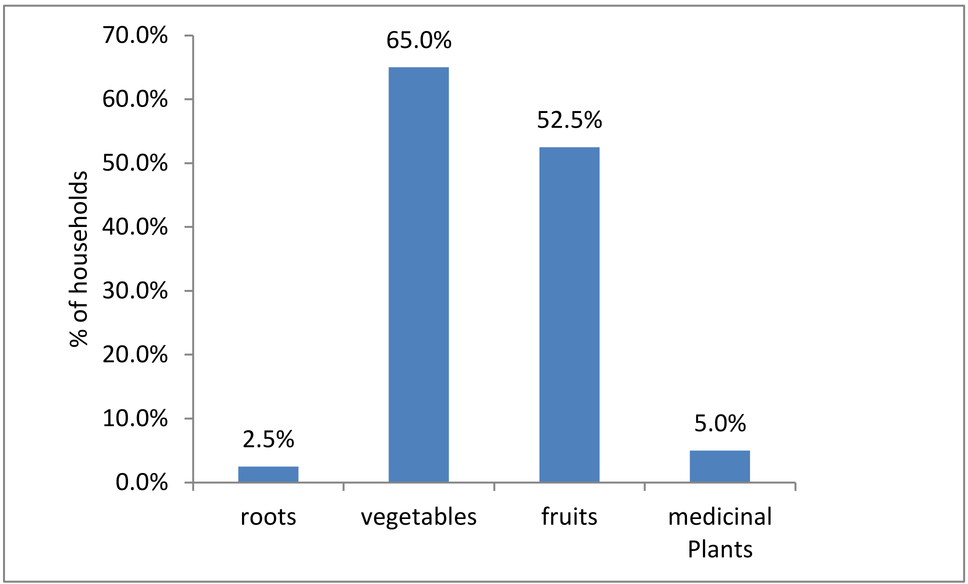

Figure 3.13 Products collected from the forest (in percentage of households)

3.3.4 Perceptions of forest status and its impacts

Sixty two percent of the households surveyed found that forest quality had decreased in the last decade. In terms of availability of fuelwood, 33% felt it had decreased while 46% felt it had remained the same and 21% felt it had increased. Reasons for the decrease in availability were attributed to increased degradation (the majority at 72%), the need to walk increasing distances (20%), and the increase in hours taken to collect fuelwood (8%). Interestingly, the minority who reported an increase in fuelwood attributed this to prohibition of use by the forest department (84%) in reserve forests and community-imposed bans (16%) in Van Panchayats, indicating that efforts to protect the forest appeared to have an impact on forest status. However, remote sensing maps of land use change point to decreasing forest cover. Only 20% felt that timber had decreased in the last decade while the majority 61% felt it had remained the same. This is consistent with studies of the forests of Uttarakhand cited earlier (e.g. Baland et al. (2006) which indicate decreases in forest quality rather than in tree stock density. Similar reasons as for fuelwood were given for increases and decreases in availability of timber. In terms of forest products collected, of the 41% who responded, 13% found their availability had decreased while the majority felt it had remained the same (25%). For fodder, of the 50% of people who responded, 14% felt it had decreased while 33% felt it had remained the same. Decreases in availability of fodder were squarely blamed on the prohibition bans of the forest department (100% of respondents who felt it had decreased).These indicators suggest a decline in forest status and increased hardship in forest product collection for some, but not all the sampled houses, perhaps related to the accessibility of different types of forest (RF, VP or civil-soyam).

About 50% felt the decrease in vegetation had negatively impacted agricultural productivity while 24% felt that soil erosion had also increased due to forest degradation and 33% felt that deteriorating forest status had impacted the quantum and 26% the distribution of rainfall in the area. As many as 38% of the households felt that vegetation decline had impacted the number of rainy days in the area. About 30% of respondents indicated that increases in summer temperatures were attributable to forest degradation. The respondents also reported an effect on water-as many as 33% of respondents felt that the availability of drinking water had decreased while 19% of respondents perceived a reduction in quality of water.

Interestingly as many as 56% of the respondents, felt that decreasing vegetation status had enhanced the migration rate while 47% felt that decreasing vegetation status had necessitated their looking for non-farm work. The response of the local community to these changes in livelihood systems relates to their coping and adaptation capacity. Short-term actions are termed as coping strategies whereas longer term actions are called adaptation (Osbahr et al, 2008). Both the coping and adaptation responses vary among the individuals within a community and are influenced by a host of factors affecting their livelihood system. What is evident in our study villages is that local communities are adjusting to vegetation degradation. In an area where land fragmentation is high and most people are marginal farmers or landless, people are highly dependent on forests. Decreasing forest status impacts agricultural productivity as well as their access to forest products for subsistence or sale. This in turn forces shifts to non-farm sources of income or out-migration.

3.3.5 Impact of tourism

A significant proportion of the sampled households (44%) benefitted from ecotourism while as many as 48% of households wanted tourism to be developed as the primary activity in the area. Eighty percent of households that felt the need to boost ecotourism cited low incomes derived from agriculture and migration as the primary rationale for this. Interestingly, many respondents viewed ecotourism as a means to protect the forest (51%) and reduce dependence on them (49%) (Fig. 3.18). They evidently view ecotourism as being less detrimental to forest management.

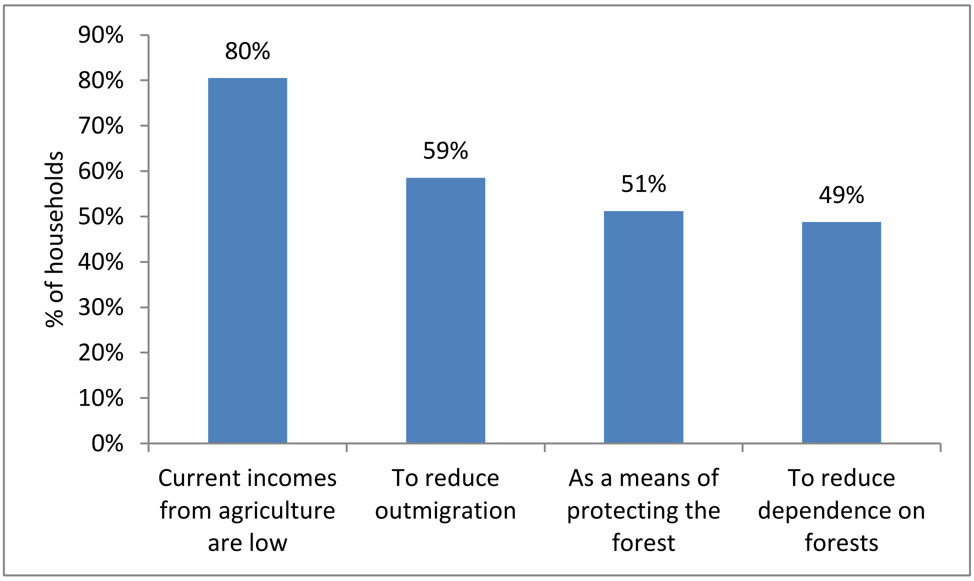

Figure 3.14 Reasons cited for strengthening ecotourism in the area

Photo 3.5 Community-based ecotourism hut in Devalsari

Photo 3.6 A quaint forest resthouse in Devalsari

3.3.6 Perceptions and ranking of forest value by community stakeholders

Perceptions of ecosystem services derived from forests

The village community was asked for their relative ranking of five different services provided by the forests and their perceptions of relative importance. We used AHP to arrive at the rankings. Interestingly, the people ranked biodiversity the highest, perhaps realising its importance for tourism as also in providing ecosystem services and ensuring forest resilience. Ecotourism ranked the second highest given that Dhanaulti is a popular tourist destination and Devalsari is slowly developing its tourism potential. Given the enormous dependence on forests for their livelihood needs, this was ranked next followed by forest products (e.g. NTFPs) and then grazing.

Table 3.7 Perceptions of ecosystem services provided by the forests[21]

Criteria	Final weights	Rank		
Biodiversity	0.246	1		
Grazing	0.144	5	Consistency Index (CI)	-0.179
Ecotourism	0.262	2	Random consistency Index (RI)	1.12
Livelihood	0.191	3	Consistency Ratio (CR)*	-0.161
Forest Products	0.158	4		

*Only abbreviations are used in subsequent tables

Importance of forest products

The local communities are dependent on a wide range of forest products. When asked to rank the value of forest products derived from the forests, fuelwood was ranked the highest (Table 3.8). This is not surprising given the almost complete dependence on forests for fuelwood and since it is the dominant forest product collected by households. Timber was ranked second, followed by fodder, medicinal plants, and then wild food. Timber is a high value product in terms of its market value and the high revenues it fetches. In general the ranking of forest products indicates the extent to which local communities are dependent on, and hence value these forest resources.

Table 3.8 Ranking of forest products

Scenario	Final weights	Rank		
Fuel-wood	0.281	1	CI	-.01
Fodder	0.206	3	RI	1.12
Timber	0.208	2	CR	.00
Medicinal Plant	0.161	4		
Wild food	0.144	5		

[21] Detailed tables are provided in Appendix

Benefits accrued from forest conservation

For the benefits accruing from forest conservation, the people rated additional sources of income and employment, increased availability of forest produce, increased availability of clean air, increased availability of water and wildlife, in that order. Again the utilitarian view for protecting forests- as sources of important subsistence and livelihood needs dominated the perception rankings. Increase in wildlife is valued the least, possibly because of human-animal conflicts resulting from population increases in species like wildboar or nilgai that damage agricultural crops.

Table 3.9 Benefits accrued from forest conservation

Criteria	Final weights	Rank		
Additional source of income and employment	0.253	1		
Increased availability of clean air	0.191	3	CI	-0.15
Increased availability of forest produce	0.243	2	RI	1.12
Increased availability of water	0.168	4	CR	-0.13
Increased availability of wildlife	0.145	5		

Ranking of various types of forests in terms of forest management and conservation

The highest score was given to Reserve Forests, possibly because they are the well-conserved in the area, while Van Panchayats are ranked second. Civil-soyam forests, that in general are highly degraded and poorly managed, ranked last.

Table 3.10 Ranking of forest management regimes with regard to their existing strategies

Criteria	Final weights	Rank		
Van Panchayat	0.35	2	CI	0.002
Reserve Forest	0.43	1	RI	0.58
Civil Soyam	0.22	3	CR	0.003

Impact of forest management regime on availability of forest products

The perceptions of people in terms of which forest management regime resulted in the highest collection of forest products were determined. Reserve forests ranked the highest followed by Van Panchayats and then Civil-Soyam forests. This could be due to two reasons a) Parts of Van Panchayats are often closed to community-usage and hence forest product collection is restricted while RFs are easier to access and/ or Reserve Forests are better managed by the forest department, are less degraded and hence provide more forest products.

Table 3.11 Ranking forest management authorities in regard to access to forest products collection

Criteria	Final weights	Rank		
Van Panchayat	0.34	2	CI	0.0012
Reserve forest	0.43	1	RI	0.58
Civil Soyam	0.23	3	CR	0.002

The current study is the first application of AHP to forest management in Uttarakhand. Many of the perceptions are intuitive since the local communities lives are closely linked to the status of their forests. The results also suggest that apart from forest products, their importance also lies in their biodiversity and ecotourism value. These perceptions underline the need to support ecotourism as an important activity and expand its reach-for example to Devalsari, which currently witnesses limited tourism. This AHP perception ranking can play an important role in forest management, and can be used to involve local communities in the decision-making process.

3.3.7 Land Use and Land Use Change

The LULC data for Dhanaulti, an important tourism spot of Tehri Garhwal indicates that the largest declines in dense forest cover occurred between 1989 to 2015 (Fig 3.19, Table 3.12). Following creation of Uttarakhand in 2000, large decreases in dense forest continued to occur-a decrease of 1414.53 ha. Correspondingly open forests increased following Uttarakhand formation, due to conversion from dense to open forests. Wastelands have also increased by 236.25 ha from 1989-2015 and 16.56 ha between 2001 and 2015. Habitation increased marginally between 2001-2015 by 12.96 ha. However, agriculture has increased substantially suggesting that some forest cover has been diverted to agriculture in the same time period (448.83 ha).

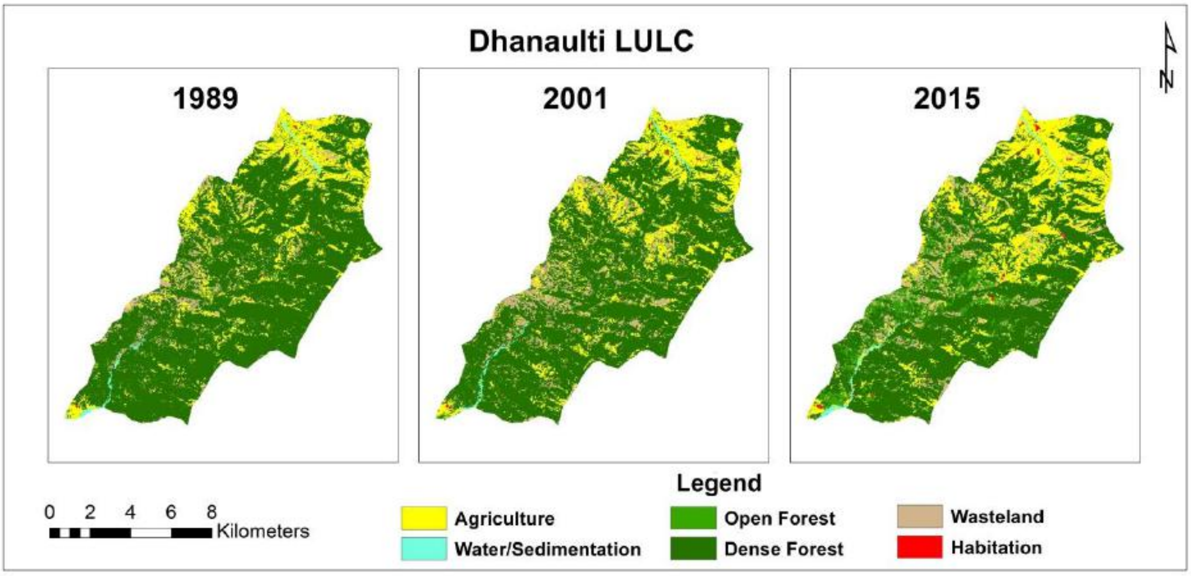

Figure 3.19 Maps indicating land use and land cover (LULC) in 1989, 2001 and 2015 in Dhanaulti MWS, Tehri Garhwal

Table 3.12 Land use and land cover (LULC) for 3 time periods-1989, 2001 and 2015 in Dhanaulti MWS, Tehri Garhwal

Land use (in ha)	1989	2001	2015	Change 2001 to 1989	Change 2001 to 2015	Change 1989 to 2001
	(in ha)	(in ha)	(In ha)			
Agriculture	1801.71	2088.36	2537.19	286.65	448.83	735.48
Dense Forest	8794.17	8262.99	6848.46	-531.18	-1414.53	-1945.71
Open Forest	187.47	196.38	1130.58	8.91	934.2	943.11
Water/ Sedimentation	80.37	85.32	87.3	4.95	1.98	6.93
Wasteland	809.73	1029.42	1045.98	219.69	16.56	236.25
Habitation	15.03	26.01	38.97	10.98	12.96	23.94
Total	11688.48	11688.48	11688.48			

The LULC data for Devalsari indicates a steep decline in dense forest cover from 1989 to 2001 but a slight increase between 2001-2015 (Fig 3.20, Table 3.13). Open forests have, however, decreased significantly from 2001-2015, of which some must have upgraded to dense forests accounting for a dense forest increase from 2001-2015 of 18 ha. The remaining open forests were probably converted to other land uses such as wastelands or scrub or for development or agriculture, given increases in these land use categories. This signifies a net decrease in open forests of 100 ha.

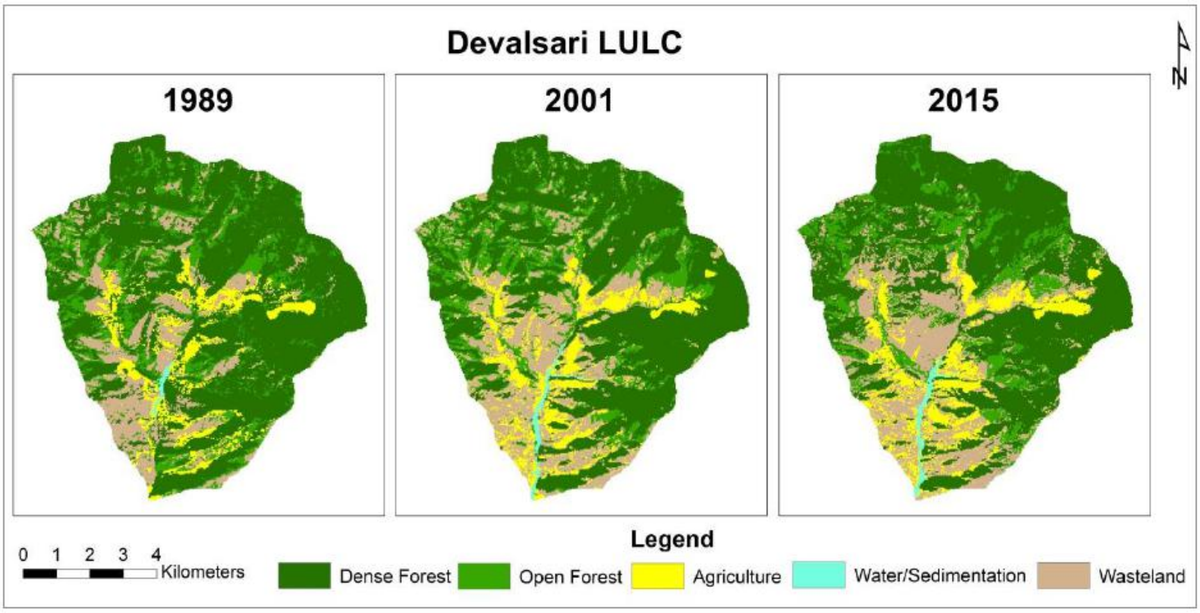

Figure 3.15 Maps indicating land use and land cover (LULC) in 1989, 2001 and 2015 in Devalsari MWS, Tehri Garhwal

Table 3.13 Land use and land cover (LULC) for 3 time periods-1989, 2001 and 2015 in Devalsari MWS, Tehri Garhwal

Area (in ha)	1989	2001	2015	Change 2001 to 1989	Change 2001 to 2015	Change 1989 to 2001
Dense Forest	3507	3009	3027	-498	18	-480
Open Forest	892	947	829	55	-118	-63
Agriculture	480	600	626	120	26	146
Water/ Sedimentation	17	48	51	31	3	34
Wasteland	942	1234	1305	292	71	363
Total	5838	5838	5838			

3.3.8 Tourism in Dhanaulti

We carried out a TCM for tourists visiting Dhanaulti as well as Devalsari. However, tourism has not picked up sufficiently in Devalsari and only 2 tourists responded from this area. Consequently, the results of this TCM relate to Dhanaulti.

Demographic profile of respondents and tourists

The majority of tourists had a higher secondary education (59%), while the number of graduates was lower at 26% (Fig 3.21). In terms of the gender profile of respondents 91%

were male- males provided the most responses, even when couples or families were interviewed. The average family size was 4.6±0.13. Almost 93% were Hindus[22] with a small proportion of Muslims (4%) and Sikhs (3%)

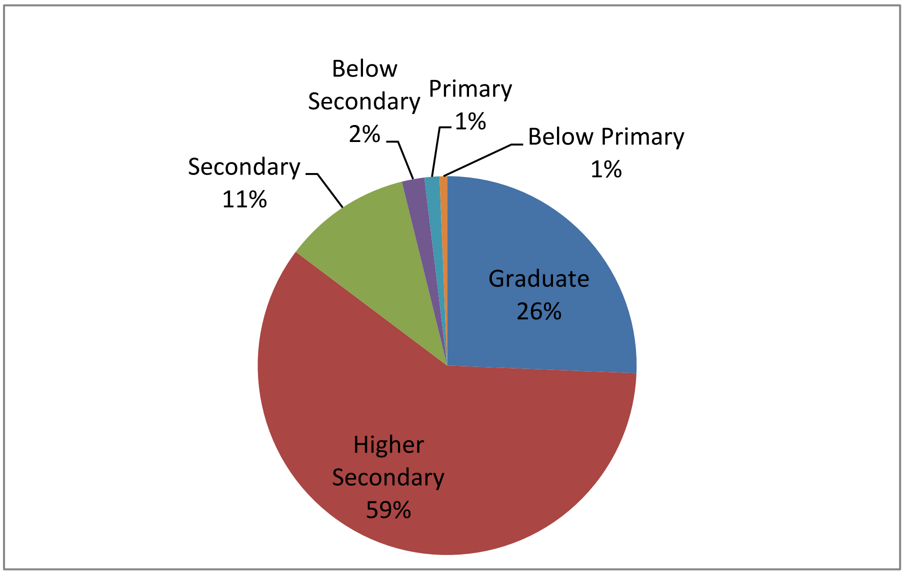

Figure 3.16 Education profile of the tourists

Permanent salaried employees (33%) and the self-employed (20%) comprise the bulk of the tourist population (Fig 3.22). Students are also a significant proportion (29%) and are particularly likely to value the area for adventure or nature tourism including treks, bird, butterfly, wildlife and nature watching.

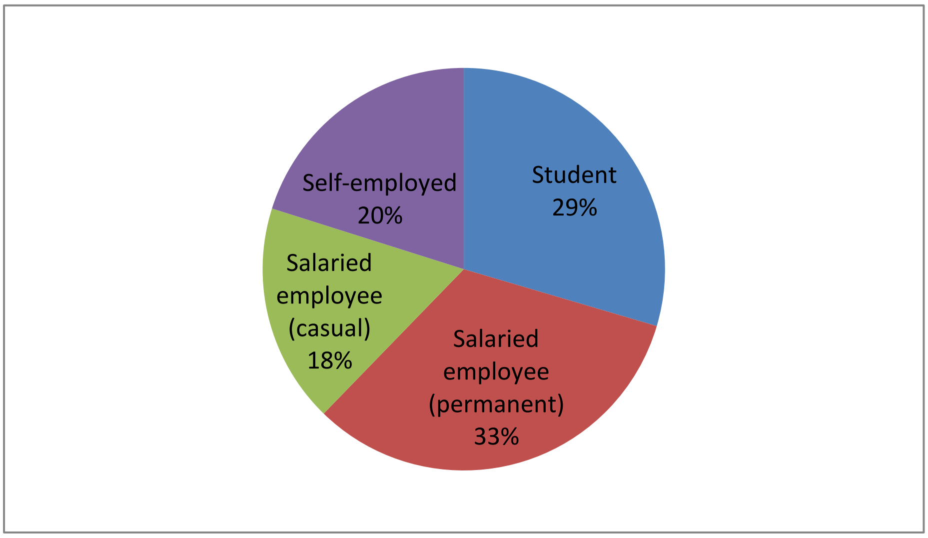

Figure 3.17 Occupation profile of the tourists

[22] Dhanaulti is also an important pilgrimage spot because of a number of Hindu shrines especially Surkanda Devi temple

Most of the people owned a house (68%) or utilised free accommodation[23] while 5% lived in rented accommodation. The average monthly rentals for those owning their own house was Rs 5378±544 (SE). The average incomes suggest that our sample on average consisted of a middle-class population (Rs 34,385±2620.84 (SE). The high standard error, however, indicates much variation in the data ranging from Rs 12000 to Rs 2,50,000.

Travel details of the tourists

The average number of days spent by the tourists was 2.5 days (2.48 ±0.11 (SE)), with a median of 2 days. Only 6.2% of the tourists spent more than 5 days at the site. Most of the tourists came on a family holiday (`60 %) while 32% came in groups of friends or colleagues. The average number of people in each group was 3.92 ±2.9 (SD), while the mean number of males, females and children (<16 years) were 1.92 ±1.7 (SD), 1.61±1.3 (SD), 1.52 ±0.8 (SD), respectively. Thus adult males outnumbered adult females marginally (median of 2 versus 1). As many as 73% of visitors came in small groups (group sizes of ≤ 4) while the largest group consisted of 30 individuals.

The majority of tourists were from neighbouring states or local tourists from Uttarakhand. (Fig 3.23). The average of the total number of annual visits to Dhanaulti was 1.05.

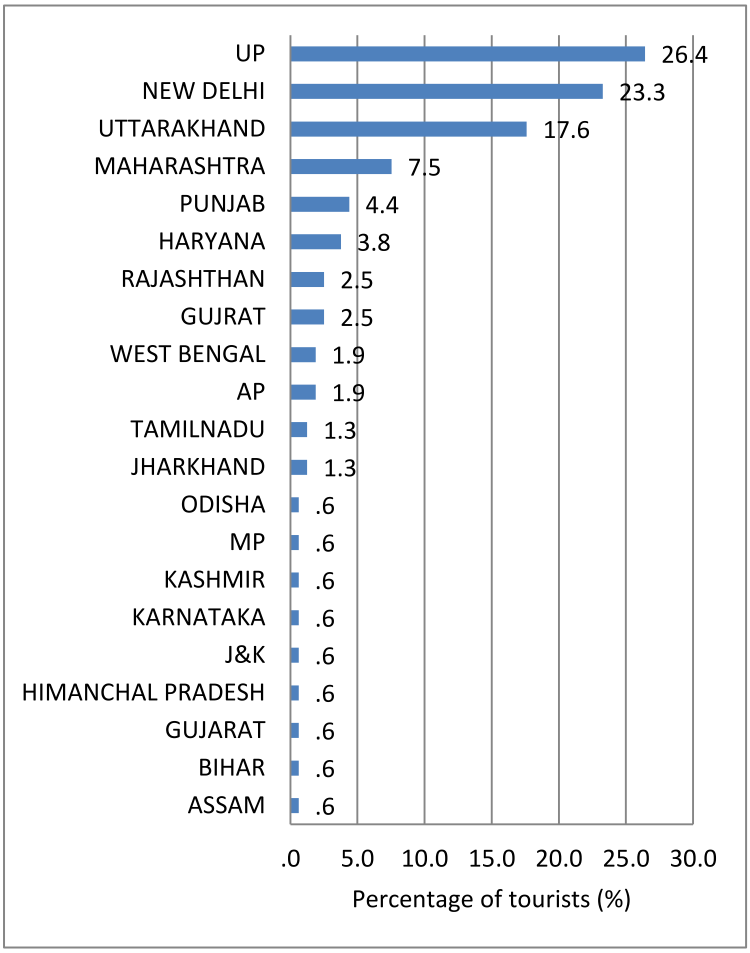

Figure 3.18 Place of origin of the tourists (in %)

[23] Government employees are normally provided with accommodation

Consequently, the majority of tourists (54.7%) travelled a maximum distance of 101-400 km to reach their destination, while 21.4% travelled more than 1000 km to reach their destination. Only 13.2 percent of visitors travelled less than 100 km (Fig 3.24).

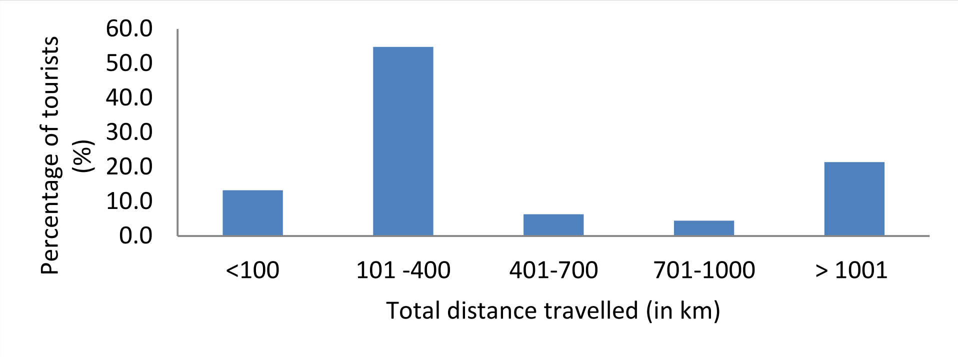

Figure 3.19 Distance travelled to their destination (% of tourists)

Since most of the tourists were from nearby areas, the primary mode of transport was by bus (76% while only 6.3% of visitors reached Dehradun (the nearest airport) by air (Fig 3.25). Naturally, 89 % of visitors had spent on local travel of which the preferred mode of transport was a taxi (79.7%) followed by an auto (10.5%). Mules were used by 9.2% of visitors. The mean expenditure on local travel was Rs 2501 although there was much variation in this figure from a minimum of Rs 200 to a maximum of Rs 18050.

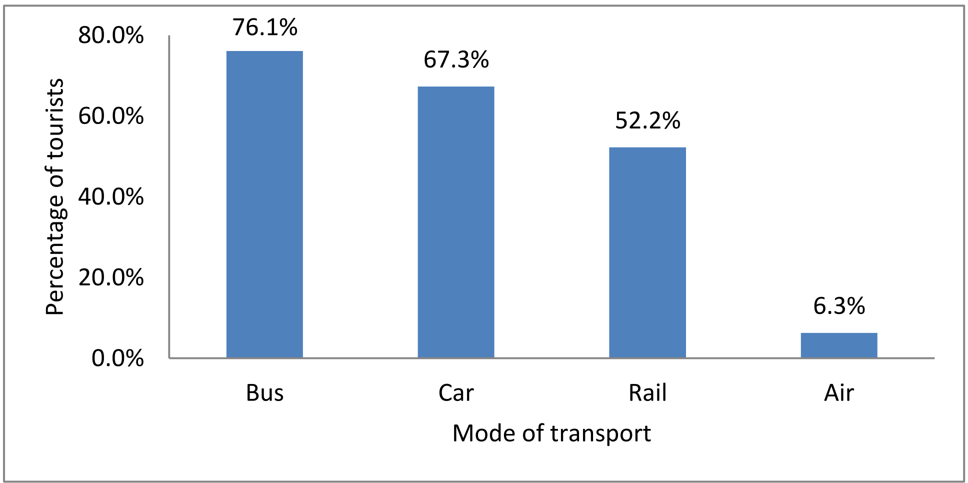

Figure 3.20 Primary mode of transport (in percentage of tourists who used these modes)

As many as 91% of the visitors had visited Uttarakhand 3 times or less while only 8.6% had visited more than 3 times. Overall, 65.4% of visitors were on a repeat visit to Uttarakhand.

Only 32.1% of visitors were aware of another recreational/ biodiversity site within Uttarakhand that they would prefer to visit. Amongst those that were 89% suggested Mussoorie while 7% suggested Rishikesh and 2% suggested Nainital

The primary expenditure of the tourists is provided in Fig 3.26. The highest expenditure was on local cuisine followed by temples and religious activities. A significant percentage of people (30%) visiting these areas were interested in nature tourism and spent on bird and butterfly guides and tours. Expenditure on the Uttarakhand Bird Festival, however, was limited to only 1% of the visitors. The estimated mean per head expenditure was Rs 12470.

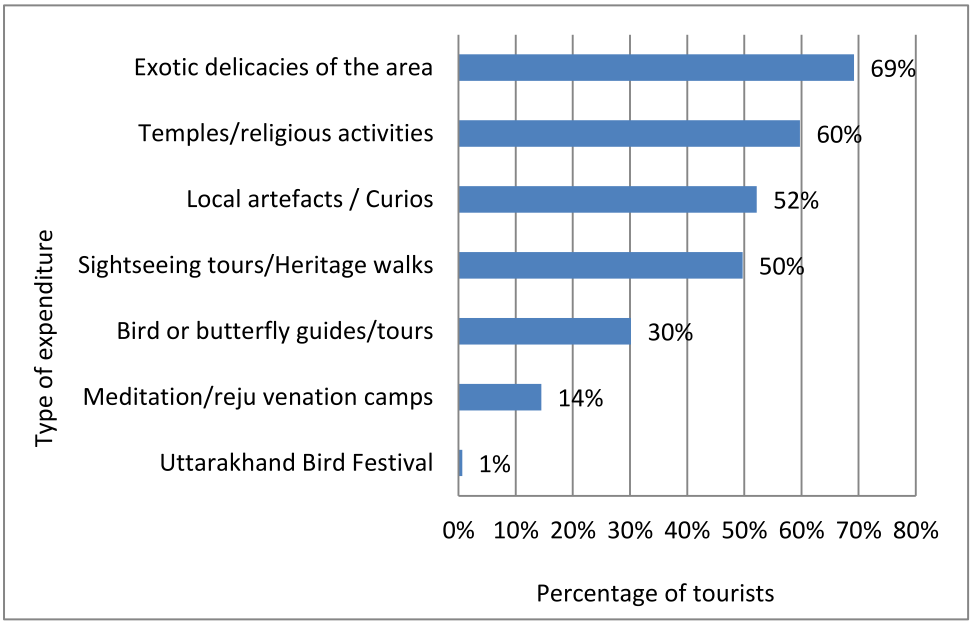

Figure 3.21 Type of expenditure (in % of tourists)

The tourist experience

For the tourists the most important attributes of Dhanaulti was its biodiversity value (98.7% of tourists). These figures suggest that loss of forest cover, degradation and biodiversity loss will endanger this area as a major tourist spot. Nevertheless, its importance as a religious spot has led to 72% valuing these attributes (Fig 3.27). Other important attributes is the experience it provides in terms of trekking. As many as 83% of the tourists were satisfied by the recreational benefits provided by the forests with 64% of tourists rating them as good or very good and the remaining rating the quality of recreational benefits as fair.

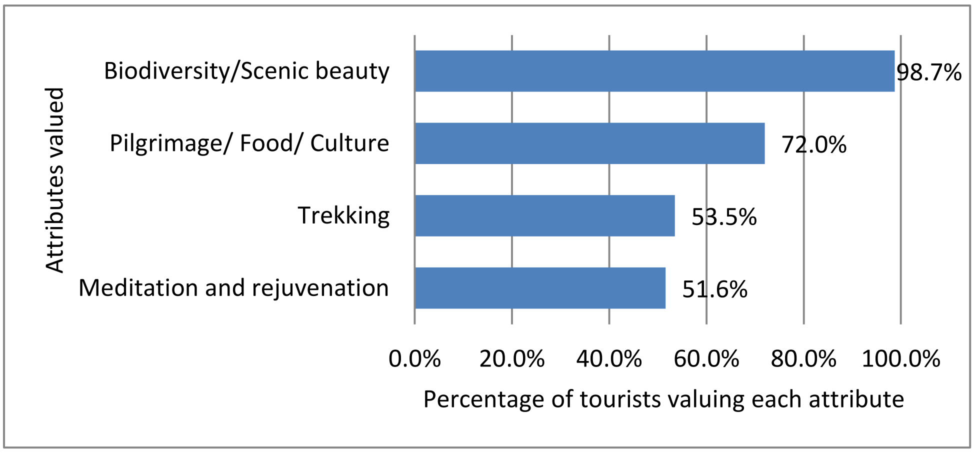

Figure 3.22 Attributes valued by tourists (in percentage of tourists rating each attribute)[24]

[24] Multiple responses were possible.

Photo 3.7 Himalayan bluetail or Himalayan red-flanked bush-robin (*Tarsiger rufilatus*)

Photo 3.8 Green-backed Tit (*Parus monticolus*)

Photo 3.9 Deodar forests touching the sky

When tourists were asked about the improvements they would like to see in the area, they provided the following assessment (Fig 3.28). 73% of the people wanted to have enhanced sightseeing facilities and improved road conditions. The lack of trained guides was also a big drawback (65%). Several of the indicators suggested that people would like to see improvements in walking trails (53%), bird and butterfly watching facilites as well as local field guides or brochures highlighting biodiversity hotspots (30%), and appropriate signate (34%). Presence of toilets and the need for improved waste disposal were also considered important.

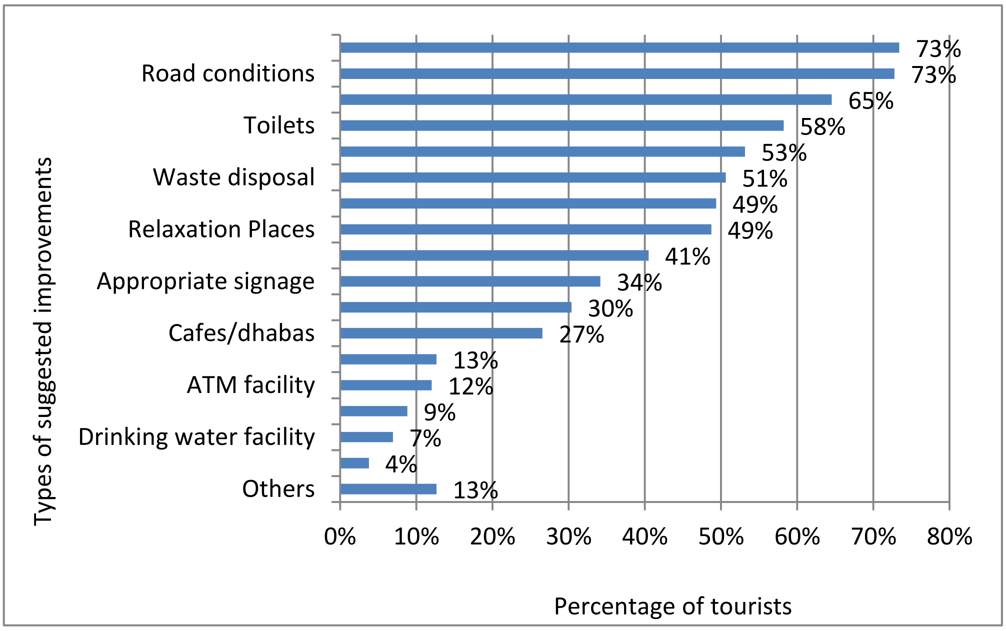

Figure 3.23 Suggested ways to enhance the recreational experience (Percentage of tourists)

Results of the TCM to estimate recreational demand

In the basic model, the number of visits to Uttarakhand is a function of factors such as the travel cost, total household income, age and gender. Having tried various functional forms, the linear functional form provided the best fit of our data.

Thus, the model may be specified as follows:

r_i = ß0 + ß1 travel cost + ß2 household income + ß3 age of visitor + β4 gender[25] +β5 biodiversity+β6 Meditation+ ei .

Where r_i the dependent variable, is the number of visits by the ith individual to Uttarakhand per unit of time. The explanatory variables are travel costs, household income, age of the visitor and attributes of the site including biodiversity-related activities and meditation.

Table 3.14 Parameter estimates of the linear regression model

Parameters	Coeff (S.E)
Constant	1.136 *** (.262)
Total household income	--3.39e-06(9.66e-06)
Travel cost	-.0006**(0.0003)
Age	.0038(0.008)
Gender	.0996(0.276)
Biodiversity of the site	.0056***(0.318)
Meditation	-.282*(0.216)
R^2	0.1
Number of observations	157

*****1% significance level, **5% significance level, *10% significance level with two- tailed tests**

Parameter estimates of the linear regression model are in Table 3.16. As expected, high travel costs incurred by individuals are inversely related to visitation rates (see Ortacesme., 2002, Khan, 2006). Thus the higher the travel cost paid by the tourists to reach Uttarakhand, the less frequently they visit. The household income has a negative relationship with demand for recreational activities although it is not significant. Age and gender are not significant factors in determining visitation rates to the site. This is in line the results of Ali et al., 2011. Visitors value the site for its biodiversity value (this is highly significant) although most people do not think that activities like meditation add to the value of the area.

Estimation of consumer surplus

The individual consumer surplus was estimated as Rs $-((1.05)^2) / (2(0.0006))$= Rs 918.75 using equation

[25] A dummy variable was used where males=0 and females=1

$CS = r^2 / -2\beta_{SL}$ where

CS: Consumer surplus

β_{SL}: Curve of the demand function (cost coefficient) (ie. ß1 of the travel cost in the regression equation cited earlier).

Or $CS = r^2 / -2\beta_1$

The number of Indian tourists that visited Mussoorie in 2005 was 1050245 (ACNielsen ORG-MARG 2008). We use this figure to determine the total recreational demand for Dhanaulti, conservatively assuming that about 20% of the people who visit Mussoorie also visit Dhanaulti, that is 210049 people. The proximity of Mussoorie to Dhanaulti suggests that this is plausible in the absence of any more accurate information and this figure is probably conservative. Using this figure, the total consumer surplus amounts to Rs 0.1 billion. With a forest area for Dhanaulti of 7979.04 ha, this works out to a consumer surplus Rs 24,186 per ha of forest area.

We estimate the present value of the benefits from recreation in Dhanaulti (Table 3.15). This is Rs 2.5 billion at a discount rate of 4%. We measure benefits in perpetuity assuming that the forest ecosystems in Uttarakhand will be preserved in their natural state indefinitely. This recreational benefit is only one of the several benefit accrued from the forest ecosystem of Dhanaulti. If the others benefits are also included the present value will increase further.

Table 3.15 Present value of benefits from recreation in Dhanaulti

Head	Amount (in billion Rs)	Per ha value (Rs)
Total Consumer surplus	0.1	24,186
PVB (at 4%)	2.5	3,13,320.9

3.3.9 Valuation of forest degradation in Dhanaulti and Devalsari

The costs of forest degradation for Dhanaulti and Devalsari from 2001-2015 using values obtained from the primary survey for fodder, fuelwood and ecotourism (recreation) and secondary values from Verma (2014) for the remaining ecosystem services are Rs 97.8 million. We calculated an NPV over 25 years using a 4% discount rate as per Verma (2014). The loss in in NPV of forests from 2001-2015 is Rs 0.049 million per ha.

3.3.10 Scenario development

Cost of forest degradation in 2030

The forest cover in 2030 was projected for Dhanaulti and Devalsari. These are provided below (Figure 3.29 to Figure 3.38 and Table 3.16 and Table 3.17). These figures were used to determine the costs of forest degradation from 2001-2030 for these areas. This was assumed to be the Business As Usual (BAU) scenario if the current pace of forest degradation continues.

Dhanaulti 2030 LULC scenarios

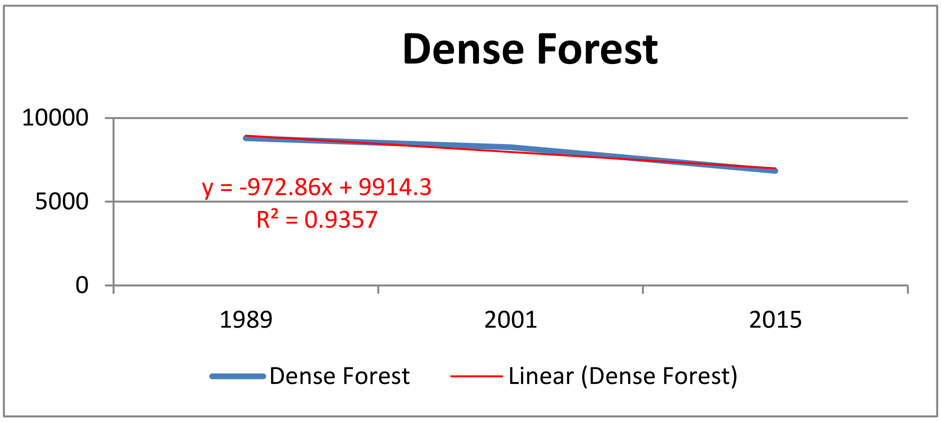

Figure 3.29 Projected dense forest cover for 2030

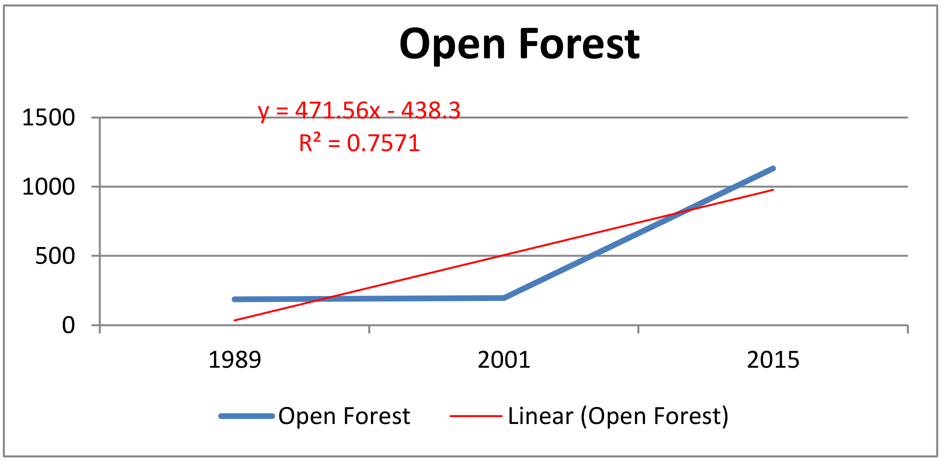

Figure 3.24 Projected open forest cover for 2030

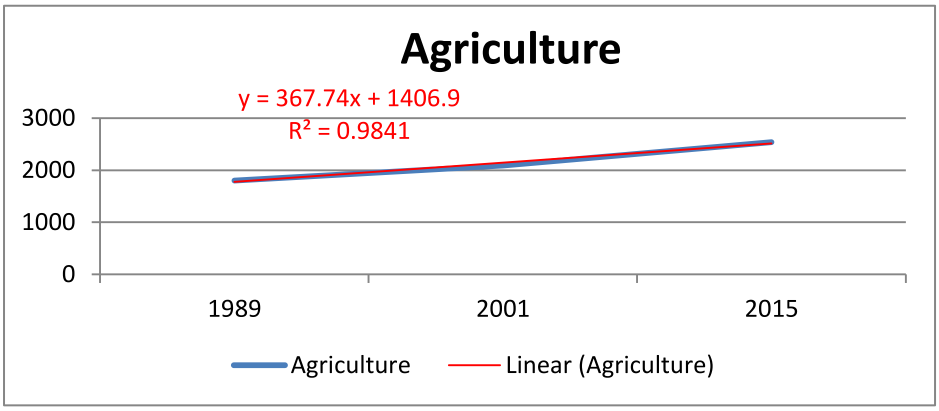

Figure 3.25 Projected agricultural cover for 2030

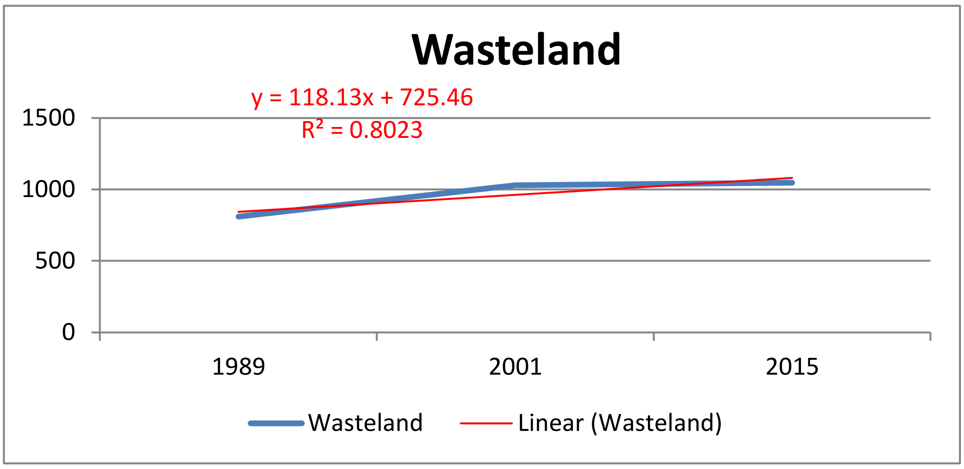

Figure 3.26 Projected wasteland cover for 2030

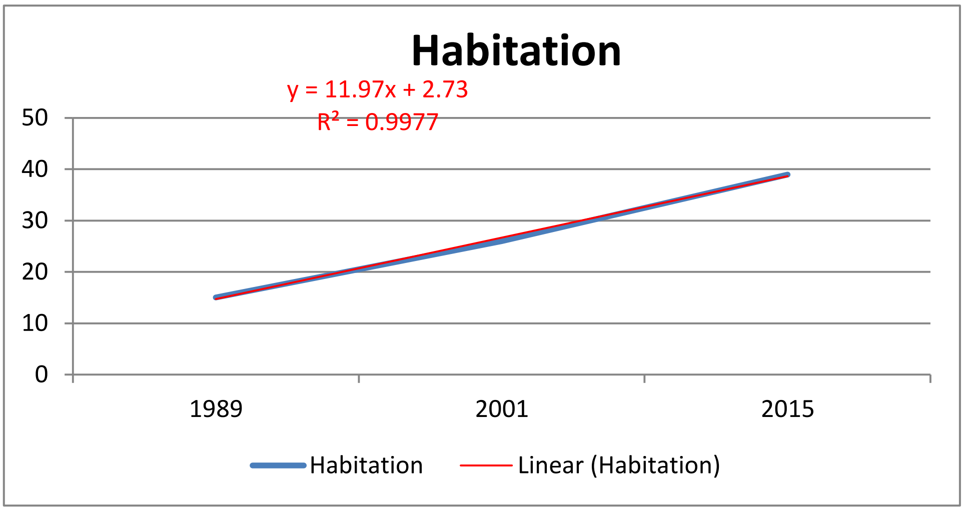

Figure 3.27 Projected habitation cover for 2030

Table 3.16 LULC for Dhanulti projected in 2030

	1989	2001	2015	2030
Agriculture	1801.71	2088.36	2537.19	2877.86
Dense Forest	8794.17	8262.99	6848.46	6022.86
Open Forest	187.47	196.38	1130.58	1447.94
Wasteland	809.73	1029.42	1045.98	1197.98
Habitation	15.03	26.01	38.97	50.61
Water/ Sedimentation	80.37	85.32	87.30	91.23
Total	**11688.48**	**11688.48**	**11688.48**	**11688.48**

Devalsari 2030 LULC scenarios

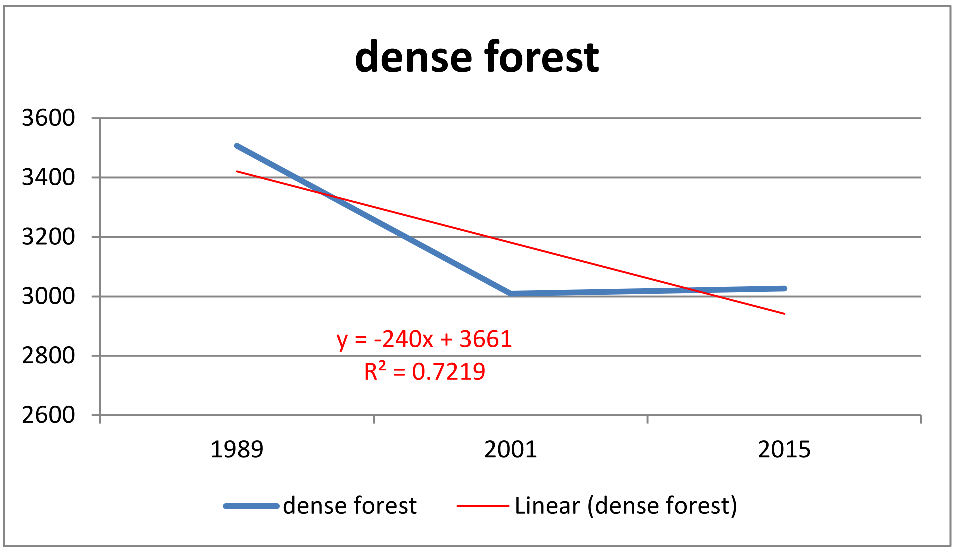

Figure 3.28 Projected dense forest cover for 2030

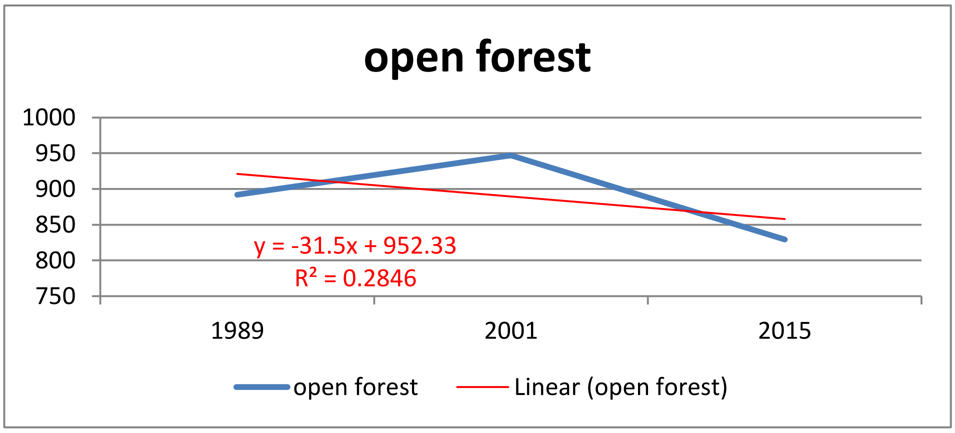

Figure 3.29 Projected open forest cover for 2030

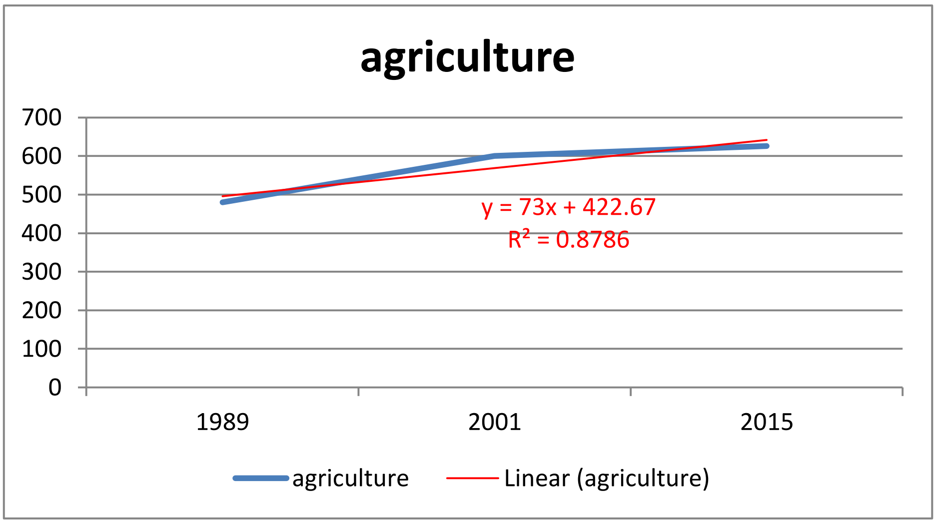

Figure 3.30 Projected agricultural cover for 2030

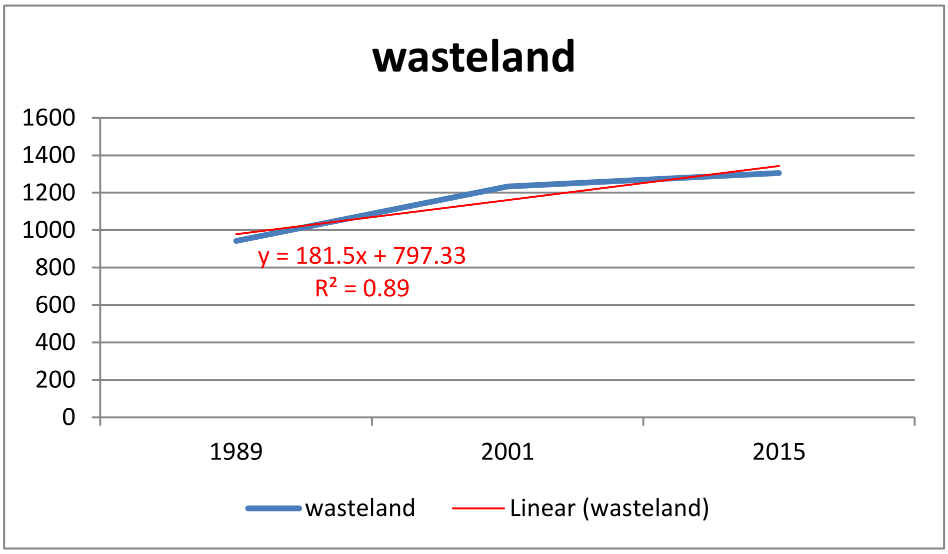

Figure 3.31 Projected wasteland cover for 2030

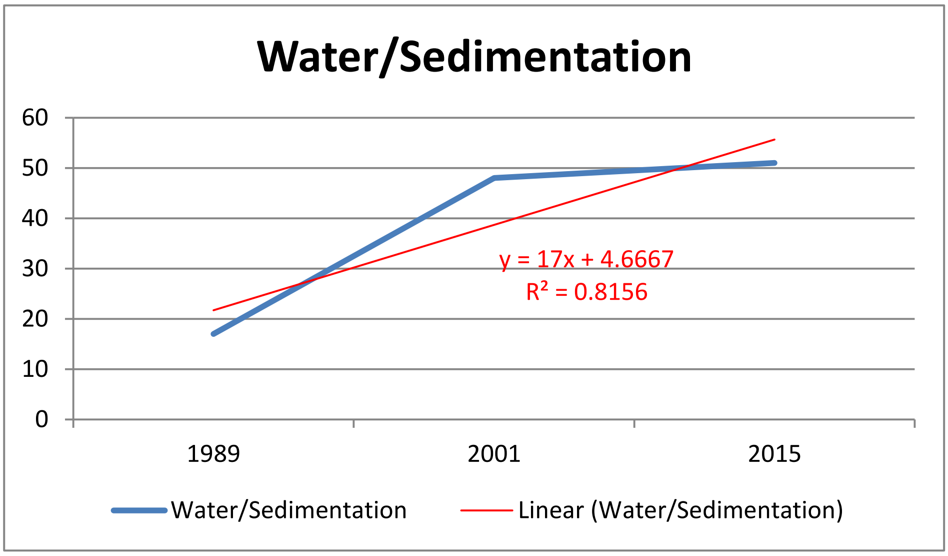

Figure 3.32 Projected water/sedimentation cover for 2030

Table 3.17 LULC for Devalsari projected in 2030

	1989	2001	2015	2030
Dense forest	3507	3009	3027	2701
Open forest	892	947	829	826
Agriculture	480	600	626	715
Wasteland	942	1234	1305	1523

	1989	2001	2015	2030
Water/ Sedimentation	17	48	51	73
total	5838	5838	5838	5838

The costs of forest degradation for Dhanaulti and Devalsari from 2001-2030 using the values for forest cover projected above and the values obtained from the primary survey for fodder, fuelwood and ecotourism (recreation) and secondary values from Verma (2014) for the remaining ecosystem services are Rs 1087.8 million (at 2013 prices). We calculated an NPV over 25 years using a 4% discount rate as per Verma (2014). The loss in in NPV of forests from 2001-2030 is Rs 0.187 million per ha (at 2013 prices).

Costs of forest reclamation till 2030

The cost of reclaiming degraded forests in 2030 was determined. The cost norms as per NAP guidelines (2009) are Rs 37085 per ha for artificial regeneration and Rs 27,163 for natural regeneration. We assume that open forests will require higher costs of regeneration as compared to moderately dense forests and hence utilise the value of Rs 37,085/ ha at 2009 prices to determine the costs of reclaiming degraded forests.We convert these to 2013 prices using the WPI which works out to Rs 49,853.85 per ha. This leads to a cost of Rs 41.2 million to reclaim open forests in 2030 in Devalsari (826 ha of open forests). For Dhanaulti, the costs of reclaiming open forests in 2030 would be Rs 72.2 million (for 1447.94 ha of open forests). Therefore, the total costs of forest regeneration in Dhanaulti and Devalsari in 2030 (at 2013 prices) would be Rs 113.4 million. The costs of forest reclamation of Dhanaulti and Devalsari (Rs 113.4 million) are only 10% of the costs of degradation projected above (Rs 1087.8 million), and hence it makes economic sense for the State to focus on a) prevention of degradation and b) forest reclamation.

3.4 Conclusion and recommendations

The results from this study underline the high costs associated with forest degradation. It also strengthens the conclusion of other studies from Uttarakhand that one of the primary causes of forest degradation in the State is fuelwood collection (Baland, TERI, 2014). Most of the households (87%) were dependent on fuelwood as their primary fuel source and forests were indisputably the main source of firewood with the most pressure imposed on Reserve Forests. The local communities also rated fuelwood as the most valued product derived from the forests. The households collect an average of 1500±130.63 (SE) kg of fuelwood per household per year. This figure translates into fuelwood usage of 1223.46 kg per ha or 1.69 cum/ ha in all the villages sampled[26]. Using a price of fuelwood of Rs 849 per cum the value of fuelwood per ha is estimated at Rs 1433. ***This study highlights the need to find alternatives to fuelwood consumption in Uttarakhand as a means to reduce forest degradation.***

The remote sensing assessment of land use change from 2001-2015 underlined the large-scale conversion of dense forests to open forests (degradation) but also conversion to other land uses (e.g. agriculture) or deforestation. ***This suggests that in our sampled forests,***

[26] This is calculated based on population figures of the villages sampled from the 2011 census.

deforestation is also an important reason for forest loss in the fifteen years since the creation of Uttarakhand.

The local people view ecotourism as an important activity for revenue generation that they believe will also reduce the pressure on forests. This view is echoed by the tourists (to Dhanaulti) for whom the most important attributes of the area was its biodiversity value (98.7% of tourists sampled).

Enhancing community run ecotourism can contribute significantly to the local economy and help reduce pressure on forests. A significant proportion of the sampled (155) households benefitted from ecotourism (44%) while as many as 48% of households wanted tourism to be developed as the primary activity in the area. Eighty % of households that felt the need to boost ecotourism cited low incomes derived from agriculture and migration as the primary rationale for this. Interestingly, many respondents viewed ecotourism as a means to protect the forest (51%) and reduce dependence on them (49%).They evidently view ecotourism as being less detrimental to forest management. ***Consequently, the need to focus on low-impact ecotourism is one of the major recommendations to emerge from this case study.***

A travel cost analysis of recreational benefits provided an individual consumer surplus of Rs 918.75 and a total consumer surplus of Rs 24,186 per ha of forest area. The present value of recreational benefits is Rs 3,13,320.90 per ha of forest area (discount rate of 4%). ***However, amongst tourists, 73% wanted to have enhanced sightseeing facilities and improved road conditions. The lack of trained guides was also a big drawback (65%). Several of the indicators suggested that people would like to see improvements in walking trails (53%), bird and butterfly watching facilites as well as local field guides or brochures highlighting biodiversity hotspots (30%), and appropriate signate (34%).*** Presence of toilets and the need for improved waste disposal were also considered important. Consequently, the overall tourism experience needs to be enhanced for people visiting the forests of Uttarakhand.

The costs of forest degradation for Dhanaulti and Devalsari from 2001-2015 using values obtained from the primary survey for fodder, fuelwood and ecotourism (recreation) and secondary values from Verma (2014) for the remaining ecosystem services are Rs 97.8 million. We calculated an NPV over 25 years using a 4% discount rate as per Verma (2014). The loss in in NPV of forests from 2001-2015 is Rs 0.049 million per ha.

This study highlights the enormous costs of forest degradation and the need to stem this loss, particularly given that it is the second most important cause of degradation in the country and the main cause of degradation in Uttarakhand. Moreover, the costs of reclaiming forests in 2030 works out to only 10% of the costs of forest degradation. It therefore, makes more economic sense to reclaim forests rather than to degrade them. ***Several measures will need to be taken at national and state levels to address the pervasive issue of forest degradation, arguably one of the most important reasons for land degradation in India.*** These issues are discussed in detail in the macrostudy in Volume I.

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Chapter 4. The Role of Farm Bunds in Enhancing Agricultural Productivity and Farm Incomes through Reduced Water Erosion in Madhya Pradesh

4.1 Introduction

Water erosion[27] is the most significant process of land degradation/ desertification in India accounting for one third of the total area undergoing land degradation/ desertification (SAC, 2016). Water erosion imposes significant costs on society in terms of loss of soil fertility of agricultural systems and loss of top soil in forested landscape. This adversely affects forest cover and regeneration and contributes to sedimentation of streams, rivers, reservoirs and other water bodies. Sedimentation in turn has significant implications for water availability and supply, fisheries, river flows, flood control, hydro power generation and recreation. All these factors cause losses to the national economy and pose a challenge to the poor and marginalised who depend on agriculture, forests and other land-based livelihoods. Land degradation due to water erosion in the sloping uplands, particularly in Asia, Africa and Latin America is also one of the major threats to agricultural sustainability. Water erosion results in loss of top soil and nutrient depletion that contributes to low agricultural productivity and thus lower income, food insecurity and poverty in many hilly areas or areas with sloping uplands (Kassie et al, 2008; Lapar and Pandey, 1999). In this study, we assess the economic benefits derived from farm bunds, an intervention to reduce water erosion in the agricultural fields of West Madhya Pradesh. We assume that these are the foregone benefits resulting from lost revenues and agricultural productivity in areas lacking interventions against water erosion.

Of the total 96.40 mha land undergoing degradation/ desertification in India, water erosion accounted for 36.10 mha in 2011-13 (SAC, 2016). Water erosion results in loss of top-soil or deformation of terrain through various processes such as gully, rill, sheet and splash erosion. The severity of soil erosion depends on several factors such as intensity of rainfall coupled with the type of slopes, soils and land use categories. It occurs widely in most of the agro-ecological zones of India. Areas in the Northern plains, Central highlands, Deccan plateau, Eastern plateau region and Eastern Ghats and the Western Himalaya region are acutely affected (SAC, 2007)

Given the widespread nature of the problem of water erosion in India, several programmes are being implemented by various state and central government agencies to control land degradation due to water erosion. The Integrated Watershed Development Programme (IWMP) implemented by the Ministry of Rural Development, Government of India along with State Government agencies has been the main initiative to address water erosion issues.

[27] "Water Erosion is loss of soil cover mainly due to rainfall and surface runoff water. Water erosion is observed in both hot and cold desert areas, across various land covers and with varying severity levels. The sheet erosion (mostly within agricultural lands) and rills are categorised in slight category, the narrow and shallow gullies are categorized as moderate erosion, while the deep / wide gullies and ravines are classified as severe erosion. Particularly in the context of desertification or land degradation as a whole, water erosion does not refer the river erosion" (SAC 2016, pp 5).

IWMP aims at restoring the ecological balance by harnessing, conserving and developing degraded natural resources such as soil and vegetative cover. Economic valuations of watershed development (WSD) programmes in India have been carried out in a few instances. Joshi et. al (2005) carried out meta-analysis of 311 WSD case studies and found that mean cost-benefit (C-B) ratio of WSD projects is 2.14. Sahu (2008) found that cost-benefit ratio for Rajasthan over a period of thirty years ranged from 1.97 to 2.34. Much higher C-B ratios were obtained by Chatuverdi (2004) who carried out an analysis of eight WSD projects in Gujarat over a ten-year period. He found that the average benefit-cost ratio was 8.56 and average benefit from the WSD project in normal rainfall years was greater than in drought years. However, profits for marginal farmers were much lower than for big farmers and depended on the presence of wells for irrigation. Palanisami et. al (2009) used the economic surplus method and obtained a cost-benefit ratio of 1.93 for 10 watersheds in Tamil Nadu. These studies make a strong case for investments in soil conservation projects as the potential benefits outweighs the costs of the interventions.

The costs of soil erosion are commonly measured in three ways; 1) the productivity approach 2) the, replacement cost approach and 3) the preventive cost approach. Mythili and Goedecke (2016), however, used the Total Economic Value (TEV) approach to estimate land degradation. Table 4.1 provides a list of studies that estimated losses resulting from soil erosion utilising either the replacement cost or the loss in production approach.

Table 4.1 Loss due to soil erosion

Study	Date Period	Type	Loss	Remark
Narayana and Ram Babu (1983)	1976	Soil erosion (water induced)	Annual loss of soil 16.4 tons/ ha	
Singh et al. (1990)	1970s	Soil erosion (water induced)	Annual loss of soil 15.2 tons/ ha	
Bansil (1990)	1986	Soil erosion (water induced)	Annual loss in production of major crops 13.5 million tons (3.1% of total production)	Cover agricultural land, other non-wasteland and non-forest land
UNDP, FAO and UNEP (1993)	1993	Soil erosion (water induced)	Annual loss in production 8.2 million tons (1.7% of total production)	Only agricultural land
Sehgal and Abrol (1994)	1990s	Soil erosion (water induced	Soil productivity declines ranges from 12% in deep soil to 73% in shallow soil	Loss is more in red and black soil as compared to alluvium derived soil
Vasisth et al (2003)	1994-96	All types of erosion	Production loss of 12% of total value of production	State wise estimates also computed

Source: Modified Mythili and Goedecke (2016)

Agricultural productivity can increase due to control of water erosion as well as better availability of water (surface and/ or ground water); the 'preventive approach'. Programmes such as the IWMP introduce a basket of interventions that aid in recovery of the soil. Bhaskar et al (2014) measured the impact of IWMP in tribal areas of Gujarat and Chhattisgarh. They found that apart from soil and water conservation, the programme was also successful in enhancing agricultural (approximately double) and milk productivity (almost double) as well as in engendering efficient and environment-friendly agricultural practices, improved animal husbandry, reduced migration and better availability of water for irrigation and domestic purposes.

Nerkar et al. (2015) also measured the impact of IWMP in hilly tribal areas of Maharashtra. They found that the IWMP programme had resulted in improved availability of water (87% in IWMP area compared to 40% in non-IWMP area), apart from an increase in crop production. Ancillary benefits also resulted in terms of health, enhanced education and employment generation (47% in IWMP area compared to 34% in non-IWMP area). Agricultural income was enhanced (57% in IWMP area compared to 37% in non-IWMP area) along with increases in firewood availability (61% in IWMP area compared to 37% in non-IWMP area).

A number of strategies are used to directly combat water erosion of which the creation of bunds is common. Kassie et al. (2008) measured the impact of '*fanya juu* bunds' on land degradation in Ethiopia, a popular soil and water conservation measure to control soil erosion in east Africa. Sutcliffe (1993) also studied the efficacy of bunds in controlling soil erosion in Ethiopia. Both concluded that bunds are more effective in areas of low rainfall. However, soil conservation may enhanced by planting fodder grass or trees on these bunds (Sutcliffe 1993).

This case study makes an attempt to measure the benefits of soil conservation interventions in India at micro level, and analyses the benefits of farm bunds (one of the interventions under IWMP) in the Indore district of Madhya Pradesh in terms of improvement in agricultural productivity, declines in cost of cultivation and increases in income of the households through primary data. The details of the methodological approach have been discussed in a subsequent section.

4.2 Integrated Watershed Management Project in the Study Area

The National Rainfed Area Authority (NRAA) in coordination with Planning Commission formulated Common Guidelines for Watershed Development Projects in 2008, on the basis of recommendations of the Parthasarathy Committee Report, other Committees' observations and past experiences. These common guidelines provided an impetus to watershed development programmes[28]. The provisions in the Common Guidelines and the observations of the Parthasarthy Committee report suggested modifications in existing watershed schemes which resulted in integration of Drought Prone Areas Programme (DPAP), Desert Development Programme (DDP) and Integrated Wastelands Development Programme (IWDP) of the Department of Land Resources into a single modified programme called Integrated Watershed Management Programme (IWMP) in 2009.

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[28] See Volume I for a detailed description of watershed programmes in India to reduce land degradation

IWMP provides a sustainable framework to integrate natural resource management with community livelihoods. The Rajiv Gandhi Watershed Mission of Madhya Pradesh implemented three Integrated Watershed Management Projects (IWMPs) in the Mhow block of Indore district in 2009-10 (named IWMP-I, IWMP-II and IWMP-III). The project was implemented through the Indore Zilla Panchayat with project implementing agencies, NGOs and corporate partners. Of the 3 IWMP projects implemented in Mhow block, IWMP I is the largest with an area of 8465 ha, followed by IWMP II with an area of 5022 ha. This study addresses the impacts of farm bunds initiated under IWMP II. IWMP-II covers four micro-watersheds and 9 villages. A significant part of the land of these four micro watersheds comprises of forest land.

A range of activities have been undertaken as part of the IWMP programmes in Mhow Block. For IWMP II of Mhow Block, the Development Support Center (DSC) is the project implementing agency (PIA) and ITC is the corporate partner. Some of the major activities that have been undertaken are:

- soil and water conservation measures that include farm bunding, grass turfing and plantation on farm bunds, stone outlets, gulley plugging, stop dams or check dams, and water harvesting measures;
- livelihood and livestock development activities like livestock support services, poultry, bee keeping; micro enterprise and micro-credit support through self-help groups;
- support for enhanced agricultural production that includes demonstration plots with HYVs (High Yielding Varieties) for different crops, sprinklers and drip irrigation demonstration, vermin-compost training, seed and pesticide kits, soil testing for information on micro nutrients, sending informative SMS' to farmers;
- Other entry point and income generation activities.

Of the four micro-watersheds under IWMP II, farm bunds or *med bandhan* as they are called locally, were built on the farms of individual farmers in two micro watersheds- Badgonda and Mehendikund covering four villages, i.e. Badgonda, Tincha, Jhikadiya Khedi and Badia. Farm bunds are earthen structures built across the slope of the farm land to reduce run-off and control soil erosion. They help in levelling the land over time. These structures also improve soil moisture and retain soil fertility. Farm bunds can indirectly result in increased productivity and reduced input costs. Though farms were identified under IWMP-II for the introduction of farm bunds in accordance with the ridge area treatment plan of the project, several farmers vetoed their creation on their lands for a variety of reasons.

4.3 Methodology

4.3.1 The Analytical Framework

The study adopted a three-stage analytical framework used by Pattanayak and Mercer (1998) to assess the benefits of a similar intervention in the Philippines. Economic benefits of soil conservation measures like farm bunds can be assessed by analysing the relationship between farm bunds and soil quality in Stage I of the analysis. In Stage II, the relationship between soil quality and individual household production is explored while Stage III of the framework explores the link between household agricultural production and household income (Figure 4.1).

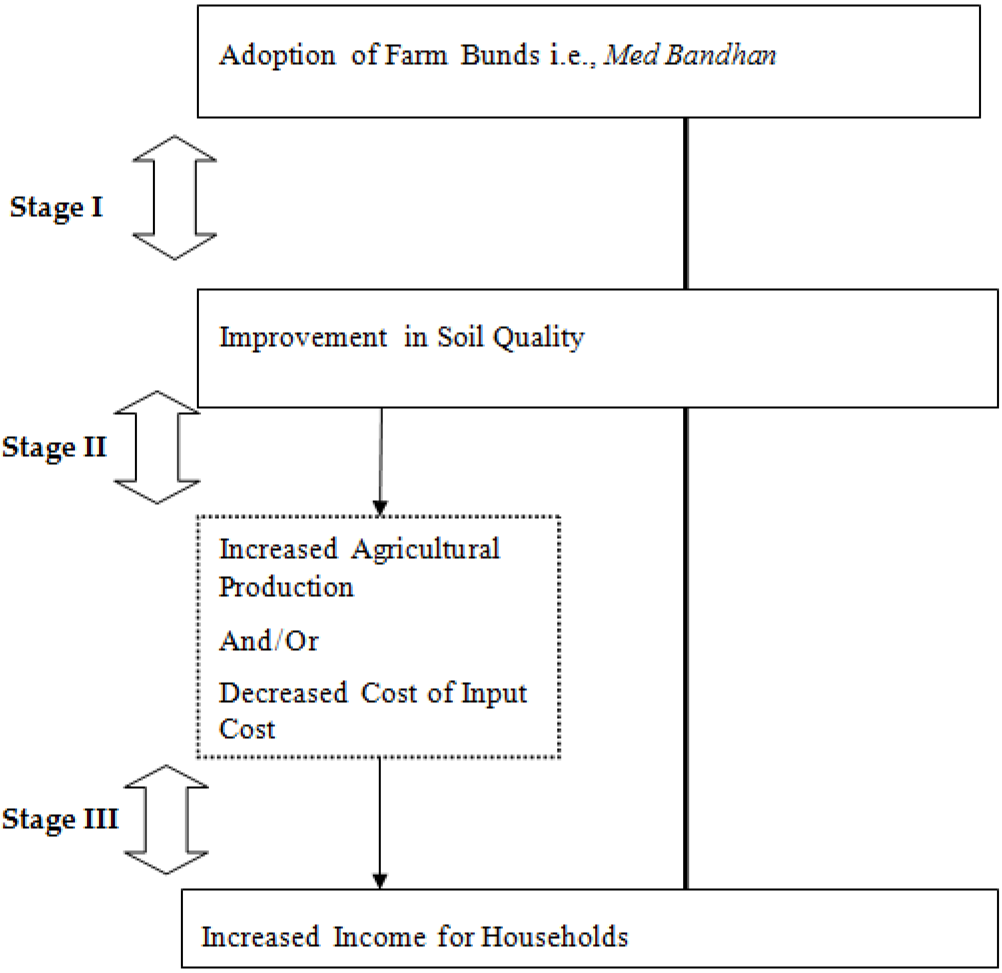

Figure 4.1 The analytical framework used in this case study on water erosion

Source: Adopted from Pattanayak and Mercer (1998)

4.3.2 Data and Analytical Tools

The study used data collected from a primary survey of farming households that adopted farm bunds as a soil conservation measure in their fields. This 'intervention group' was compared with a 'control' group of farmers without farm bunds. The survey covered 225 households spread across four[29] of the nine villages located within two the micro-watersheds of Badgonda and Mehendikund. To measure the impact of farm bund interventions under the IWMP programme on the average productivity of crops, we adopt a regression model. An improvement in the average productivity of a crop is considered to be a proxy for the improvement in the welfare of the people. Such an increase in productivity results in an enhancement of income and livelihood diversification. Farm bund interventions also provide various direct and indirect benefits to households. The regression model used is:

$$AP = \alpha_0 + \alpha_1{*}H + \alpha_2{*}C + \alpha_3{*}SI + \alpha_4{*}PI + \alpha_5{*}I + \alpha_6{*}CV + \varepsilon$$

[29] The farm bunds as an intervention were implemented only in these four villages as the agricultural land in these four villages are more undulating and hence more prone to water erosion.

Where α_r (r=0/ 1/ 2/ 3/ 4/ 5) represents the coefficients which measure the degree of impact of each independent factor on the dependent variable and their sign (+ve or –ve) represents the direction of impact.

AP represents improvement in the welfare of people measured in terms of average productivity i.e. production per unit of land.

H is the average years of education attained by each household.

C represents the average cost of cultivation which comprises of labour costs, capital costs and raw material costs.

SI represents a soil index which includes average soil type, average soil depth, average soil fertility and average soil erosion. The details are provided below.

PI represents a plot index which includes average distance from home, average distance from source of irrigation and percentage of sloping land.

I is a dummy variable representing the presence of a farm bund. A value of '1' represents the presence of a farm bund in the plot while '0' indicates its absence.

CV represents any other control variable such as soil type, soil depth, soil fertility or soil erosion, whose impact is considered individually apart from the soil index.

The soil index and the plot index

The soil index and plot index were computed from the primary data collected through a household survey. Soil index comprises of variables representing soil characteristics such as average soil type, average soil depth, average soil fertility and average soil erosion. The index is created with the help of principal component analysis (PCA). Data of three variables were in qualitative form which was first converted into quantitative form. In case of soil type, a value of '1' is assigned to black soil, '0.5' to brown soil and '0' to red and other type of soil. In case of soil fertility, a value '1' is given if the soil fertility is very good, '0.66' if it is good, '0.33' if it is poor and '0' in case of very poor soil fertility. In case of soil erosion, a value of '1' is assigned if there is no erosion, '0.5' is assigned if there is medium erosion and '0' in case of high erosion. Average values of all the four variables were standardized and were uni-directional. Following this, a PCA was carried out and a soil index calculated. The soil index was then standardized. Higher values of the index represent enhanced quality of soil, increased soil depth, higher fertility and less soil erosion. Similarly, a plot index was calculated. As mentioned earlier the plot index comprises of variables representing plot characteristics such as average distance of plot from home, average distance of plot from source of irrigation and percentage of sloping land. The plot index was also created using PCA. Higher values of the plot index represent lower distances of the plot from home, as well as from sources of irrigation and lower land slopes.

The operationalization of the analytical framework and tools discussed above involved selection of sites and collection of primary data through household surveys among the farming households. The details of site selection and the household survey are discussed below.

4.3.3 Selection of Study Site

As discussed in Chapter 1, Vol. I, the project followed a three-tier system to select the site for a micro-economic assessment. The first criterion for site selection was to identify states lying within the drylands. The second tier for site selection was to include those states most impacted by land degradation as well as those encompassing the major processes of land degradation (water, wind, salinity/ alkalinity, vegetal). Water erosion is the dominant causal mechanism for land degradation in our country and Madhya Pradesh ranks second in terms of land degradation brought about by water erosion (ICAR-NAAS (2010) (see Figure 4.2).

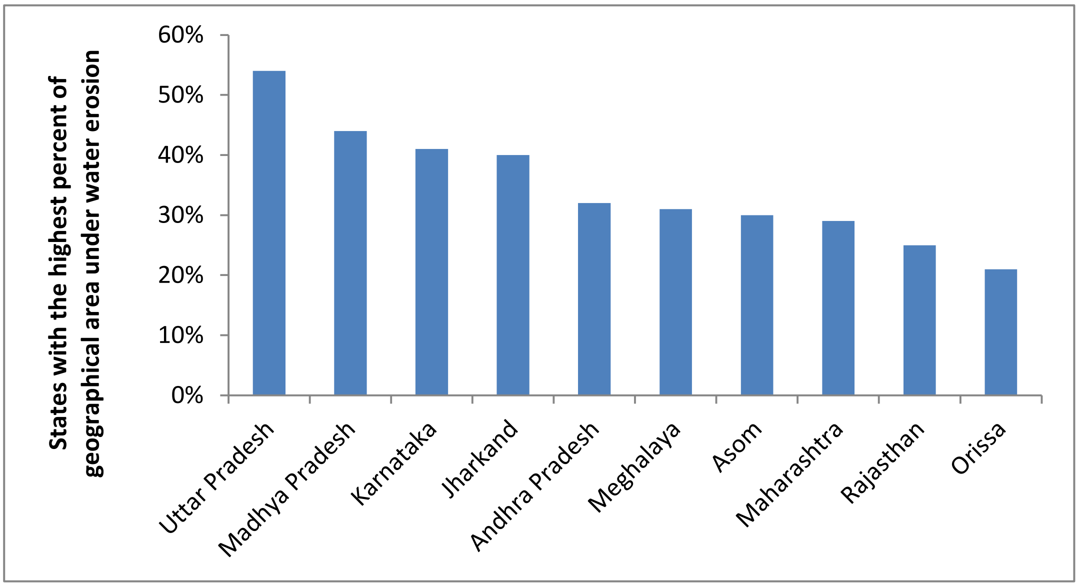

Figure 4.2 Top ten states that are most impacted by water erosion

Source: ICAR-NAAS (2010)

The state comprises of semi-arid and dry sub-humid areas and its share in the total degraded area of the country is 11.71%. Consequently, Madhya Pradesh was selected for an assessment of the costs of degradation resulting from water erosion. An analysis of the state's degradation status from ICAR, 2010 (Table 4.2) indicates that the state accounts for as much as 16% of the country-wide area affected by category 1 or water erosion and by category 2 or water erosion under open forest as well as category 4 or acid soils under water erosion (ICAR, 2010). The share of each class of degradation in the total area of MP was 84.29% for water erosion and 11.24% for water erosion under open forests.


Photo 4.1 Land degradation resulting in production losses for farmers

Photo Courtesy: Bibhu Prasad Nayak

Note: Surface run off is a major cause of land degradation in the region causing huge productivity loss. The depth of the soil in most of the land is less than 15 cm.

When the analysis was repeated on a district basis, Indore was the most degraded district (Figure 4.3, 4.4, and 4.5) and hence was selected as the case study district.

Table 4.2 Share of Madhya Pradesh in the country-wide area affected by degradation and share of class in degraded area of Madhya Pradesh

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Share of Madhya Pradesh in the country-wide area affected by the class of degradation (%)																		
16.05	17.05	2.38	5.80	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.84	4.62	0.00	5.00	0.00	9.23	0.00
Share of class in total degraded area of Madhya Pradesh (%)																		
84.29	11.24	0.86	2.36	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.35	0.00	0.01	0.00	0.17	0.00

1 **Exclusively water erosion (>10 tonnes/ha/yr);**
2 **Water erosion under open forest;**
3 Exclusively acid soils (pH <5.5);
4 **Acid soils under water erosion;**
5 Acid soils under open forest;
6 Exclusively wind erosion;
7 Exclusively saline soils;
8 Eroded saline soils;
9 Acid saline soils;
10 Saline soils under wind erosion;
11 Saline soils under open forest;
12 Waterlogged saline soils;
13 Exclusively sodic soils;
14 Eroded sodic soils;
15 Sodic soils under wind erosion;
16 Sodic soils under open forest;
17 Eroded sodic soils under open forest;
18 Mining/Industrial waste;
19 Waterlogged area (Permanent)

Source: ICAR and NAAS (2010)

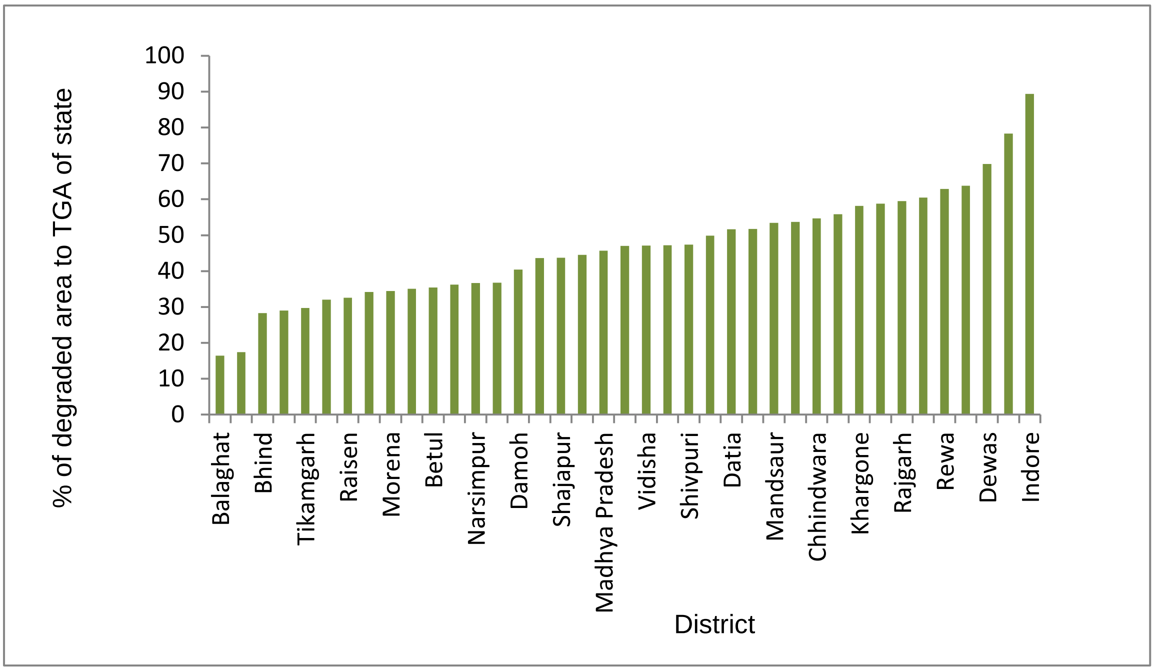

Figure 4.3 Share of MP districts in state-wide degradation (%)

Source: ICAR and NAAS (2010)

Note: TGA: Total Geographical Area of State

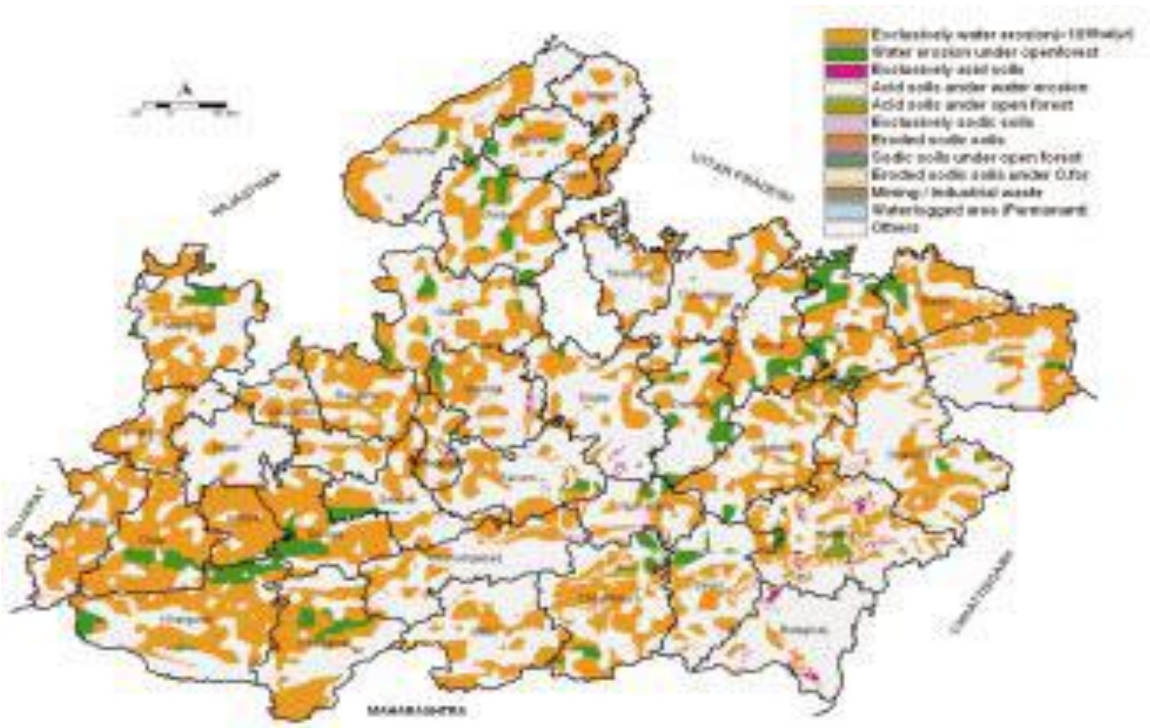

Figure 4.4 Degraded areas of Madhya Pradesh

Source: ICAR and NAAS (2010)

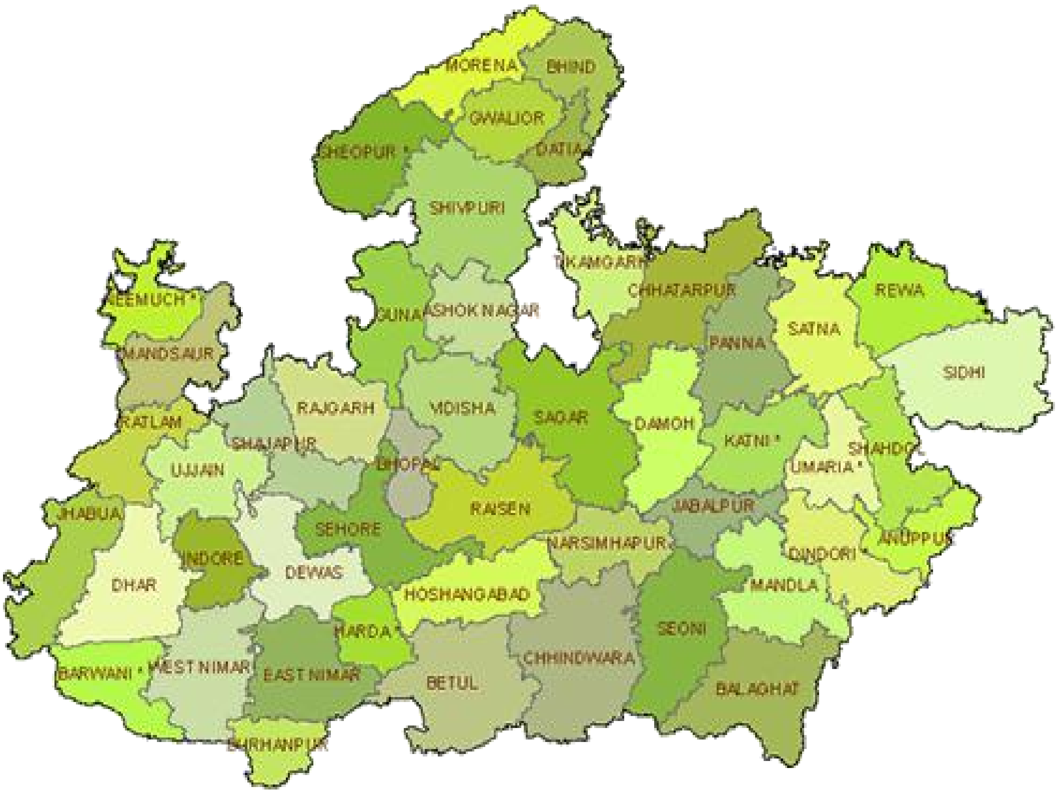

Figure 4.5 District map of MP

Source: ICAR and NAAS (2010)

4.3.4 The Household Survey

As discussed earlier, there are nine villages under IMWP II in Mhow block of Indore district. Farm bunds have been implemented in four of these nine villages. The household survey was carried out in all four villages. The household survey covered 225 households, of which 150 farmer household have plots of land where farm bunds were built (the intervention group) while 75 farmer households did not have farm bunds and are included in the control group. In terms of sample selected we interviewed almost all the beneficiary households[30] in the four villages. The non-adopting farmers selected for our survey included immediate neighbours (in terms of location of farm plots) of the beneficiary farmers.

[30] IWMP Project Office maintains the record of intervention plots, not the beneficiary farmers. So data is unavailable on the percentage of beneficiary households covered by the survey.

Photo 4.2 Land without farm bunds and with farm bunds respectively.

Photo Courtesy: Bibhu Prasad Nayak

Note: The two plots of land were adjacent to each other.

A detailed farmer household survey was conducted in these four villages and farming households are the unit of analysis for the survey. An assessment of the impacts of farm bund interventions was undertaken through collection of primary data. The household survey was undertaken through a structured household questionnaire. The questionnaire included both quantitative as well as qualitative questions and both closed and open-ended questions were asked based on study objectives (See Appendix 4.1).

Several rounds of focus group discussions (FGDs) were conducted in all study villages for a better understanding of the field situation which is critical to the study design. The questionnaires were also tested in the field and revised. The study team visited offices of different agencies responsible for implementation of the IWMP and collected secondary information about the study area.

The questionnaire was designed to collect the following information:

1. The productivity, cost of cultivation and other variables to link soil quality, agricultural production factors and individual household characteristics;
2. Benefits in terms of change in income as well as an indication of change in cropping pattern, increase in number of crops, livelihood change and any other direct/ indirect benefits resulting from farm bund creation.

The questionnaire survey collected information on household demography, land holding number and size, cropping patterns, soil conservation measures adopted by the farmer households, details of the physical characteristics of the farm plots owned and operated by the household, details of crop-wise productivity and input cost of the intervention and control plots, household dependence on forests of the area for firewood, fodder and other needs. Details were collected of the income of the households for the survey year (2015) and five years previously (2010) through recall methods to understand the impact of the intervention.

4.3.5 Description of Study Area

This case study site is located in the Indore district of Madhya Pradesh. Indore is the largest city in Madhya Pradesh and is situated on the Malwa plateau at an altitude of 553 m above sea level, on the banks of two small rivulets-the Saraswati and the Khan. Indore is located geographically between 22°37'29.66''N 75°46'86''E and 22°48'34''N 75°56'32''E at an average altitude of 553 meters above sea level. It is located 190 KM away from the State capital, Bhopal on NH - 3. Indore is spread over an area of 3898 km^2. Indore city area is 13717 hectares and is bounded by the districts of Ujjain to the north, Dewas to the east, Khargone (West Nimar) to the south, and Dhar to the west. (DPR, 2012)

The study site was Mhow block of Indore district, located in the Malwa Plateau in central India. It is located on the intersection of 22° 33" N, Latitude and 75°46" E Longitude. It is 491 meter (1650 feet) above sea level. The vegetation is mainly tropical dry deciduous dominated by *Acacia* species. Mhow is the biggest commercial centre of Madhya Pradesh and is located 23 kilometres south of Indore city. Mhow is the birthplace of Dr. Bhimrao Ambedkar; consequently in 2003 it was renamed Ambedkar Nagar. The climate of Mhow is extreme for most part of the year. The summer is hot with an average maximum temperature of 40° C and average minimum temperature of 25°C. Temperatures sometimes reach 45°C in the months of May and June. The winter is pleasant with average maximum and minimum temperatures of 25°C and 10°C respectively. The monsoon typically reaches here in the first week of June and the maximum rainfall period is between July and September. The average annual rainfall here is 94 cm. There are some important tourist spots located in Mhow block like Patal Pani waterfall and Mehendikund waterfall (DPR, 2012)

4.4 Results and Discussion

4.4.1 Socio-economic profile of the study area

The study focuses on two micro-watersheds of Mhow block- Badgonda and Mehendikund in which farm bunds are used as an intervention to prevent soil erosion. The villages lying within these two micro watersheds are Badgonda, Tinchha, Jhikadiya, Khedi and Badiya. The population of the block is 85,023 as per the 2011 census with 54% males and 46% females. The literacy rate is 72% with male literacy rate of 78% and female literacy rate at 65%. Table 4.3 provides a detailed socio-economic profile of the study villages such as area of the micro-watershed, total number of households and number of landless households, which are compiled from the detailed project reports (DPRs) of the IWMP programme.

Table 4.3 Area of the micro-watersheds and socio-economic profile

Name of the Micro-watershed	Area of the Micro-watershed (in ha.)	Name of the villages	Total number of households in the village	Number of land-less households
Badgonda	2230	Badgonda	429	259
		Tinchha	91	37
Mehendikund	382	Jhikadiya Khedi	17	7
		Badiya	119	23

Source: DPR of Badgonda and Mehendikund watersheds, IWMP II

The geographical area of Mehendikund micro-watershed is about 382 ha while the geographical area of Badgonda micro-watershed is about 2230 ha. Amongst the 4 villages, Badgonda and Badia have the most households. Among all the four villages, the proportion of landless households is highest in Badgonda village. In the Badgonda watershed, most of the agricultural land is irrigated. In contrast in Mehendikund watershed, agriculture is rainfed. Badgonda village in Badgonda micro-watershed has the largest area under fallow land (Table 4.4).

Table 4.4 Land use patterns in the four villages (in ha)

S. No	Name of the Micro Watershed	Name of the Village	Agricultural land			Non-Cultivated Land			Others	Total
			Irrigated	Rainfed	Total	Temporary Fallow	Permanent Fallow	Total		
1	Badgonda	Badgonda	247.59	78.45	326.04	4.81	756.054	760.864	764.31	1761.21
		Tinchha	41.22	4.965	46.185	3.64	244.232	247.872	85.04	379.097
2	Mehendikund	Jhikadiya Khedi	0	12.37	12.37	2.29	0	2.29	255.43	270.01
		Badiya	0	78.77	78.77	0	1.32	1.32	31.83	111.91

Source: DPR of Badgonda and Mehendiknd Watersheds, IWMP II

Table 4.5 indicates land ownership patterns in the four villages. Most of the land is under forest cover in Jhikadiya Khedi village while in Badiya village no forests exist. Private as well as communal ownership of land is highest in Badgonda village.

Table 4.5 Land Ownership in the four villages (Area in ha)

S. No	Name of the Micro Watershed	Name of the Village	Private Land	Forest Land	Community Land/Govt. Owned land	Others	Total
1	Badgonda	Badgonda	1086.90	114.64	649.669	0	1851.20
		Tinchha	294.06	55.893	29.147	0	379.1
2	Mehendikund	Jhikadiya Khedi	14.5	253.78	1.81	0	270.09
		Badiya	90.1	0	20.495	1.32	111.91

Source: DPR of Badgonda and Mehendikund Watersheds, IWMP II

As indicated in figure 4.6, the population is dominated by Schedule Tribes comprising 63% of the population. General category and OBCs together comprise 35% of the population. Only 2% of the population comprises Scheduled Tribes.

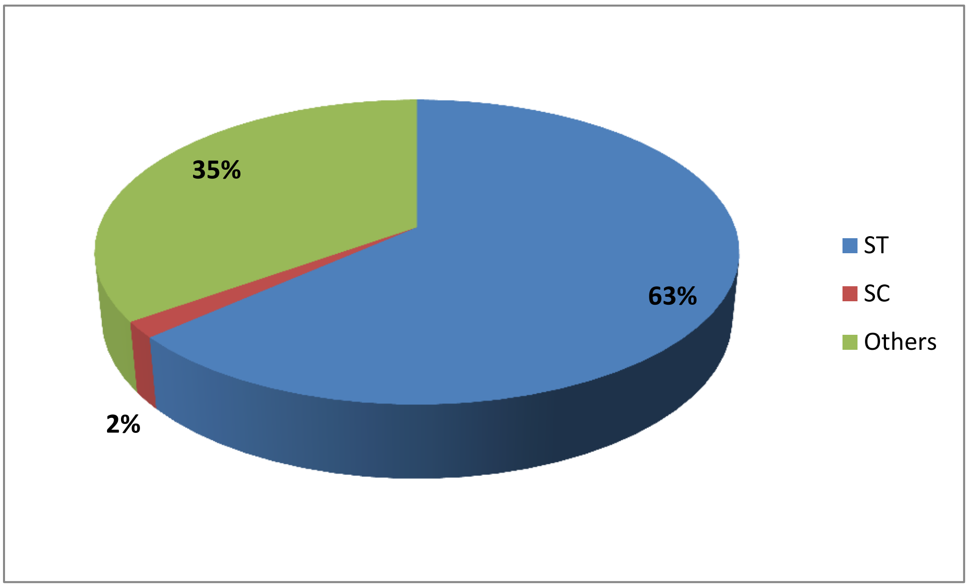

Figure 4.6 Caste distribution of the study area (in % of population)

Source: DPR of Badgonda and Mehendiknd Watersheds, IWMP II

The detailed break up of caste composition for the four villages is provided in Table 4.6. Jhikadiya Khedi has a 100% ST population. Villages like Badiya and Tinchha are also dominated by a ST population accounting for 50% of the total.

Table 4.6 Population distribution of the villages in the micro-watershed area

Village	ST	SC	Others	Total
Badgonda	769	52	995	1816
Tinchha	521	2	110	633
Jhikadiya Khedi	84	0	0	84
Badiya	661	1	11	673
Total	2035	55	1116	3206

Source: DPR of Badgonda and Mehendikund Watersheds, IWMP II

Agriculture is the primary occupation of more than 90% of the households in the area. The major crops grown are soyabean and wheat. Table 4.7 indicates that soyabean is the major *kharif* (monsoon) crop in both Mehendikund and Badgonda micro-watersheds and is grown in 77.8 % and 54.62% of the total sown area respectively. Other kharif crops in Mehendikund micro-watershed are maize, groundnut and a combination of maize and soyabean (simultaneous production by partition in the field). Other important kharif crops in Badgonda micro watershed are maize, groundnut, pumpkin and a combination of maize and soyabean.

Table 4.7 Area under *kharif* (monsoon) crops (in ha)

Village Name	Maize	Maize and Soyabean	Soyabean	Groundnut
Jhikadiya Khedi	1.764	9.546	2.453	1.758
Badiya	2.9875	6.567	75.2	5.786
Badgonda	1.00	91.28	172.54	2.40
Tinchha	0	14.19	30.77	0.49

Source: DPR of Badgonda and Mehendikund Watersheds, IWMP II

Wheat is the major *rabi* (winter) crop in both the micro-watersheds. It is grown in 88.16% of the total sown area in Mehendikund micro-watershed but only in 47.47% in Badgonda watershed. *Rabi* crops grown in this area include *chana*, potato, garlic and onion. In Jhikadiya Khedi village no *rabi* crop is grown due to absence of irrigation. Badia village grows wheat, chana dal, potato and garlic, with the nearby river aiding irrigation. (Table 4.8)

Table 4.8 Area under *rabi* (winter) crops (in ha)

Village Name	Wheat	Chana	Potato	Garlic	Onion
Jhikadiya Khedi	0	0	0	0	0
Badiya	78	2.145	8.645	2.465	0
Badgonda	105.2	8.65	111	6.29	13.9
Tinchha	31.85	0.57	8.78	0	0

Source: DPR of Badgonda and Mehendikund Watersheds, IWMP II

In the Mehendikund micro-watershed area there are 92 cows, 58 buffaloes, 205 goats and 98 bullocks. In the Badgonda micro- watershed area there are 566 cows, 267 buffaloes, 243 goats and 140 bullocks. Cows and buffaloes are of local breeds. In the micro-watersheds, milk productivity is low due to the shortage of green fodder.

The soil types in the area are red, black and brown soil. Red soil predominates comprising more than 50% of the micro-watershed area. The depth of red soil is about 1.5-2.5 feet and this soil is least fertile. Black soil is considered most fertile followed by the brown soil.

4.4.2 Socio-economic profile of sample households

The household size in the study area ranges between 2-14 persons, with an average of 4 people per household. The age of household head varies from 25 years to 75 years, with an average of 50 years. Household head as used in the study refers to the member of the family who makes key decisions and whose authority is recognized among all other members of the household. Out of 225 household heads, 99 heads are educated and have received some years of education. Out of these 99 household heads, average years of education are 8 years and one-third of them have 10 or more than 10 years of formal education.

All the households studied in the sample were agro-pastoralists, practicing some crop farming alongside livestock holding. Major source of income for the households studied in the sample is agriculture. Non-agricultural income is obtained through livestock rearing and through off-farm activities. Livestock comprised of bullocks, cows, buffaloes, calves, goats, and sheep (figure 9). Off- farm income generating activities included non-agricultural income (salary and wage labor), and income from other sources (rent from leased- out land/ room, business, pension). On average, the number of families engaged in livestock rearing has increased over time for both groups. Farm sizes ranged from 1 hectare to 15 hectare in the sample. In the sample, 52 % of the famers are marginal farmers while the figures for small and large farmers are 41 and 7.8 % respectively. In the sample, soyabean and wheat are grown on an average in 4.2 and 3.8 hectares.

Photo 4.3 Livestock in the area

Photo 4.4 Open grazing by goats

Photo 4.5 A fuelwood headload.

Photos Courtesy: Bibhu Prasad Nayak

Most of the households in both the groups (approximately two-third for the intervention group and three-fourth for the control group) have cooking arrangements in their house. In case of consumption of cooking fuel, there is a minor difference in the usage of LPG and firewood among farmers with and without the intervention (Figure 10)[31]. For example, LPG consumption is marginally higher among farmers of the control group. Similarly, there are marginal differences among farmers of the two groups regarding frequency of firewood collection (Figure 4.8). As an indicator of educational qualifications, average literacy rate (number of literate members as a proportion of total household members) was measured but, there is little difference between the two groups (Figure 4.9)[32]. These results suggest that the intervention and control groups are relatively similar in their social composition, education, farm sizes and in their use of fuel sources.

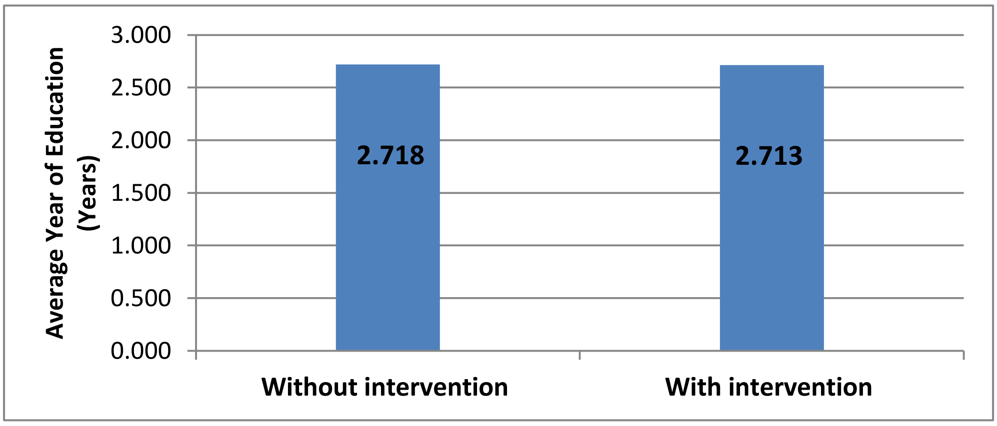

Figure 4.7 Average household consumption of fuel by category in control and intervention groups

Source: Primary data.

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[31] t-value = -0.2057 and *df* = 98.5246 in case of Firewood and twigs and t-value = 1.1271 and *df* = 76.5836 in case of LPG

[32] t-value = 0.5441 and *df* = 88.0883 in case of education

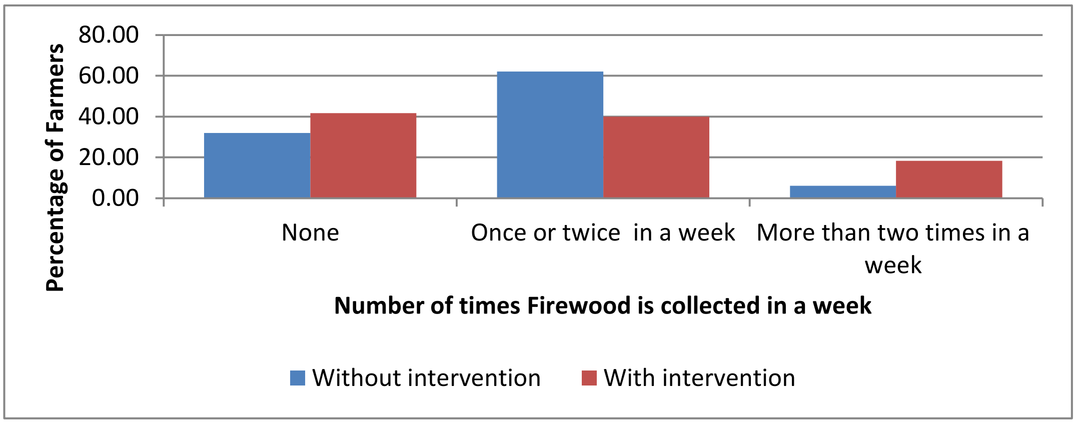

Figure 4.8 Frequency of firewood collection per week in control and intervention groups
Source: Primary data.

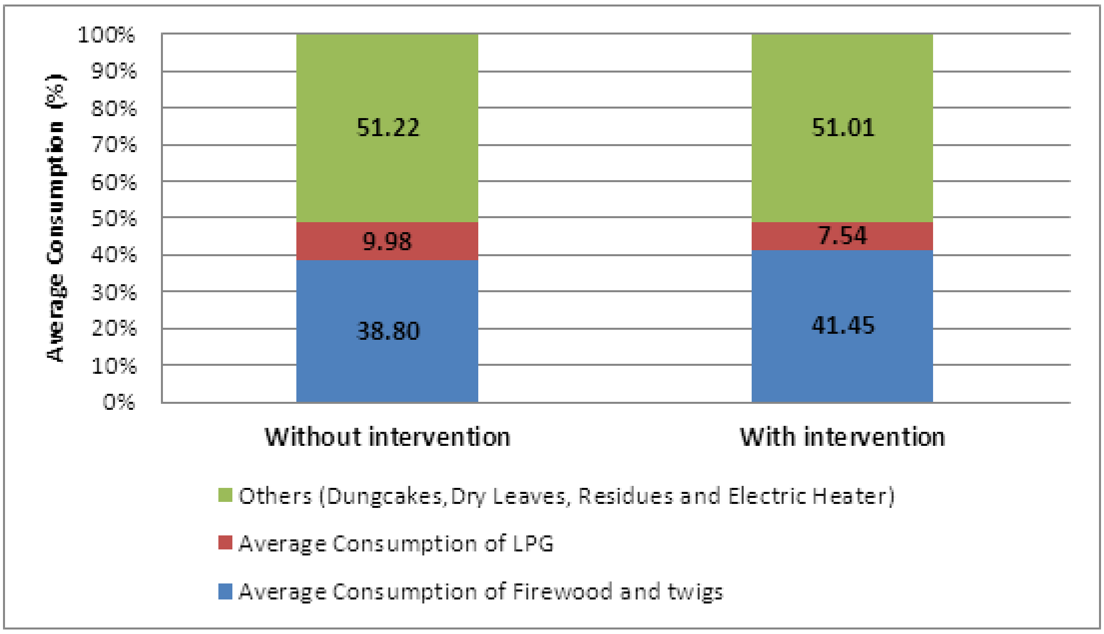

Figure 4.9 Average number of years of education attained by households in each group
Source: Primary data.

Figure 4.10 shows the socio-economic characteristics of the household considered in the sample. Majority of the households are electrified irrespective of the group they belong to.[33] About 75% of households in the intervention group are electrified while the figure is 80% in the control group. However, there is a difference in source of drinking water but this is not statistically significant.[34] While the majority (52%) of farmers from the intervention group use tube-wells as a major source of drinking water, the control group uses other sources of drinking water. Similarly, while the majority (54%) of the control group are BPL card holders, the majority (53%) of farmers from the intervention group are above the poverty line. However, most of the farmers irrespective of their group, utilize PDS facility. Similarly,

[33] t-value = -1.5675 and *df= 93.5592* in case of household electrification

[34] t-value = 0.7769 and df= 73.5166 in case of source of drinking water

the majority of each group has a MNREGA card. But very few of the households from either group are benefited by the housing scheme of the government. None of the socio-economic differences discussed above are statistically significant[35]. It implies that the differences are only minor and the sample households both in control and treatment group are relatively similar on a range of parameters. This suggests that any difference that emerges between the two groups is likely related to the intervention.

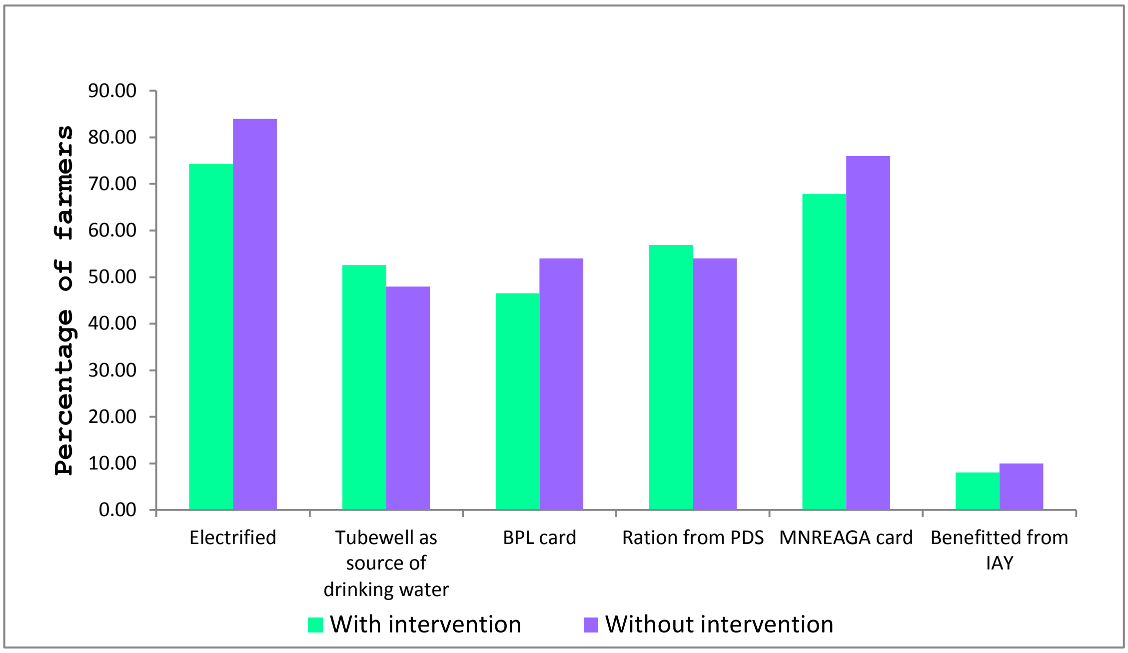

Figure 4.10 Socio-economic characteristics of sampled households

Source: Primary data.

Note: IAY refers to Indira Awaas Yojana

4.4.3 Adoption of farm bund interventions and their efficacy

Farmers from the intervention group were asked about the benefits of farm bunds. Farmers indicated that increased productivity (51% of households sampled) followed by recharge of wells (34%) were the most important benefits provided by the farm bund intervention (Figure 4.11). These results suggest that farm bunds are an effective measure to control water erosion and consequently lead to benefits of enhanced productivity and ground water recharge.

[35] t-value= -0.9570 and *df* = 79.9155 in case of BPL card, t-value= -1.2140 and *df* = 86.5014 in case of household members hold MNREGA card, t-value= 0.3194 and *df* = 79.5334 in case of ration from PDS and t-value= -0.4207 and *df* = 74.0264 in case of IAY

Photo 4.6 Image showing improvement in soil fertility and soil moisture as a result of farm bund creation

Photo Courtesy: Bibhu Prasad Nayak

This finding is in line with Bhaskar et al (2014) who confirm increases in agricultural productivity along with water level improvement in case of Gujarat and Chhattisgarh as a result of water erosion interventions. Farmers from the control group were asked why they had not adopted farm bund interventions. A number of reasons were voiced including the absence of provisions for farm bunds[36] (23%), inadequate land available to construct these bunds (23%), and a lack of awareness about the benefits (21%) (Figure 4.12). In a recent study, Gopinath (n.d.) has also concluded that except Maharashtra, there is significant lack of awareness and understanding among farmers regarding IWMP interventions across the country.

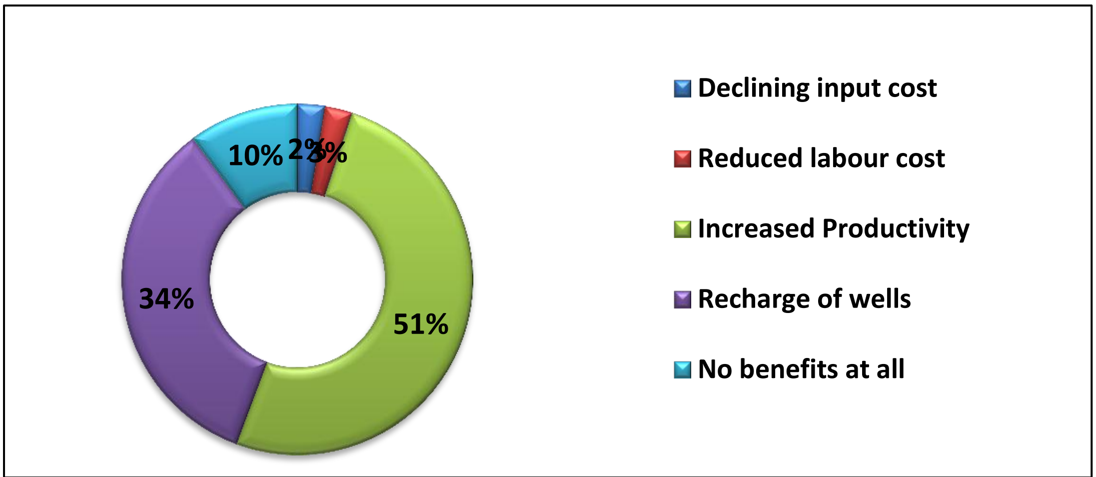

Figure 4.11 Reported benefits of farm bunds (in % of households surveyed in the intervention group)

Source: Primary data.

[36] The farm plots for these households are located outside the intervention area identified/ demarcated by the project.

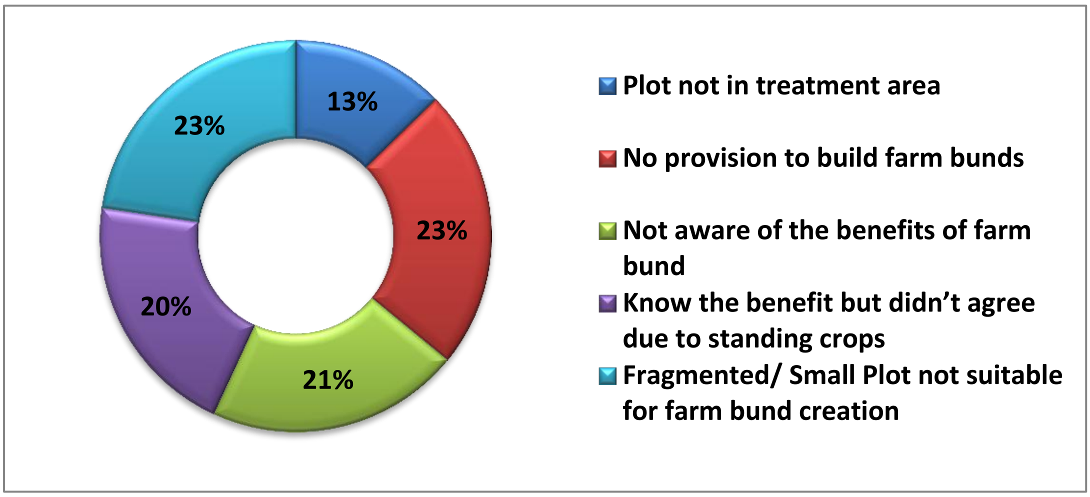

Figure 4.12 Reasons for non-adoption of farm bunds under IWMP programme

Source: Primary data.

4.4.4 Agricultural benefits and farm incomes deriving from farm bunds

Soyabean and wheat are the two most important crops in the study area. While almost all the farmers produce soyabean, most of them also produce wheat as second crop. Potatoes and onions are also grown by some farmers in the study area. This is in line with socio-economic profile of the study area described earlier Wheat is the major *rabi* crop grown in 88.16% of the total sown area in Mehendikund micro-watershed while it is grown in 47.47% of the total sown area in Badgonda watershed. Soyabean is the major kharif crop grown in 77.8% of the total sown area in Mehendikund micro-watershed and 54.62% in Badgonda watershed. Farmers were asked about their production and the cost of cultivation for each of the crops they produce. They were also asked about the sale price of each of the crops. With this information the profit and average profitability per unit of land was calculated.

The average productivity is higher in case of the intervention group as compared with the control for each of the four crops they produce in the study region (Figure 4.13). However, the average cost of cultivation was lower in the intervention group compared to the control group only in case of soyabean and wheat (Figure 4.14). *This result suggests that farm bunds have a positive impact on average productivity for all the four crops although the cost of cultivation is only reduced for soyabean and wheat*. When profit (=production*price-cost of cultivation) was calculated, the results indicated that average profitability per farmer is higher in the intervention group only in case of soyabean and wheat (Figure 4.15). However, for the other two crops, on an average, farmers incurred economic losses from their production. This may be due to loss in production or fall in sale price.

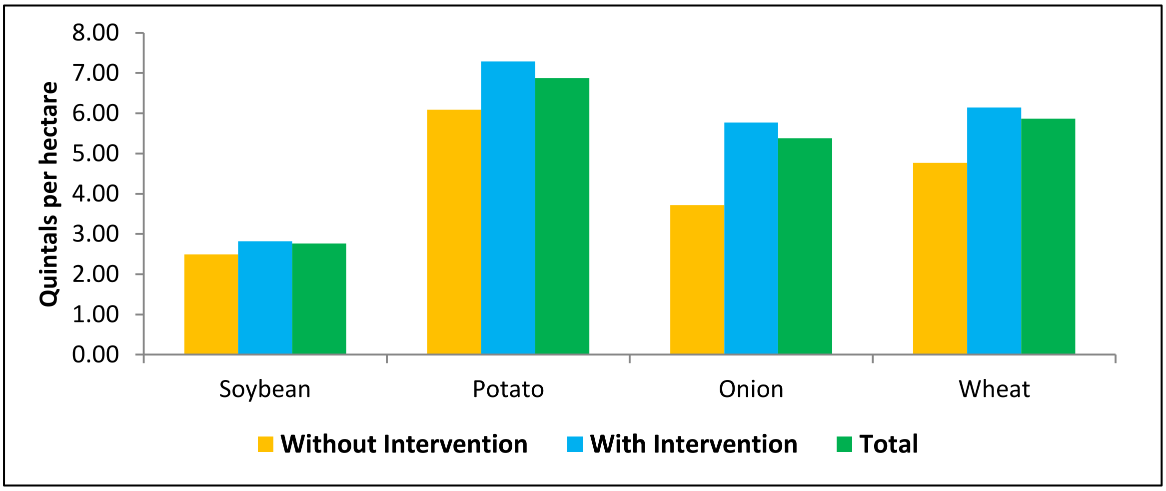

Figure 4.13 Graph showing productivity of crops for the control and intervention group
Source: Primary data

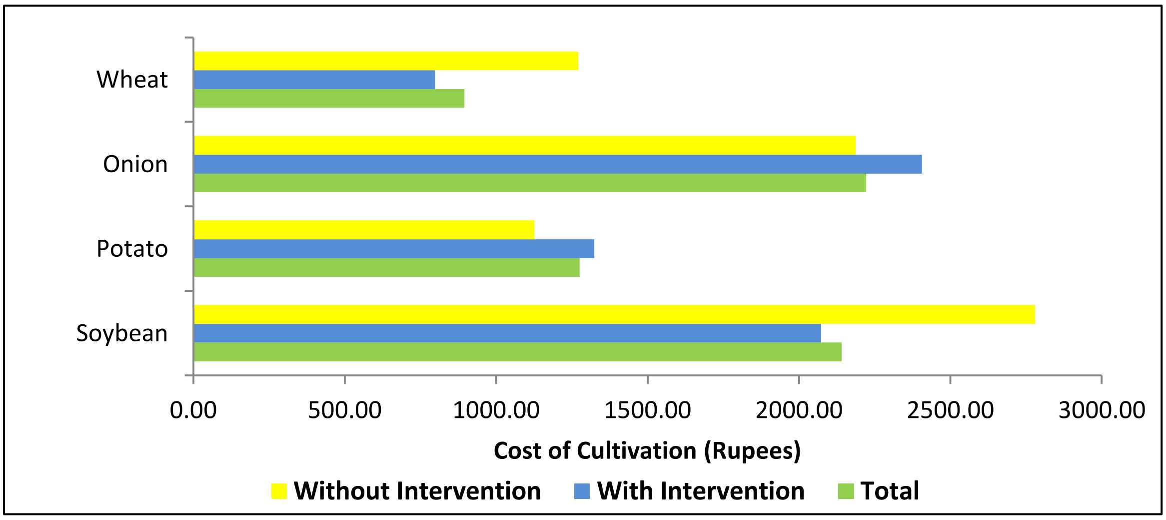

Figure 4.14 Graph showing cost of cultivation for the control and intervention group
Source: Primary data

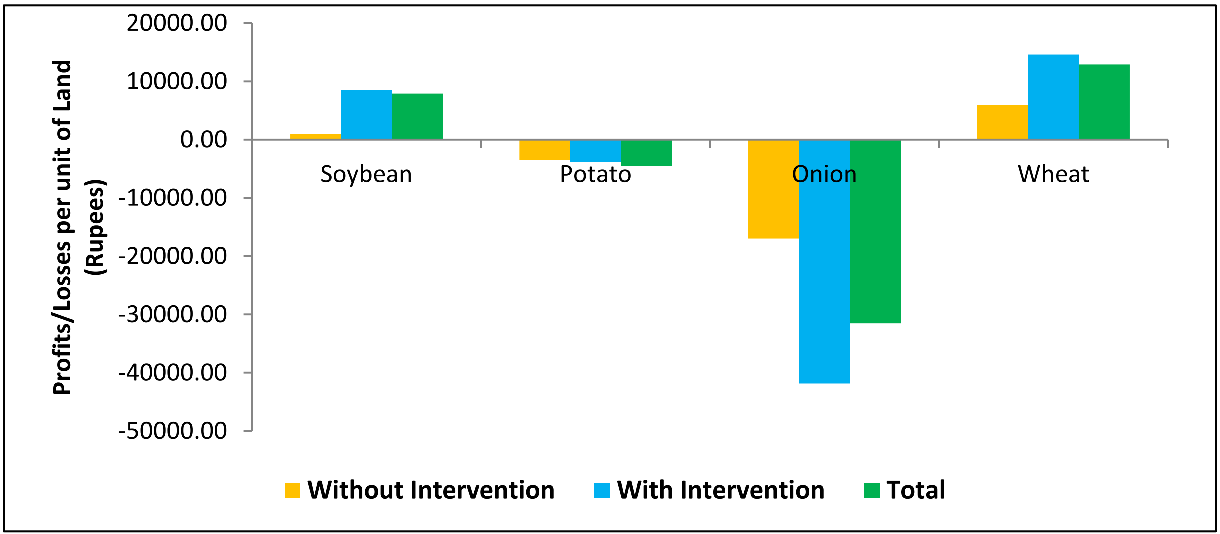

Figure 4.15 Graph showing profit per unit of land for each crop

Source: Primary data

The primary data reveals that average profitability per unit of land for an average farmer in the intervention group is higher than that of the control. It suggests that farm bunds, interventions to reduce water erosion, have positively impacted the profitability of both soyabean and wheat. Thus, farm bunds appear to be an effective land degradation measure against water erosion, at least for the study site which is very prone to the problem. However this is true mainly for soyabean and wheat which are extensively cropped in the study area. In fact, wheat is the major *rabi* crop (88.16% of the total sown area in Mehendikund micro watershed while 47.47% area in Badgonda watershed is under wheat) and soyabean is the major *kharif* crop (77.8 % of the total sown area in Mehendikund micro watershed while in 54.62% area in Badgonda watershed is under soyabean) in this area. Thus if the intervention is able to generate significant benefits from soyabean and wheat, it will have an overall beneficial impact on the study area. But the intervention does not appear to lead to increased yields of potatoes and onions. This may be due to the nature of these crops (both are vegetables) or weather conditions prevailing during the period of cultivation or because of the low land areas under potato and onion cultivation or because five years is too early for the farm bunds to translate into positive outcomes for these two crops. Farm bunds were created in the 2012 in the study area while our survey was conducted just three years later in 2015. Thus it may be too short a period to judge the full impact of the programme as benefits of the intervention might not have been realized yet.

The difference in cost of cultivation and production, i.e., increase in incomes or gain in average productivity or savings in the average cost of cultivation are the benefits realized by farmers within the intervention group. In other words, the differential between the intervention group) and control group is the benefit of the farm bund intervention. In case of soyabean, on average, the intervention group has 12% higher productivity compared to the control group (average productivity is 2.82 qnt/ ha vis-à-vis 2.49 qnt/ ha for with and without intervention groups) while the cost of cultivation for the intervention group is 26% lower than the control (in monetary terms, average cost of cultivation is INR 5981 per ha vis-à-vis INR 8051 per ha for with and without intervention group). In case of wheat, the intervention group has 22% higher productivity (average productivity is 6.15 qnt/ ha vis-à-vis 4.77 qnt/ ha for with and without intervention groups) while the cost of cultivation is

21% lower than for the control group (average cost of cultivation is INR 4314 per ha vis-à-vis INR 5473 per ha for with and without intervention group). Since, both groups of farmers are similar on a range of socio-economic parameters, the difference in productivity and cost of cultivation can possibly be attributed to benefits of the intervention. Other reasons for the change could be that farmers invest more in response to the creation of farm bunds. Even if this is true, the end results irrespective of whether they are directly related to physical changes in the land or to behavioural changes in the farmers point to the success of farm bunds in causing productivity gains or savings in the cost of cultivation.

The results suggest that farmers within the intervention group are benefitted by the farm bund intervention because of savings obtained from declines in the average cost of cultivation and/ or gains in average productivity. But farmers who produce wheat and soyabean are the most benefitted from farm bunds. These savings in average cost of cultivation (for wheat and soyabean) and gains in average productivity are the cost of land degradation in absence of water erosion control interventions. That is, farmers without farm bunds lose these benefits to water erosion, and their decreased agricultural productivity and lower incomes are in essence the 'costs of land degradation.'

In short the results suggest that farmers who have adopted farm bunds have benefitted from them. In the pre-intervention period, there was no significant difference[37] in average income between the intervention and control groups while there is a significant difference[38] in average income between the groups in the post-intervention period. Moreover, the average income has increased for both the control and intervention groups, while the intervention group report a higher increase (48%) in average income compared to the control group (31%) in monetary terms (Figure 4.16).

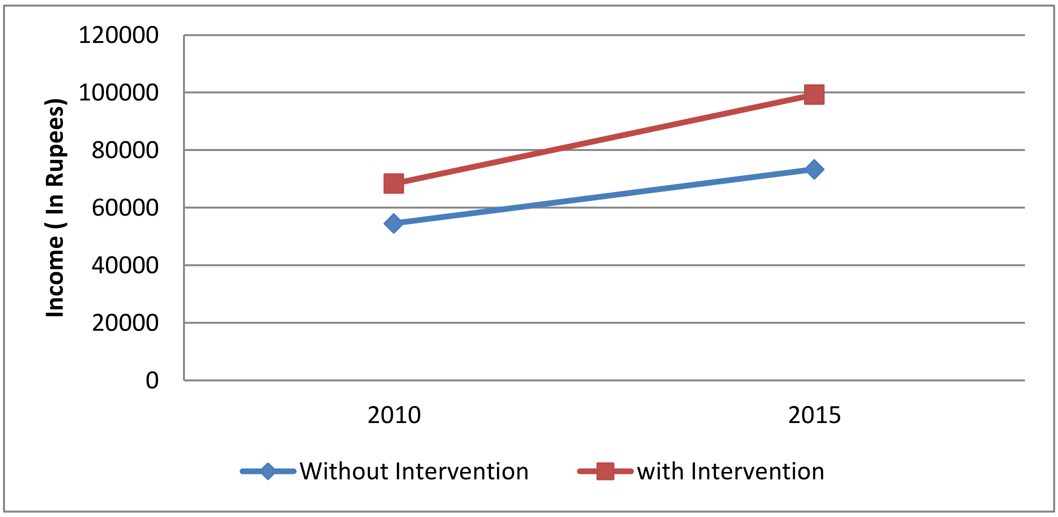

Figure 4.16 Change in income of the households in the study area over a five year period

Source: Primary data.

[37] t-value = -2.6242 and *df*= 178.962 for income in pre-intervention period

[38] t-value = -3.4356 and *df*= 158.483 for income in post-intervention period

There could be many other factors (fertility of land, background of the farmer, amongst others) which could influence productivity, the cost of cultivation and profits from cropping. To identify these factors, tease out their relative contribution and measure their impact on productivity, a set of regressions were also conducted. The regression results are presented in Tables 8, 9, 10 and 11. We have considered average education level of household head ("education") as a major explanatory variable as it can indicate the awareness level of the farmers. As discussed in the methodology the other explanatory variables include plot index and soil index along with individual soil characteristics. Another important explanatory variable is average cost of cultivation.

Table 4.9 indicates that the intervention had a significant positive impact on wheat productivity. Cost of cultivation was also significant for wheat productivity. Similar results were obtained for soyabean productivity and on the costs of cultivation (Table 10). In the case of onions and potatoes, the intervention did not have a significant impact on productivity, although the costs of cultivation in both cases were significant and positive. The results suggest that farmers within the intervention group are benefitted by the farm bund intervention because of improvement in average productivity (for wheat and soyabean). The gains in average productivity (for wheat and soyabean) are the cost of land degradation in absence of water erosion control interventions. That is, farmers without farm bunds lose these benefits to water erosion, and their decreased agricultural productivity and lower incomes are in essence the 'costs of land degradation.' As mentioned earlier, for soyabean, average productivity is 2.82 qnt/ha for the intervention group vis-à-vis 2.49 qnt for the control group. Similarly, average productivity for wheat is 6.15 qnt/ha for the intervention group vis-à-vis 4.77 qnt/ha for the control group. and lower costs of cultivation (average cost of cultivation is INR 5981 per ha for the intervention group and INR 8051 per ha for the control group in case of soybean while the average cost of cultivation is INR 4314 per ha for the intervention versus INR 5473 per ha for the control in case of wheat. Therefore, the average profitability per unit of land for an average farmer in the intervention group (INR 2192 per ha for soybean and INR 3940 per ha for wheat) is higher than that of the control group (INR 524 per ha for soybean and INR 751 per ha for wheat). These savings in average cost of cultivation and gains in average productivity are the cost of land degradation in absence of water erosion control interventions.

Table 4.9 Impact of intervention on average productivity of wheat

	Average Productivity of Wheat							
	b/se	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
Intervention	2.240***	2.258***		2.253***				
	(0.65)	(0.65)		(0.65)				
Soil index	1.305		1.409					
	(1.25)		(1.29)					
Plot index	0.486	0.575	-1.162	0.556	-1.175	-1.297	-0.962	-0.093
	(1.89)	(1.89)	(1.88)	(1.92)	(1.90)	(1.94)	(2.07)	(1.96)
Education	0.088	0.078	0.071	0.079	0.065	0.062	0.061	0.072

Average Productivity of Wheat								
	b/se	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**	**b/se**
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Average cost	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soil Type				0.044	0.269			
				(0.67)	(0.68)			
Soil Fertility						0.696		
						(1.55)		
Soil Erosion							0.036	
							(0.28)	
Soil Depth								3.293
								(1.98)
Constant	-0.199	0.498	3.058	0.494	3.768*	3.577*	3.668	2.499
	(1.93)	(1.81)	(1.73)	(1.82)	(1.59)	(1.68)	(2.03)	(1.76)
No. of Obs.	161	161	163	161	163	163	163	163
Significance	0	0	0	0	0	0	0	0
Adjusted r-square	0.326	0.325	0.278	0.321	0.273	0.273	0.272	0.285

Note: *Significant at 1% level, **Significant at 5% level and ***Significant at 10% level.

Table 4.10 Impact of intervention on average productivity of soyabean

Average Productivity of Soyabean								
	b/ se	b/ se	b/ se	b/ se	b/ se	b/ se	b/ se	b/ se
Intervention	0.564*	0.552*		0.556*				
	(0.27)	-0.264		(0.27)				
Soil index	0.154		0.08					
	(0.33)		(0.33)					
Plot index	0.314	0.325	0.195	0.297	0.183	0.147	0.149	0.218
	(0.44)	-0.439	(0.44)	(0.44)	(0.44)	(0.46)	(0.46)	(0.49)

Average Productivity of Soyabean								
education	-0.003	-0.004	0.002	-0.003	0.002	0.002	0.001	0.002
	(0.02)	-0.022	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Average cost	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00
Soil Type				0.086	0.057			
				(0.18)	(0.18)			
Soil Fertility						0.155		
						(0.37)		
Soil Depth							-0.197	
							(0.48)	
Soil Erosion								0.005
								(0.07)
constant	-0.104	-0.017	0.592	-0.045	0.615	0.588	0.701	0.606
	(0.52)	-0.483	(0.41)	(0.49)	(0.38)	(0.39)	(0.42)	(0.51)
No. of Obs.	117	117	121	117	121	121	121	121
Significance	0	0	0	0	0	0	0	0
Adjusted r-square	0.744	0.745	0.734	0.744	0.734	0.734	0.734	0.734

Note: *Significant at 1% level, **Significant at 5% level and ***Significant at 10% level.

Table 4.11 Impact of intervention on the average productivity of onions

Average Productivity of Onions								
	b/ se	b/ se	b/ se	b/ se	b/ se	b/ se	b/ se	b/ se
Intervention	0.03	-0.123		-0.084				
	(0.63)	(0.66)		(0.70)				
Soil index	2.921		3.105					
	(1.44)		(1.98)					
Plot index	-5.859	-4.661	11.914*	-4.948	11.466*	11.816**	10.668*	-8.275

Average Productivity of Onions								
	(3.36)	(3.53)	(4.28)	(3.84)	(4.68)	(3.93)	(4.42)	(4.75)
Education	0.197*	0.193*	0.069	0.196	0.073	0.024	0.063	0.081
	(0.09)	(0.09)	(0.12)	(0.10)	(0.12)	(0.11)	(0.12)	(0.12)
Average cost	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soil Type				0.185	0.554			
				(0.86)	(1.10)			
Soil Fertility						5.946*		
						(2.30)		
Soil Depth							-0.262	
							(3.28)	
Soil Erosion								0.606
								(0.53)
Constant	3.138	3.839	9.803*	3.965	10.877*	7.960*	10.569*	7.333
	(3.07)	(3.25)	(3.71)	(3.37)	(3.91)	(3.57)	(3.94)	(4.67)
No. of Obs.	28	28	30	28	30	30	30	30
Significance	0	0	0	0	0	0	0	0
Adjusted R-square	0.732	0.696	0.524	0.683	0.483	0.588	0.478	0.504

Note: *Significant at 1% level, **Significant at 5% level and ***Significant at 10% level.

Table 4.12 Impact of intervention on average productivity of potatoes

Average Productivity of Potato								
	b/ se	b/ se	b/ se	b/ se	b/ se	b/ se	b/ se	b/ se
Intervention	0.417	0.393		0.453				
	(0.70)	(0.71)		(0.70)				
Soil index	2.208		2.092					
	(1.55)		(1.51)					
Plot index	-0.495	-0.106	-0.377	-1.01	-0.892	-0.046	0.238	-0.589

Average Productivity of Potato								
	(3.02)	(3.04)	(2.78)	(3.02)	(2.79)	(2.83)	(2.80)	(2.99)
Average cost	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soil Type				1.271	1.219			
				(0.75)	(0.74)			
Soil Fertility						0.609		
						(2.20)		
Soil Depth							2.826	
							(2.92)	
Soil Erosion								-0.233
								(0.39)
constant	3.379	4.65	3.597	4.577	4.750*	4.326	4.16	5.687*
	(2.76)	(2.64)	(2.41)	(2.58)	(2.24)	(2.78)	(2.37)	(2.78)
No. of Obs.	44	44	46	44	46	46	46	46
Significance	0	0	0	0	0	0	0	0
Adjusted r-square	0.348	0.331	0.355	0.36	0.367	0.327	0.34	0.331

Note: *Significant at 1% level, **Significant at 5% level and ***Significant at 10% level.

4.5 Scenario development for 2030

For the State of Madhya Pradesh, we project the area likely to be impacted by water erosion in 2030 utilising data from 2003/ 05 and 2011/ 2013 of the Space Applications Centre. We then use these estimates to determine the costs of reclamation of water erosion for the State of Madhya Pradesh in 2030. The extent of water erosion in 2030 is shown in Table 4.13. The extent of water erosion in the State shows an increasing linear trend (Fig 4.17) based on available data ($y = 5197x + 1115024$; $R^2 = 1$). According to the Pradhan Mantri Krishi Sinchayee Yojna (2015), the watershed norms for land reclamation is Rs 12,000 in the plains and Rs 15,000 in the hills. Using the higher values of Rs 15,000/ ha, the cost of reclaiming lands degraded by water erosion in 2030 is Rs 17076 million in 2015 prices.

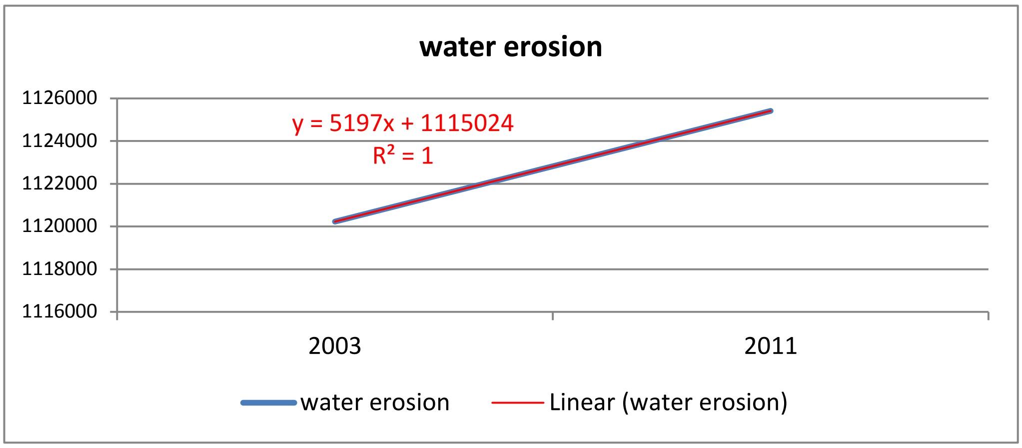

Figure 4.17 Trend of water erosion in the State of Madhya Pradesh (till 2030)

Table 4.13 Projected extent of water erosion in 2030

Extent of water erosion					
Year	2003	2011	2019	2027	2030
Water erosion (in ha)	1120221	1125418	1130609	1135804	1138402

4.6 Conclusion

The study indicates that the average crop productivity for farmers who adopted the farm bunds is higher than those who did not for all four crops. The costs of cultivation, however, are lower for only two of the four crops (wheat and soyabean). Therefore, in terms of the differential between input costs and incomes, the farmers who adopted farms bunds enjoy the cost advantage of only two of the four crops i.e., soyabean and wheat.

The input costs reported by the farmers for potatoes and onions, on an average, are higher than the value of output. This may be due to loss in production or fall in sale price. Moreover, root vegetables like potatoes and onions are also input intensive. The data reveals that for soyabean and wheat, the average profitability per unit of land for an average farmer who adopts farm bund is higher than those who do not have farm bunds in their plots. Consequently, the gain in income due to increased productivity and reduced input costs for some crops (wheat and soyabean) are the positive benefits of controlling agricultural land degradation resulting from water erosion. That is, farmers without farm bunds lose these benefits to water erosion, and their decreased agricultural productivity and lower incomes are in essence the 'costs of land degradation'. Reclaiming water-eroded lands in the State of Madhya Pradesh in 2030 is projected to cost Rs 17076 million in 2015 prices.

4.7 Recommendations

The findings of this study suggest that there is an urgent requirement of intensification of measures to reduce water erosion in the country. The study based on a primary survey of 225 farmers in Madhya Pradesh finds that the farmers who adopted the farm bund intervention (under IWMP) realized the benefits of water erosion control measure primarily through increase in agricultural productivity and/ or reduced cost of cultivation. However, benefits vary across nature of crops and pattern of cropping. The study suggests that the scope of such an intervention should be expanded to include more farmers. Moreover, farmers who were not part of the intervention were either not aware of the intervention or the plots they owned were not suitable for inclusion. Thus creating awareness about the potential benefits to be derived is critical to programme success as is identifying appropriate measures for those whose plots do not qualify.

The importance of supplementary programmes like skill enhancement, providing proper and necessary agricultural information, creating relevant infrastructure and better access to market as well as financial support are are required as supportive measures. These supportive measures are important to exploit the maximum benefit of the intended programme. Since, agro-climatic conditions and cropping pattern as well as socio-economic conditions of the farmers vary across regions, area-specific flexibility may be incorporated into the overall watershed programme to make it more effective based on requirement of the local farmers. In summary, the recommendations emerging from the study include:

- Cover maximum number of beneficiaries under the programme
- Spread awareness about the details and benefits off the programme
- Provide alternative measure for plots that cannot be covered by the intervention
- Implement supportive measures to augment the intended programme
- Incorporate area-specific flexibility

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Chapter 5: Reclaiming Sodic Land in Mainpuri, Uttar Pradesh – A Case Study

5.1 Introduction

Land degradation resulting from soil sodicity, salinity, or a combination of both is considered to be amongst the major impediments to agricultural productivity (Thimmappa *et al.*, 2013). These soils are found extensively in arid and semiarid regions and globally cover approximately 7 percent of the total land area (Ghassemi *et al.*, 1995). India has 6.73 Mha of salt affected soils, of which 3.72 Mha is sodic soils predominantly present in the Indo-Gangetic plains (Mandal *et al.*, 2010). Depending upon the physiochemical properties and the nature of salts, the soil is classified into saline, sodic and saline-sodic. Sodic soils are characterized by the occurrence of excess sodium that adversely affects soil structure and crop growth (Qadir and Schubert, 2002).

Accumulation of salts and sodium (Na^+) in salt-affected soils originates either through the weathering of parent minerals (causing fossil or primary salinity/ sodicity) or from anthropogenic activities involving the inappropriate management of land and water resources - contributing to man-made or secondary salinity and sodicity (Quadir and Oster, 2004).The adverse effects of sodic soils on crop growth stem from structural problems created by certain physical processes – slaking, swelling and dispersion of clay and specific conditions – surface crusting and hard setting (Shainberg and Letey, 1984; Sumner,1993; Quirk, 2001; Quadir and Oster, 2004, Gill and Quadir, 1998).Such problems may affect water and air movement, plant-available water holding capacity, root penetration, seedling emergence, runoff, erosion and tillage and sowing operations. In addition, imbalances in plant-available nutrients in salt-affected soils may affect plant growth (Qadir and Schubert, 2002).

5.1.1 Problem of Sodic Soils in India

India has 6.73 Mha of salt affected soils, of which 3.72 Mha is sodic soil predominantly present in the Indo-Gangetic plans (Mandal *et al.*, 2010). According to the Indian Council of Agricultural Research (2010), this problem affects land in 11 Indian states, including, Haryana, Punjab and Uttar Pradesh contributing to about 45 percent land degradation due to sodic soils in India, 36 percent of which are found in Uttar Pradesh (Table 5.1).

Sodic soils can be categorized by a disproportionately high concentration of sodium (Na), in their cation exchange complex. In addition to structural problem, excess Na causes imbalance in plant-available nutrients and thus interferes in plant growth. Sodic soils either, occur naturally, or are formed due to anthropogenic activities, such as intensive irrigation with marginal quality water, also known as secondary soil sodification. The emerging problem of secondary soil sodification is affecting the productivity of farmland in north-western region of India, including the states of Punjab, Haryana, and Uttar Pradesh (Sharma et al., 2016[39]). These states have played a significant role in achieving food security, during

[39] Sharma DK, Singh A and Sharma PC (2016) Role of ICARSSRI in sustainable management of salt-affected soils, achievements, current trends and future perspectives. In:Souvenir 4th International Agronomy Congress, Novemeber 22-26, 2016 (Eds. R. Prasad, G. Singh, R.L. Yadav and I.P.S Alhawat), Indian Society of Agronomy, p.91-103.

Green Revolution in 1970s, and continue to contribute significantly to national food security. [40]

The macro study on land desertification and degradation conducted by TERI in 2016 (see Volume I), estimates the total loss due to land degradation at about 2.5 percent to total Gross Domestic Product (GDP) and about 15.9 of the Gross Value Add (GAV) from agriculture and the forestry sector. Sodic soils were estimated to contribute about INR 162,809 million, to the total cost of land degradation to GDP and GVA from agriculture and forestry sector.

Table 5.1 States affected by sodic soils in India (in lakh hectare)

S.No.	State/UT	Alkali / Sodic Soil	Degraded Area	Geographical Area	Proportion of total degraded area within State	Proportion of total State Geographical area
1	Andhra Pradesh	1.94	91.94	275.05	2%	1%
2	Bihar	1.06	13.71	94.16	8%	1%
3	Gujarat	5.45	31.29	196.03	17%	3%
4	Haryana	1.84	5.51	44.21	33%	4%
5	Karnataka	1.45	80.93	191.79	2%	1%
6	Madhya Pradesh	1.24	140.95	308.64	1%	0%
7	Maharashtra	4.21	97.26	307.71	4%	1%
8	Punjab	1.52	4.94	50.36	31%	3%
9	Rajasthan	1.52	204.25	342.24	1%	0%
10	Tamil Nadu	3.52	29.97	130.06	12%	3%
11	Uttar Pradesh	13.2	144.05	238.57	9%	6%
	Total (Lakh ha.)	36.95	844.8	2178.82	4%	2%
	Total (Million ha.)	3.7	120.4	328.73	3%	1%

***Source**: ICAR-NAAS (2010)

[40] The macro study on land desertification and degradation conducted by TERI in 2016 estimates, sodic soil to contribute about INR 162,809 million, to the total cost of land degradation to GDP and GVA from agriculture and forestry sector.

5.1.2 Reclamation of Sodic Land in India

The reclamation of sodicity affected land in India was initiated in the the 1860s. A couple of experimental leaching and drainage stations were established in India till independence (Sengupta, 2002). Subsequently, reclamation of sodic land was started in different parts of the country in irrigated and peripheral areas through leaching and drainage experiments. The technology for reclaiming alkaline soil was evolved by the Central Soil Salinity Research Institute (CSSRI), a national level institution set up in 1969 at Karnal (Haryana), under the Indian Council of Agricultural Research, for developing and promoting technologies for salt-affected land. The technology to reclaim alkaline soil, evolved by the Central Soil Salinity Research Institute (CSSRI), includes amelioration of sodic soils by application of gypsum, which enhances the availability of exchangeable Calcium ion (Ca_2^+) to effectively remove the superfluous Na^+ from the soil and thus arrest sodicity induced anomalies in soil physical conditions. Excess Na^+ is subsequently leached down by ponding the fresh water. The sodic land reclamation technology was adopted in 1.5 million ha land of India by the year 2005-06, most of which has been located in Punjab, Haryana and Uttar Pradesh (Tripathi, 2009[41]).Table 5.2, provides details of sodic land reclaimed under various programmes within India. Uttar Pradesh accounts for 40% of the total reclaimed area.

Table 5.2 State-wise Sodic Land Reclaimed across India

State	Area Reclaimed (ha)	Percentage to total reclaimed area
Uttar Pradesh	605405	40.35
Punjab	547012	36.46
Haryana	278196	18.54
Gujarat	38300	2.55
Rajasthan	22400	1.49
Tamil Nadu	5100	0.34
Karnataka	2900	0.19
Bihar	1000	0.07
Madhya Pradesh	100	0.01
Total	1500413	100.00

***Source**: Alkali Land Reclamation(Tripathi, 2009)

A micro-study was planned to study the effectiveness of interventions adopted to make agricultural land affected with sodic soils economically viable. Uttar Pradesh was selected for the study, considering that a significant proportion of reclamation work over the last three decades was undertaken in the State.

[41] Tripathi, R.S. (2009) Alkali Land Reclamation. Mittal Publications, New Delhi.

5.1.3 Sodic Soils in Uttar Pradesh

Uttar Pradesh has about 16 percent of land under agriculture and accounts for 16 percent of total food grain produce; however, average yield is much lower in comparison to other states including Punjab and Haryana. According to Pandey and Reddy (2012) there exists a strong relationship between agricultural productivity and poverty. They estimated that an increase of 10 percent in land productivity would reduce poverty by 4.3 percent. Thus, interventions aimed to enhance agricultural productivity substantially contribute to reducing poverty in the rural areas.

Agricultural productivity of Uttar Pradesh suffers due to several reasons – soil health, uneconomic size of land holdings, lack of quality seeds and imbalanced use of fertilizers. However, soil health is most critical and a visible concern. Soil in Uttar Pradesh is affected by wind erosion and sodium content in the soils.

The problem of alkaline soil in Uttar Pradesh, commonly known as *Usar* land is known to be associated with the problem of poor drainage and impervious sub-soil in arid and semi-arid regions (Singh and Bajaj, 1988). Uttar Pradesh has more than 1.3 million hectares of sodic wasteland which accounts for 10 per cent of the total cultivable area in the state and about 17 per cent of the total sodic land in the country. Several studies have indicated an inverse relationship between alkalinity and agricultural productivity; the crop yield decreases with increase in the level of alkalinity (Dwivedi and Qadar, 2011; Abrol and Bhumbla, 1979; Timmappa *et al*. 2010).

5.2 Methodology

Table 5.3 shows the top 20 districts of Uttar Pradesh affected by alkalinity. Mainpuri in comparison to other districts, has a large land affected with sodic soils. **Sodic land in Mainpuri was found to comprise 44 percent of total geographical area of the district and thus was considered for the micro case study, conducted by TERI in 2016.**

Table 5.3 First 20 districts based on area of land affected by sodic soils

Districts	Degarded and wasteland classes (in '000 ha)		Total Sodic land (in '000 ha)	Total Gross Area (District)	Proportion from total district area
	Exclusively Sodic Soils	Eroded Sodic Soils			
Mainpuri	57	63	120	274	44%
Jaunpur	56	69	125	402	31%
Auraiya	37	18	55	204	27%
Kannauj	36	17	53	198	27%
Partapgarh	34	60	94	367	26%
Azamgarh	32	68	100	420	24%
Etawah	30	18	48	226	21%
Sultanpur	26	59	85	440	19%

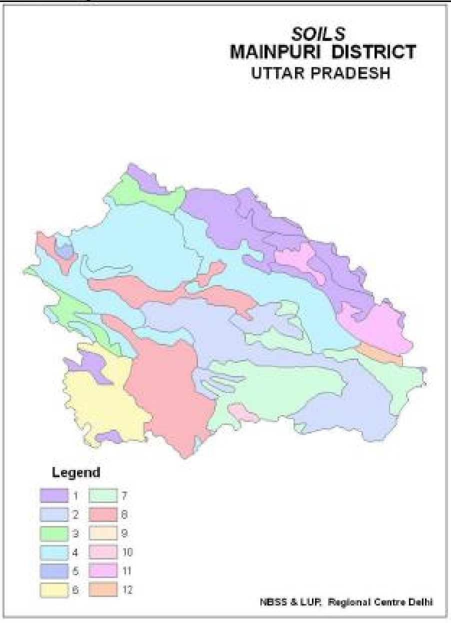
Districts	Degarded and wasteland classes (in '000 ha)		Total Sodic land (in '000 ha)	Total Gross Area (District)	Proportion from total district area
	Exclusively Sodic Soils	Eroded Sodic Soils			
Ghazipur	21	44	65	336	19%
Etah	55	24	79	441	18%
Firozabad	36	7	43	234	18%
SantRavidas	7	10	17	94	18%
Rai Bareli	32	39	71	453	16%
Lucknow	17	20	37	251	15%
Varanasi	12	11	23	156	15%
Kanpur Dehat	31	2	33	311	11%
Hatras	6	13	19	175	11%
Ambedkar	0	24	24	235	10%
Chandauli	7	13	20	254	8%
Mau	7	7	14	171	8%

5.2.1 District Profile

Mainpuri district situated between 260°53'N to 270°31'N and East Longitude 780°27'E to 790°26'E, lies in the semi-arid region. The district is further divided into five administrative units, namely Mainpuri, Bhongaon, Karhal, Kishni and Ghiror. Spread over an area of 2760 sq. km., Mainpuri is bounded on the North by Etah District, on the East by District Farrukkhabad and Kannauj, on the South by District Etawah and on the West by the District Firozabad and Etah.

As per 2011 census, the total population of Mainpuri is 18.47 lakhs that has grown by 15.69 per cent since the last decade. The state has a population density of 670 persons per sq. km, which is almost double the national density of 382 people per sq. km. Mainpuri has a sex ratio of 876 females for every 1000 males, and a literacy rate of 78.26%.

Mainpuri lies in the South-West, Semi-arid Zone IV, with maximum temperature of 45.6°C and minimum 7.4°C and receives rainfall between 620 and 750 mm. The soil of Mainpuri district is characterized by alluvial soil that originates from Ganges and its tributaries. Textural classes vary from sandy-loam to silty–clay–loam. The soil map of Mainpuri districts shows that the problem of salt-affected soils is pronounced in the district.



SOILS OF MAINPURI DISTRICT (U.P.)

Alluvial plain (0-1% slope)

1. Deep, loamy soils and slightly eroded .
2. Deep, silty soils, slightly saline and strongly sodic associated with loamy soils.
3. Deep, fine soils moderately saline and sodic associated with loamy soils, slightly eroded
4. Deep, silty soils with moderately salinity and sodicity associated with loamy soils with moderate salinity and sodicity and water logging .
5. Deep, loamy soils, moderate salinity and sodicity associated with loamy soils with moderate salinity and strong sodicity .
6. Deep, loamy soils and slightly eroded associated with loamy soils with moderate salinity and sodicity and moderate water logging.
7. Deep, silty soils and slightly saline/ sodic .
8. Deep, loamy soils, slight salinity and moderately sodicity associated with silty soils slightly eroded
9. Deep, silty soils with moderate salinity/sodicity associated with loamy soils slightly eroded .
10. Deep, silty soils and slightly eroded.

Old Alluvial plain with river left out channels/Oxbows/point bars (1-3% slope)

11. Deep, fine soils with moderate water logging associated with fine soils with slight salinity/moderate sodicity .

Active Flood Plain (1-3% slope)

12. Deep, stratified loamy soils, with severe flooding associated with loamy soils with moderate flooding .

Figure 5.1 Soil Map of Mainpuri District

Source: NBSSLUP (2015)

5.2.2 Uttar Pradesh Sodic Land Reclamation Project

Uttar Pradesh Bhumi Sudhar Nigam has been implementing the Uttar Pradesh Sodic Land Reclamation Project (UPSLRP) since 1993, with the assistance of the World Bank. Currently, the project is in its third phase. Project Implementation Plan (PIP) of Uttar Pradesh Sodic Land Reclamation – III Project (USLRIIIP), identifies 538 thousand hectares of sodic lands spread over 48 districts of the state lying barren. Moreover, substantial marginal sodic lands that are single or double cropped also have very low productivity. UPSLRIIIP is designed to reclaim 130,000 ha of sodic land in 24 intensively sodic districts, including Mainpuri, over a period of five years.

The USLRIIIP, PIP also identifies the ownership of sodic lands with economically backward farmers or landless farmers who were allotted sodic lands and became first-time owners under a Government policy. There is a need to ameliorate these soils to make them productive, but the high cost of amendments (gypsum and pressmud), water and labour makes it difficult for marginalized farmers in the areas affected by sodic soils to sustain their livelihood.

Components of UPSLRIIIP

UPSLRIIIPis a package intervention, which has five components out of which four are technical and one is project management. These components are:

1. On-farm development (OFD) and land treatment
2. Improvement of drainage systems
3. Agriculture support systems
4. Institutional strengthening for improved market access
5. Project management

OFD and land treatment is the core component of the intervention with expected results of land reclamation, increased cropping intensity and improved soil quality, which is manifested as increased productivity. One of the major causes of low agricultural productivity is the poor drainage network. Sodic soils tend to develop poor structure and drainage over time because sodium ions on clay particles cause the soil particles to disperse. Because salts can only be leached downward in the soils with soil water, attention to drainage is very important. The second component tries to improve the drainage systems to remove leached effluents and ultimately reduce sub-surface waterlogging. The third component of agricultural support services include livestock management and training as an opportunity for livelihood diversification in addition to supporting crop diversification, availability of quality seeds and inputs for soil health to sustain yield. The fourth components provide support for institutional and capacity building to the farmers to ensure that their produce fetches better prices. The fifth component addresses project management.

Key Indicators of UPSLRIIIP

The UPSLRIIIP development objective for farmers of degraded agricultural land is to achieve greater agricultural productivity as a result of reversal of land degradation, enhancement of soil fertility and improved provision of agricultural support services. The project identifies three key indicators, viz.

- Increase in productivity of rice and wheat,
- Diversification in agricultural production, and
- Increase in farm income

5.2.3 Analytical Framework

A micro study was designed by TERI to study the impact of UPSLRIIIP interventions on the productivity and income of farming households in Mainpuri, Uttar Pradesh. This study aims to address the following objectives:

- To study the impact of the intervention on changes in productivity of rice and wheat, on farm income and other associated activities
- To assess the cost of degradation due to sodic soil in the selected villages.

A pre-post, non-randomized control design was adopted for the research which helps to establish thecausality of an intervention, and thus was considered to be the most appropriate research design. Figure 5.2 shows the research design adopted for the study. Due to the absence of baseline or pre-test data, a recall method was adopted to reconstruct a baseline. To study changes in soil quality, the project MIS data was considered. The micro-study, aimed to address three broad questions, namely –

- Whether there is a change in productivity of sodic land?
- Is the change because of the project?

- What contributed to the change?

To identify the change due to the project there is a need to compare key indicators such as productivity to a matching non-intervention area. Thus, inorder to establish a counterfactual for the study, the sodic area selected by UPSLRIIIP in 2015 for the intervention was considered as the control group-that is prior to the intervention. The study design is presented in Figure 5.2.

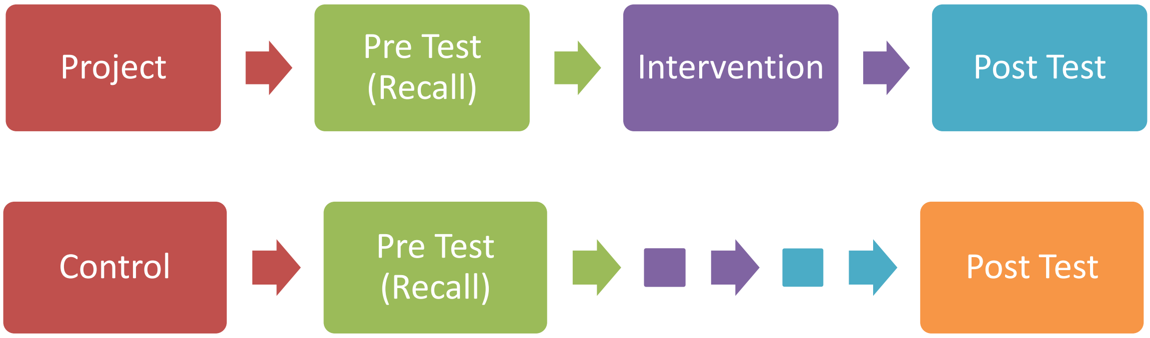


Figure 5.2 Research Design

The study used data collected from a primary survey of farming households that were beneficiaries of UPSLRIIIP in 2013-14, 2014-15 and 2015-16. The beneficiary households adopted by the project in 2013-14 and 2014-15 formed the treatment orintervention group and beneficiary households selected in 2015-16 were considered as the control group or counterfactual (in the absence of the intervention). Further, the questionnaire survey included questions on key variables both prior to implementation of UPSLRIIIP or treatment on affected sodic land as well as post intervention.The study design allowed us toestimate change as the difference over time in outcomes between project and control groups, assuming that changes in the control group over time will also occur in the non-intervention group in the absence of the programme, and thus can be written as

$\Delta\bar{Y} = \Delta\bar{Y}P - \Delta\bar{Y}C$

$= \bar{Y}P2 - \bar{Y}P1 - (\bar{Y}C2 - \bar{Y}C1)$

Where, $\bar{Y}$ is the mean value of variable of interest, 1 and 2 are the two time periods and, P and C denotes the project and control group, respectively.

The project classifies sodic soil into three groups on the basis of its pH and EC value viz. slightly sodic (B+), moderately sodic (B) and severly sodic (C). The level of sodicity is understood to be closely associated with productivity of the land; type C land is the most unproductive of the three and thus is left fallow both in Rabi and Kharif, type B land is slightly better than C with a single crop in a year during Kharif season and B+ is most productive of the three with two annual crops during Kharif and Rabi. Change in productivity thus was studied for all the three classes of land paired through an independent sample T-test.

In order to estimate the influence of various variables on the change in productivity due to the project, the linear regression model used is:

$\Delta Y\% = \beta_0 + \beta_1 P + \beta_2 * S^i_1 + \beta_3 * P.S^i_1 + \beta_4 x_1 + \beta_5 x_2 + \beta_6 x_3 + \varepsilon$

Where,

$\Delta Y\%$ = % change in productivity between the initial and final year normalized by the final year $(Y^i_2 - Y^i_1 / Y^i_2 * 100)$

β_0= constant

β1 = effect of in soil type (between B+ and B, and C category soil)

β3 = effect of intervention on B+ and B category soil in comparison to no intervention

P = dummy variable representing exposure, where P = 1, if project group is observed and 0 control group

S^i_1 = soil type before the project, where S = 1, if B+ and B, and 0 if C

$P.S^i_1$ = is the interaction term of P and S^i_1

x_1 = area of Plot, measured in ha

x_2 = ownership of improved agriculture implements, where x_2 = 1 if owned by the household, and 0 if not

x_3 = literacy status of the head of the household, where x_3= 1 if literate and 0 if illiterate

ε= error term

5.2.4 Site Selection

Villages were selected from the list of villages where UPSLRIIIP had completed its operations in 2013-14 (Project Year 4) and 2014-15 (Project Year 5). Villages where the project was due to start its operations in 2015-16 was considered for control sites.

5.2.5 Sample Design

Sample Size

Total sample from project villages was calculated using the formula given below:

$$\text{Sample Size} = \frac{Z^2 * p(1-p)/ e^2}{1+(Z^2 * p(1-p)/ e^2 N)}$$

Where,

Z = Critical value of the Normal distribution from the statistical table (e.g. for a confidence level of 95%, and the critical value is 1.96),

e= margin of error (6.4%)

p = sample proportion (50% - It provides maximum sample size)

N = population size (Population of beneficiaries in the selected project villages was considered i.e. 1,523 as per the beneficiary list provided by Bhumi Sudhar Nigam)

A sample of 205beneficiaries from project is sufficient to assess the effectiveness of UPSLRIIIP intervention with 95 percent confidence interval and 6.4percent margin of error. It was considered appropriate to gather a minimum of 50percent of the total project sample to serve as a counterfactual (control group) for the study. However, a total of 132 control sample(65% of project sample) beneficiaries were selected. A total of 337 beneficiaries were sampled for the study.

Sample Selection

The total sample was then proportionately distributed in accordance with the total beneficiaries of UPSLRIIIP in each of the selected villages. The farmers were selected from the UPSLRIIIP beneficiary list provided by Bhumi Sudhar Nigam, Mainpuri, Uttar Pradesh, using Simple Random Sampling. Only those beneficiaries who continued farming after the project were considered for the survey.

Table 5.4 Sample size across sodic classes

	Villages	Project Year	Beneficiaries distribution				Sampled HH
			Land classes			Total	
			B+	B	C		
Project	AkberpurOnchcha	2013	10	6	183	199	27
	Manauna	2013	10	9	253	272	37
	Veer Singhpur	2013	25	20	298	343	46
	Chauraipur	2014	34	5	117	156	21
	Nahilkathegra	2014	72	18	118	208	28
	Sahan	2014	50	18	112	180	24
	Tisauli	2014	51	18	94	163	22
	Total Beneficiaries		252	94	1175	1521	-
	Sampled HH		28	16	161	-	205
Control	Agotha	2015	32	22	16	70	19
	DharamAngadPur	2015	17	17	52	86	23
	KakarVikramPur	2015	31	7	92	130	35
	Noner	2015	23	12	184	219	55
	Total Beneficiaries		103	58	344	505	-
	Sampled HH		17	12	103	-	132

5.3 Results and Discussion

5.3.1 Sampled villages' profile

A total of 11 villages was sampled for the study, namely, *Akbarpuroucha, Chauraipur, Manauna, Nahilkatengra, Sahan, Tisauli, Veersinghpur, Angotha, Dharmangadpur, Noner, and Kakan*. Of the selected villages UPSLRIIIP was implemented in 2013 and 2014 while four villages were slated for intervention implementation in 2016 (the control group). Table 5.5 provides the demographic profile of the villages. According to the 2011 census, the project villages had a total population of 36,459 people and that of control was 30,383 people with an average household size of 6 members. The project villages are mainly dominated by Hindus. Schedule Castes comprised a significant proportion of the selected villages accounting for19 percent and 21 percent in project and control villages, respectively (Census, 2011). The literacy rate was found to be 62 percent in project villages and 67 percent in control areas, which is much below the state and national average. Farming is the main occupation, however, farmers with marginal or small landholdings, supplemented their household income by engaging in skilled and unskilled labour work. As shown in Table 5, the project and control villages matched on all the key demographic indicators – gender composition, and literacy.

Table 5.5 Demographic Profile of the Villages

Village	Number of Households	Total Population	Male (%)	Female (%)	Total Literacy (%)	Male Literacy (%)	Female Literacy (%)
Project Villages							
AkbarpurOuncha	1410	8579	54%	46%	61%	68%	52%
Chauraipur	688	3557	53%	47%	64%	71%	56%
Manauna	1044	6552	51%	49%	58%s	67%	48%
Nahilkathengara	681	4074	54%	46%	66%	73%	58%
Sahan	1109	6820	53%	47%	64%	73%	54%
Tisaulli	886	5477	55%	45%	68%	77%	56%
Veersighpur	237	1400	54%	46%	59%	66%	51%
Control Villages							
Augautha	1420	9105	54%	46%	66%	74%	57%
Dharmangadpur	118	722	53%	47%	77%	80%	73%
Noner	2701	15516	53%	47%	68%	74%	60%
Kakan	868	5040	53%	47%	67%	73%	61%

Landholding size and sodic soils in sampled villages and plots

The average land holding size was 0.82 ha and most of the farmers were marginal or small landholders. The villages have a total agricultural land of 1032.86 ha owned approximately by 1256 households. The sampled plots mainly belonged to marginal and small farmers (Fig 5.3).

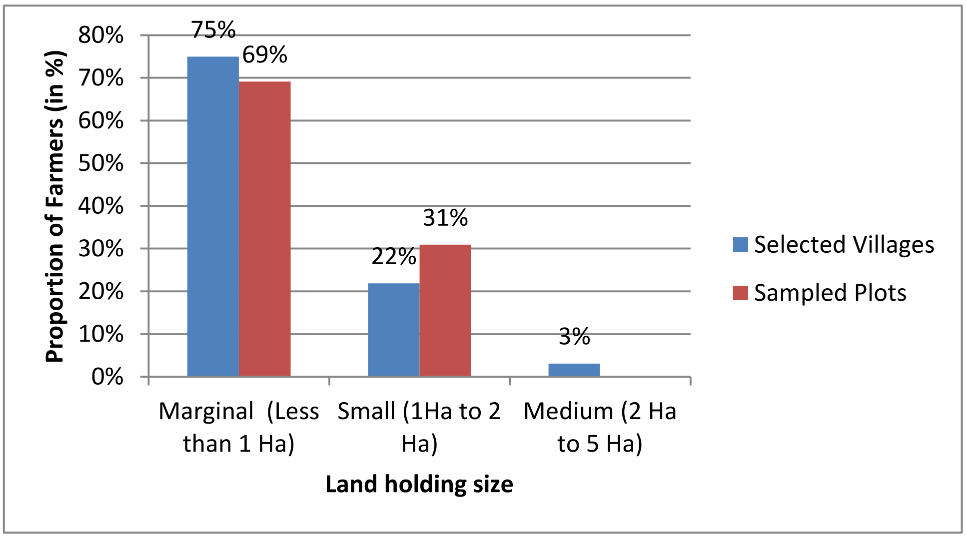


Figure 5.3 Landholding size within selected villages and sampled plots

Degraded land constituted 55.4 percent of the total farmer land holdings with varying levels of soil sodicity. The land has been classified into 'slightly', 'moderately' and 'severely' sodic soils, (classified as B+, B and C, respectively under UPSLRIIIP) (figure 5.4). Farmers with slightly affected sodic soils grew rice and wheat. Farmers with moderately affected land grew only rice while for the severely affected land category, land was mostly left fallow.

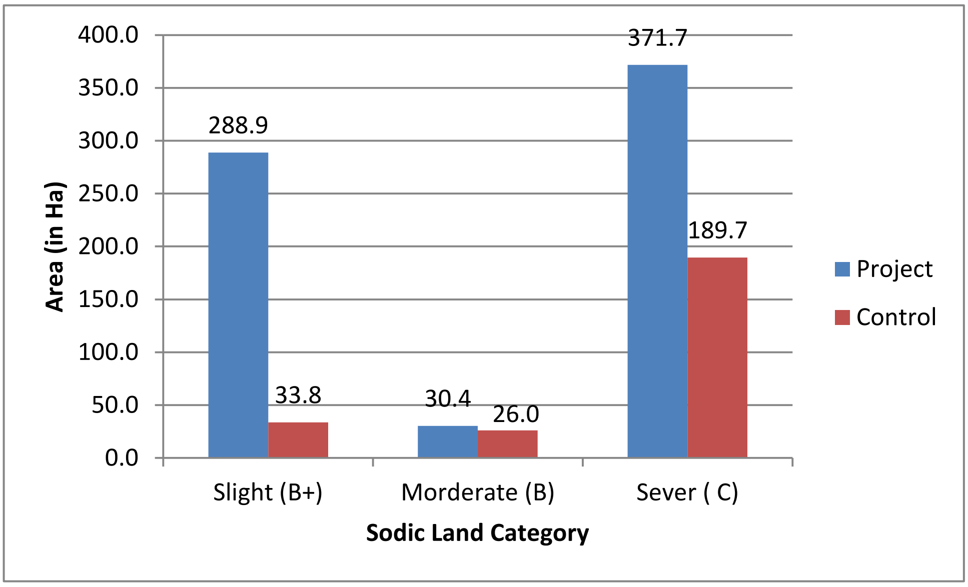


Figure 5.4 Sodic land classes in project and control villages

5.3.2 Respondent Profile

A total sample of 337 beneficiaries was covered under the micro-study, comprising of 205 beneficiaries of project sites and 132 beneficiaries from the control area. The sampled beneficiary households comprised of 1976 total members and an average household size of 6 members.

Gender Profile

Farming in India is dominated by men, while women have a supportive role. Thus, as shown in Figure 5.5, the farmers interviewed for the survey were mainly men both in project and control villages.

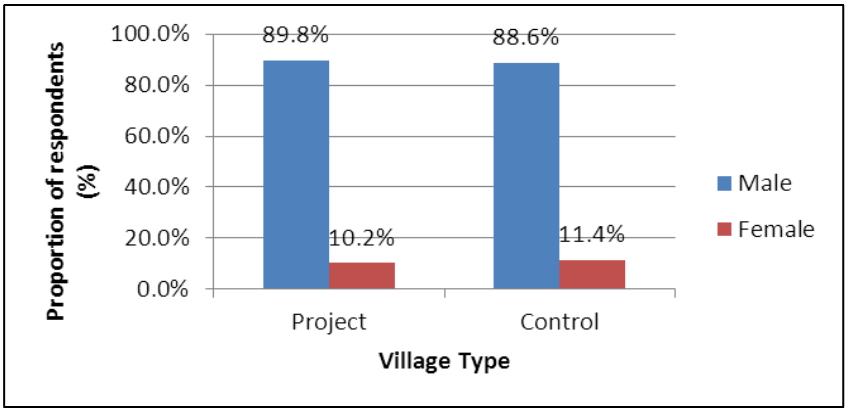


Figure 5.5 Gender Profile of the Respondents

Religious Profile

As shown in figure 5.6, a majority of the sample beneficiaries both in project and control villages followed Hinduism.

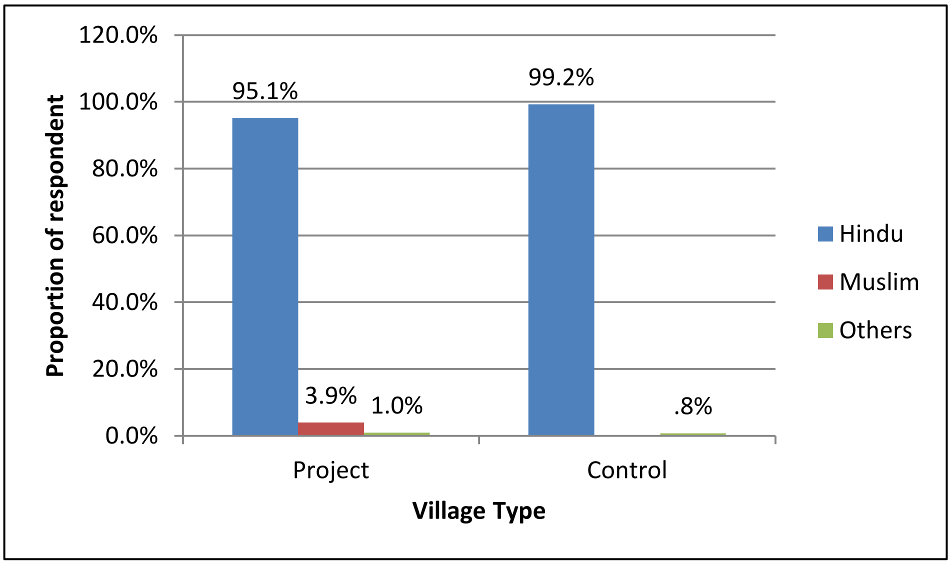


Figure 5.6 Religion Profile of the Respondents

Caste Profile

UPSLRIIIP aims to improve the economic conditions of weaker sections of society. The Indian Constitution recognises caste as an important indicator to identify socially and economically weaker sections of society. Caste-based analysis of the sampled households shows that in addition to the general caste, a significant proportion of the households belong to economically weaker sections, including Scheduled Castes, Other Backward Castes, and Scheduled Tribes. Among the weaker sections, SCs, STs and OBCs formed the major proportion in both project and control areas (Fig 5.7).

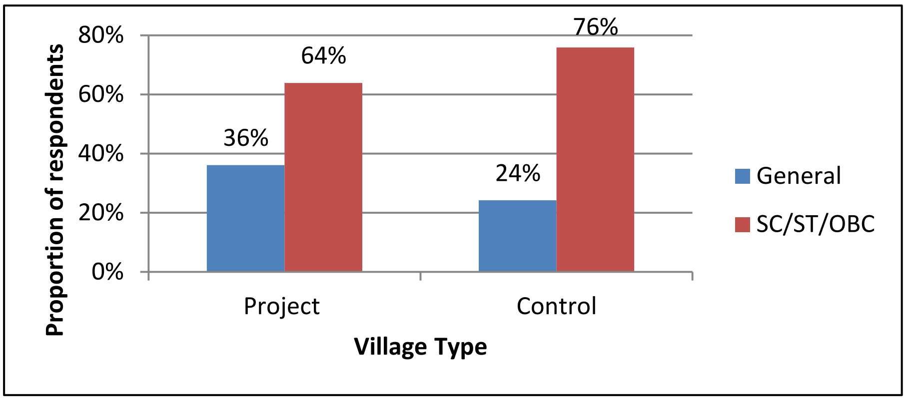


Figure 5.7 Caste Profile of the Respondent

Education

A large proportion of household members were illiterate; 19 percent in project and 18 percent in control villages (Fig 5.8). Further, 27 percent in project villages and 29 percent in control villages only had a primary education, and only 3 percent in the project and 4 percent in the control groups were graduates. Due to low profitability in agriculture and other traditional jobs, a large number of youth had received vocational training; 21 percent in project and 16 percent in control. A large number of centres providing training in computers, mobile repair etc., have sprung in the district headquarters to cater to this trend.

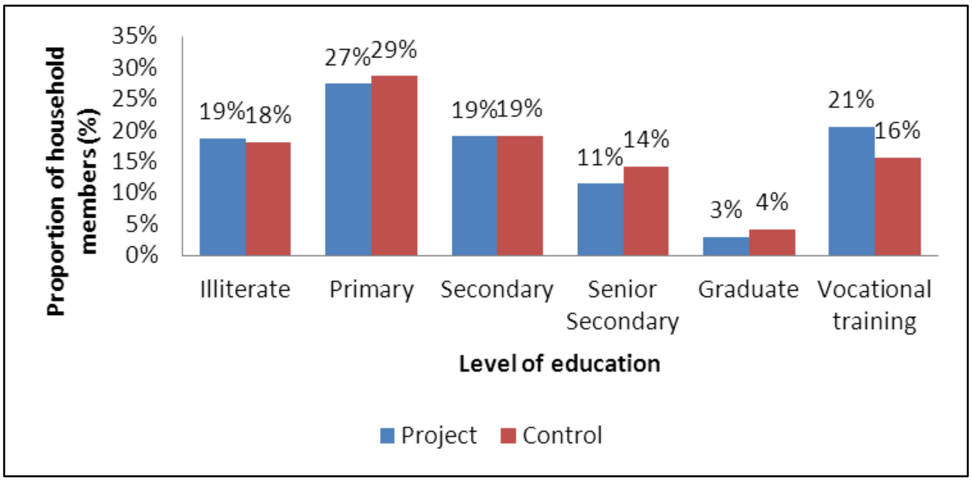


Figure 5.8 Education profile of respondent's household members

Occupation

Since the survey primarily focussed on changes in agricultural productivity due to interventions targeted at reducing sodicity, the survey targeted farmers. Consequently, at least one of the members was involved in farming. The occupation profile of reflected this (Figure 5.9).Farming is the main occupation involving 43 percent and 37 percent of the household members**,** in project and control villages, respectively. A large proportion of members were also engaged as labourers (agricultural labourers and other labourer). Tertiary sector included 8 percent of household member both in project and control villages.

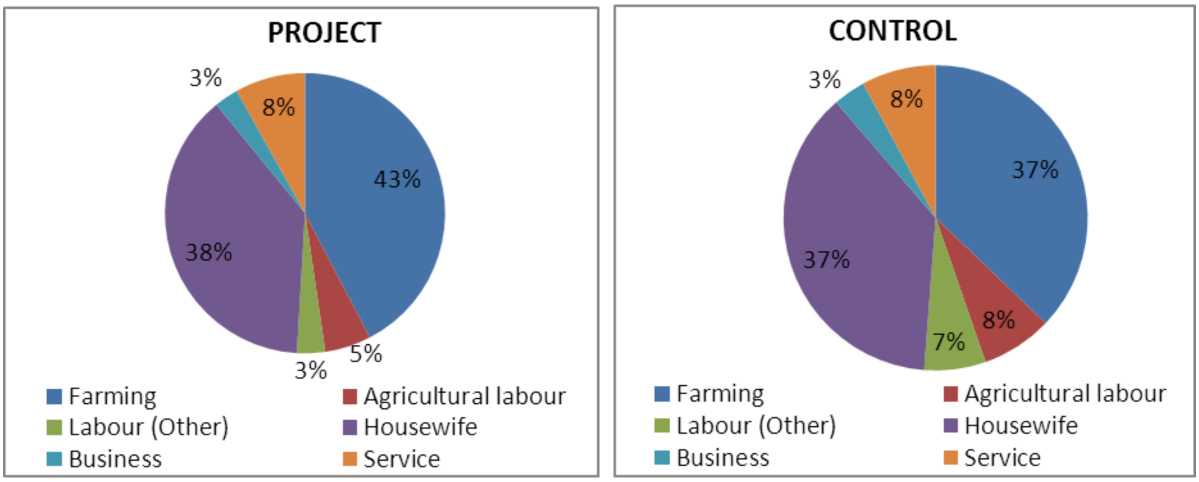


Figure 5.9 Occupation profile of household members

Migration

The selected households were dependent upon agriculture for their household income. However, due low productivity, households were forced to migrate for better employment opportunities. The rate of migration was estimated to be 4 percent for project villages and 2percent in control villages. As reported by respondents, the migrant population was in the age group of 11 years to 30 years. Also shown in Figure 5.10, a majority of respondents reported decreased productivity of land to be the reason for migration, viz. 89 percent in project and 94 percent in control villages.

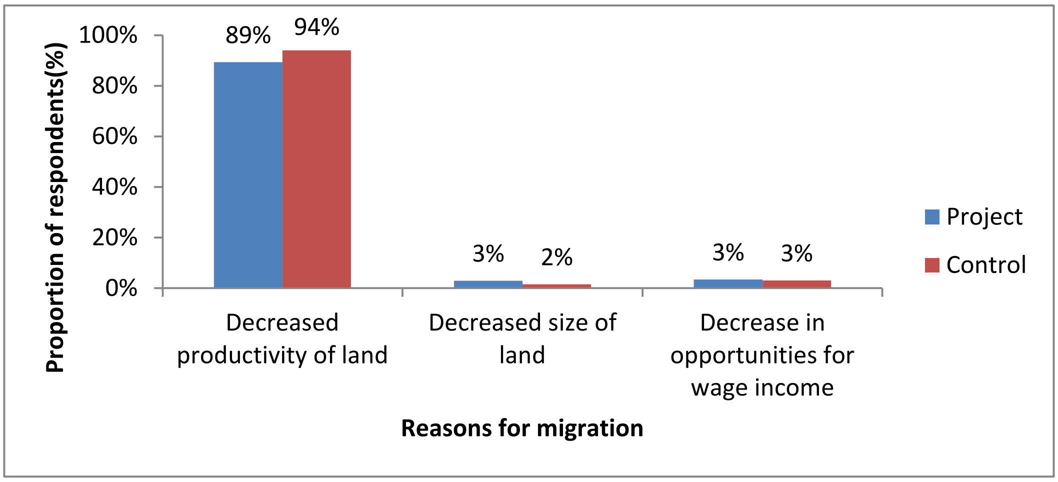


Figure 5.10 Reasons for migration

Figure 5.11 shows the socio-economic characteristics of sampled households. Both project and control villages were not significantly different in their socio-economic profile. The households sampled for the study were commonly observed to own the house they were living in, the house was made of concreate, was electrified and had private sources of drinking water – tap/ tubewell/ well. The households owned cycles, agricultural implements and electric fans. Of the sampled households, 14 percent in project and 16 percent in control had a BPL card; also 20 percent in the project villages and 28 percent in control villages had a toilet within their house.

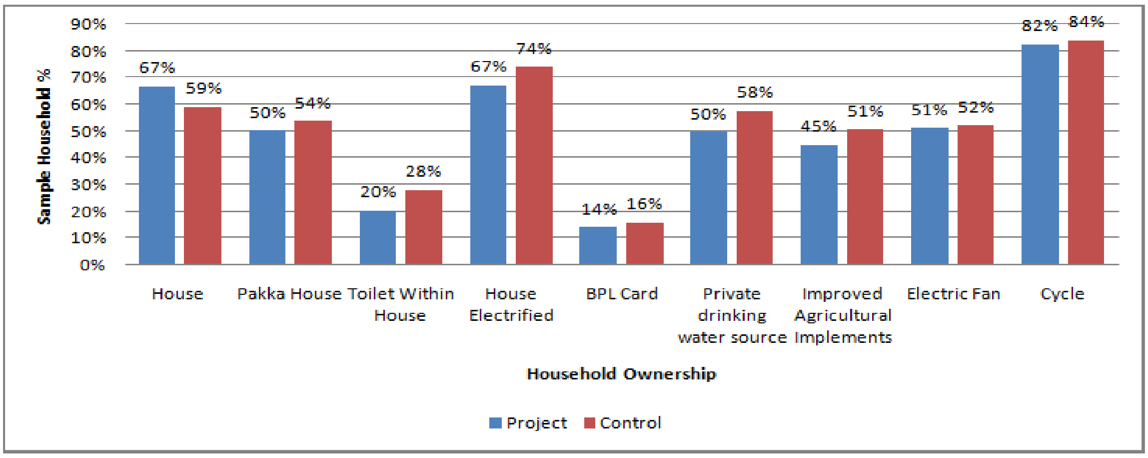


Figure 5.11 Household assets

5.3.3 Impact of intervention on livestock, milk productivity and household incomes

Under the project the livestock sector has been identified as an opportunity for livelihood diversification as improved livestock incomes can substantially improve overall household incomes. Animal husbandry training was therefore provided to the beneficiary households. This section summarises changes in ownership of livestock, productivity of milk and household incomes obtained after the intervention.

Ownership of Livestock

Of the Beneficiaries in the project villages, 34 percent reported to have received training and 23 percent had also attended demonstrations on livestock development and/ or had received support for livestock management. As shown in figure 8, sampled households in project villages had increased livestock ownership in comparison to the control villages, especially, for buffaloes and goats. A change was observed not only in the number of households owning cows and buffaloes, but also in the total number of cows and buffaloes in the project and control area, however the change was higher in the project villages (refer Table 5.6)

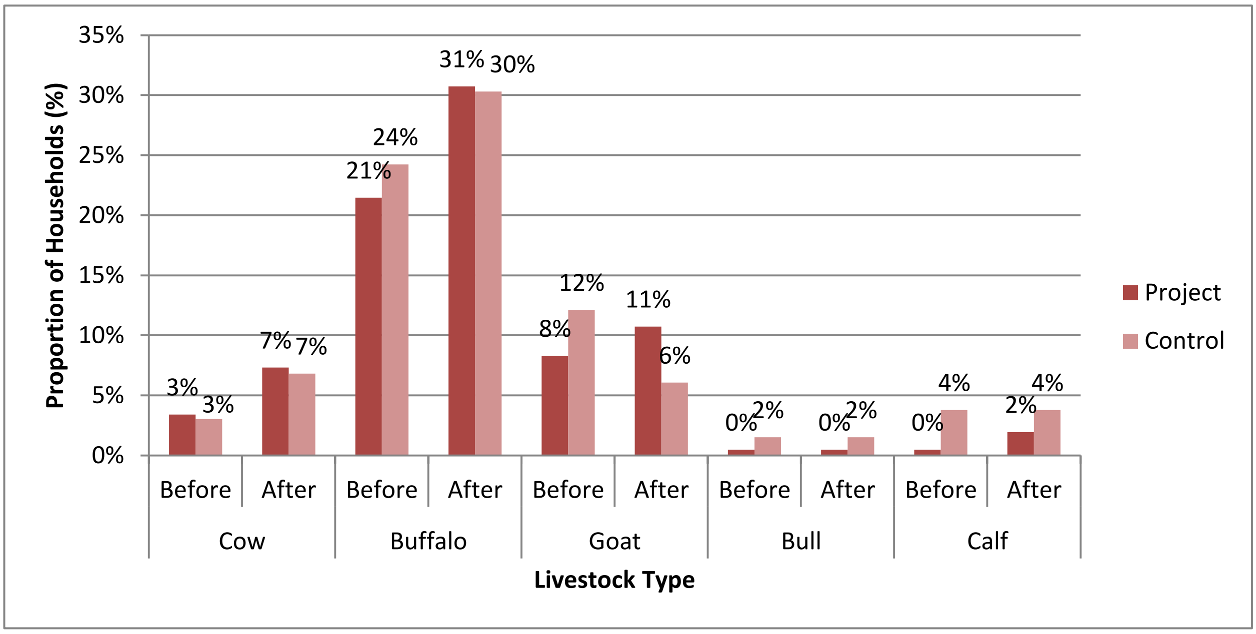


Figure 5.12 Changes in livestock ownership of project and control households

Income from Livestock

Changes in milk produce and incomes deriving from them are provided in Table 5.6. Both milk produce and incomes from milk produce have improved significantly from the baseline- the change was higher in the project villages than in the control villages.

Table 5.6 Milk produce and income from livestock

	Project		Control	
	Before	**After**	**Before**	**After**
Average Produce	797.7	1012.5	928	1040.6
No. of Households	44	66	32	57
Total Milching Cattle	80	135	67	102
Mean income	12857	25195	12920	13706
Mean Difference Income(in Rs.)	12338.67***		4227**	
Mean Difference Produce (in liters)	214.77***		112.5***	

5.3.4 Impact of the intervention on soil sodicity

Detailed soil quality monitoring was conducted by the project authorities. Table 5.7 provides the soil monitoring results of pre-and post reclamation (two years after reclamation). The figures indicate that there is an improvement in soil quality, with significant reduction in pH and Electrical Conductivity (EC) values. The reduction in EC after reclamation was much more rapid, as soluble salts are leached out easily. The main purpose of sodic soil reclamation is to reduce their exchangeable sodium content and make soil suitable for crop production (Thimmappa *et. al, 2015).* The monitoring data indicate that the project intervention has improved soil properties. The MIS recorded a seven percent decrease in pH level and 55 percent decrease in EC, both important indicators of soil health. Further, an enhancement of soil organic carbon was observed from the baseline value of 0.19 to 0.22, recording a 16 percent increase.

Table 5.7 Impact of application of amendments on sodicity

Soil health indicators	2013	2015	% change
pH level	9.99	9.28	-7%
EC level	1.64	0.73	-55%
Organic Carbon	0.19	0.22	16%

Source: UPSLR III Project MIS

5.3.5 Change in cropping patterns

Rice and wheat are commonly adopted by farmers of Indo-Gangetic Plains of Uttar Pradesh (Thimmappa *et*.al, 2013). After application of Gypsum the farmers are required to take three rotations of crops including, Paddy in Kharif, Wheat in Rabi and Barsem in Zaid. Table 5.8, provides details of cropping pattern (in *kharif*, *rabi* and *zaid*) during pre- and post-reclamation years across project and control sample plots. A change in crops sown across seasons for the project plots was observed. Over one-fifth of the respondents were cultivating paddy in Kharif season of the pre-reclamation, most marginal farmers with C category plots were unable to cultivate any crop due to poor soil quality. However, after reclamation all the farmers were growing atleast 2 crops in a year during kharif and rabi seasons. Further, four percent were able to cultivate a third crop during Zaid.

Table 5.8 Crops sown by the sampled farmers

Season	Crop	Project		Control	
Pre-reclamation					
Kharif	Paddy	44	21.5%	29	22.0%
Rabi	Wheat	28	13.7%	17	12.9%
Zaid	Maize	4	2.0%	0	0.0%
Post-reclamation					
Kharif	Paddy	205	100.0%	29	22.0%
Rabi	Wheat	205	100.0%	17	12.9%
Zaid	Maize	11	5.4%	0	0.0%

Season	Crop	Project		Control	
	Dhencha	2	1.0%	0	0.0%
Total N		205		132	

5.3.6 Change in cropping intensity

As discussed under land holdings, farm production is affected by the severity of soil sodicity. However, change in cropping was observed in the intervention plots, post-reclamation. Cropping intensity (Table 5.9) shows the extent of cultivated area used for crop production out of total net area sown in a year. The cropping intensity during *rabi*in the pre-reclamation period was recalled to be low, both in project and control plots. However, the cropping intensity increased remarkably by 172.5 percent points for the project plots. The increased cropping intensity contributed to the higher total farm production and income.The cropping intensity in the control plots decreased marginally by 1.4 percent points.

Table 5.9 Cropping intensity (%) by sodicity classes

	Annual net sown area			
	PRE recreation		Post recreation	
	Project	Control	Project	Control
B+	186.4	200.0	199.5	186.2
B	100.0	100.0	199.3	96.4
C	0.0	0.0	200.0	0.0
Average in *kharif*	18.1	19.4	100.0	19.4
Average in *rabi*	8.2	10.0	98.8	8.6
Annual average	26.3	29.4	198.8	28.0

5.3.7 Change in crop yields

Prior to reclamation, for both project and control plots, the ‘severe’ category of sodic plots remained barren in both the seasons. Heavy salt stress generally leads to reduced growth and even plant death (Qadar, 1998; Parida and Das, 2005). In addition to poor physical properties of sodic soils, which directly limit crop growth through poor seedling emergence and root growth, they also exert indirect effects on plant nutrition by restricting water and nutrition uptake and gaseous exchange (Curtin and Naidu, 1998) which ultimately results in reduced crop yield and quality (Grattan and Grieve, 1999).

Salt concentration was observed to impact crop yield severely, reclamation of such land using the packaged intervention under UPSLRIIIP had led to an increase of both rice and wheat yields. Table 5.10, summarises the change in productivity of land due to the intervention.

Table 5.10 Average yield (t/ha) of rice and wheat in different sodicity classes

		Slight (B+)	Moderate (B)	Sever (C)
Rice				
Project	Pre-reclamation	2.76	1.81	0
	Post-reclamation	4.88	2.74	2.9
	Mean difference	2.12***	3.37***	-
Control	Pre Reclamation	2.71	1.82	-
	Post Reclamation	2.65	1.71	0
	Mean difference	-0.053	0.118	0
Wheat				
Project	Pre Reclamation	1.81	0	0
	Post Reclamation	2.74	2.7	2.66
	Mean difference	0.93***	-	-
Control	Pre Reclamation	1.71	-	-
	Post Reclamation	1.82	-	-
	Mean difference	0.117	-	-

*****Significatly different at 1% level**

Rice

A large number of studies show that the sodicity acts as a deterrent to cultivation of rice; it inhibits shoot and root growth of rice seedlings and has less biomass when grown under sodic conditions (Chhabra, 1996; Van Aste *et al.*, 2003; Wang *et al.*, 2011). As suggested by the T test given in Box 1 and Box 2, the land reclamation had a profound impact on productivity of rice for slightly sodic and moderately sodic plots. The change in productivity due to UPSLRIIIP was estimated separately for slightly and moderately sodic plots and can be understood as the difference between change in productivity in project and control plots post reclamation, it is mathematically presented as follows

$\Delta\bar{Y} = \Delta\bar{Y}^{P} - \Delta\bar{Y}^{C}$

$= \bar{Y}^{P}_{2} - \bar{Y}^{P}_{1} - (\bar{Y}^{C}_{2} - \bar{Y}^{C}_{1})$

where, $\bar{Y}$ is the mean value of productivity of rice, 1 and 2 are the two time periods and, P and C denotes Project and Control group, respectively.

The productivity of rice on slightly sodic plots for project group increased from 2.76 t/ ha before reclamation to 4.88 t/ ha after reclamation, with an increase of 76.8 percent point. The T test results suggest that there was no significant difference between productivity of rice for project (m=2.76, sd=0.455) and control (m=2.71, sd = 0.749) plots at t(43)=0.307, p = .761 before the intervention. However, the productivity of rice was observed to differ significantly for project plots, before intervention (m=2.76, sd=.455) and after intervention (m=4.88, sd=.855) at; t(27)=10.42, p = .001. The control plots on the other hand were found to have no significant difference in productivity of rice, before intervention (m=2.65, sd=.177) and after intervention (m=2.71, sd=.182) at; t(16)=-.240, p = .813. Thus, UPSLRIIIP was found to have a positive impact on productivity of rice for slightly sodic plots with an increase of 2.18 t/ ha.

Similarly, T test of moderately sodic plots shows that there was no significant difference between the productivity of project and control plots in moderately sodic plots, before the intervention. However, post reclamation under UPSLRIIIP the productivity of the project plots increased resulting in significant difference between project and control plots. The change in productivity of rice for moderately sodic plots due to reclamation effort under UPSLRIIIP was calculated as 1.04 t/ ha.

Further, a crop productivity of 3.9 t/ ha was obtained on the severely sodic plots, post-reclamation, which during pre-reclamation were left fallow.

Factors Responsible for change in productivity of rice

An overall regression model for rice was developed. Table 5.11, shows the regression results, where the dependent variable is% change in rice productivity. Change in productivity of rice was significantly affected by the severity of sodicity and was found to be inversely related with change in productivity, i.e. higher the sodicity lower the productivity and vice versa. The intervention significantly improved the productivity of sodic land and explained 83.5 percent of the change in rice productivity. However, productivity of slightly and moderately sodic plots increased significantly in comparison to severly sodic plots. Plot area was also found to affect productivity, thus the large farmers benefited more from the intervention as compared to the small and marginal farmers.

Table 5.11 Impact of intervention on % change in Productivity of Rice

	% change in Productivity of Rice						
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
Soil Type	31.512 (6.29)***		-11.379 (-4.87)***	-4.628 (-1.159)	-3.958 (-1.01)	-3.980 (-2.68)**	-3.857 (-0.98)
Intervention Dummy		90.803 (0.914)***	96.130 (0.97)***	100 (33.09)***	104.09(33.22)***	104.077 (33.17)***	104.110 (33.125)***
Interaction Term				-10.221 (-2.08)*	-15.036 (-3.03)**	-15.081 (-3.036)**	-15.156 (-3.046)**
Plot Area					15.451 (3.96)***	15.448 (3.95)***	15.293 (3.891)***
Ownership of Agricultural Implements						0.719 (0.352)	0.764 (0.373)
Literacy status of head of the household							-1.148 (-0.45)

% change in Productivity of Rice							
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
Constant	38.323 (10.77)***	-1.017(-.592)	1.483 (0.853)	-1.097 (-5.86)***	-6.808 (-2.709)**	-7.107 (-2.68)	-6.199 (-1.85)
Adjusted R square	.103	.835	.846	.847	.854	.853	.853
Std. Error of the Estimate	45.99444	19.72021	19.08443	18.99000	18.58553	18.61009	18.63263

Wheat

Studies on yield of wheat in sodic soils attribute greater loss of yield to higher sodicity l (Sharma *et al.*, 2010). Yield of wheat is highly dependent upon the number of spikes produced by each plant; Sodic conditions negatively affect number of spikes produced per plant (Maas and Grieve, 1990) and the fertility of the spikelets (Seifert *et al., 2011; Fatemeh* et al., 2013). Sodic soils usually have poor availability of micronutrients, which is generally attributable to high soil pH (Naidu and Rengasamy, 1993).

Both for project and control plots, there was no wheat production in 'moderate' and severe category of soil sodicity classes. High pH damages plants directly and causes deficiencies of nutritional minerals such as iron and phosphorous (Guan *et al*., **2009**).

Before reclamation, wheat production was 1.81 ton per hectare in slightly sodic land and increased to 2.74 ton per hectare in the post reclamation period, with a 51.38 percent increase from the baseline. The yield was also found to improve for moderate and severe land categories, with a yield of 2.7 tons per hectare and 2.66 ton per hectare, respectively which were uncultivated in the pre-reclamation period. No change was observed in the control plots between pre and post reclamation period.

T test of productivity of wheat of slightly sodic plots, suggest no significant difference in the productivity of wheat of project (m=1.81, sd=.3.68) and control plots (m=1.706, sd=.375) before intervention at t(43)=0.890 . The productivity of wheat for project plots increased, suggesting a significant difference, before (m=1.81, sd=.3.68) and after (m=2.74, sd=.430) values at; t(27)=9.635, p = .000, though no significant difference in the productivity of wheat of control plots was observed, before intervention (m=1.706, sd=.375) and after intervention (m=1.824, sd=.375)at; t(16)=1.399, p = .181. The change in productivity of wheat in project plots post reclamation, attributable to UPSLRIIIP was estimated 0.82 t/ ha.

Factors responsible for change in wheat productivity

An overall regression model incorporating various explanatory variables responsible for change in productivity of wheat is shown in Table 5.12. The results are similar to rice. Change in productivity of wheat was significantly affected by the severity of sodicity and was found to be inversely related with change in productivity, i.e. higher the sodicity lower the productivity and vice versa. This was reflected by the variable interaction term. The intervention significantly improved the productivity of sodic land and explained 84.3percent of the change in productivity of wheat. Plot area was also found to affect productivity, thus the large farmers benefited more from the intervention as compared to the small and marginal farmers.

Table 5.12 Impact of intervention on % change in wheat productivity

	%change in Productivity of Rice						
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
Soil Type	34.100 (11.038)***		-7.684 (-3.347)**	3.395 (.876)	4.013 (1.055)	3.987 (1.047)	4.034 (1.055)
Dummy		90.052 (42.417)***	93.649 (39.828)***	99.999 (34.091)***	103.776 (34.046)***	103.758 (33.995)***	103.771 (33.940)***
Interaction Term				-16.774 (-3.519)***	-21.218 (-4.399)	-21.270 (-4.403)***	-21.299 (-4.400)***
Plot Area					14.258 (3.753)***	14.254 (3.748)***	14.195 (3.712)***
Ownership of Agricultural Implements						0.845 (.425)	0.862 (.433)
Literacy status of head of the household							-0.441 (-.177)
Constant	38.323 (11.038)***	0.746 (.450)	2.434 (1.426)	1.204 (6.629)	-6.282 (-2.570)	-6.633 (-2.568)**	-6.284 (-1.931)
Adjusted R square	.124	.843	.847	.852	.858	.857	.857
Std. Error of the Estimate	44.86907	19.02395	18.74065	18.42927	18.07746	18.09980	18.12634

5.3.8 Change in profits

Gross and net returns from rice and wheat were calculated for project plots and are presented in Table 5.13. Returns from farming rice and wheat were observed to have an inverse relationship with soil sodicity. So higher sodicity is associated with lower returns. Further, the net income was observed to decrease more sharply than the gross income. The farmers incurred losses for growing rice in moderately sodic soils and for wheat in slightly sodic soil, Rs.17743 and Rs 8112, respectively. Low productivity for wheat resulted in negative total net returns. However, the intervention proved successful in ameliorating the farmers' loss due to improved productivity which is also reflected in the higher benefit-cost (B-C) ratio for post-reclamation. A tremendous improvement of B-C ratio was observed for crops (both rice and wheat) in the slightly affected sodic soils and that of rice grown in moderately affected sodic soils. Overall UPSLRIIIP was found successful in improving farm incomes for the intervention group.

Table 5.13 Costs and returns (in Rs. per hectare) per crop

Sodic Classes	Gross Income		Total Cost		Net Return		Total Net Return	B-C Ratio	
	Rice	Wheat	Rice	Wheat	Rice	Wheat		Rice	Wheat
Pre Reclamation									
Slight	42580	24638	40315	32750	2265	-8112	-5847	0.06	-0.25
Moderate	18837	-	36580	-	-17743	-	-17743	-0.49	-
Post Reclamation									
Slight	58822	37258	45675	35635	13147	1623	14770	0.29	0.05
Moderate	55836	36725	44560	35970	11276	755	12031	0.25	0.02
Severe	44377	36215	43455	35345	922	870	1792	0.02	0.02

Change in household incomes and expenditure

Analysis of household income revealed that the intervention had an impact on the total income of the project households. In the pre-intervention period, there was no significant difference[42] in average income between the intervention and control groups while there is a significant difference[43] in average income between the groups in the post-intervention period. Moreover, the average income has increased for both the control and intervention groups, while the intervention group report a higher increase (27%) in average income compared to the control group (9%) in monetary terms (Figure 5.13).

[42]t-value = 0.452 and *df= 242.453*for income in pre-intervention period

[43]t-value = 2.681 and *df*= 178.962 for income in post-intervention period

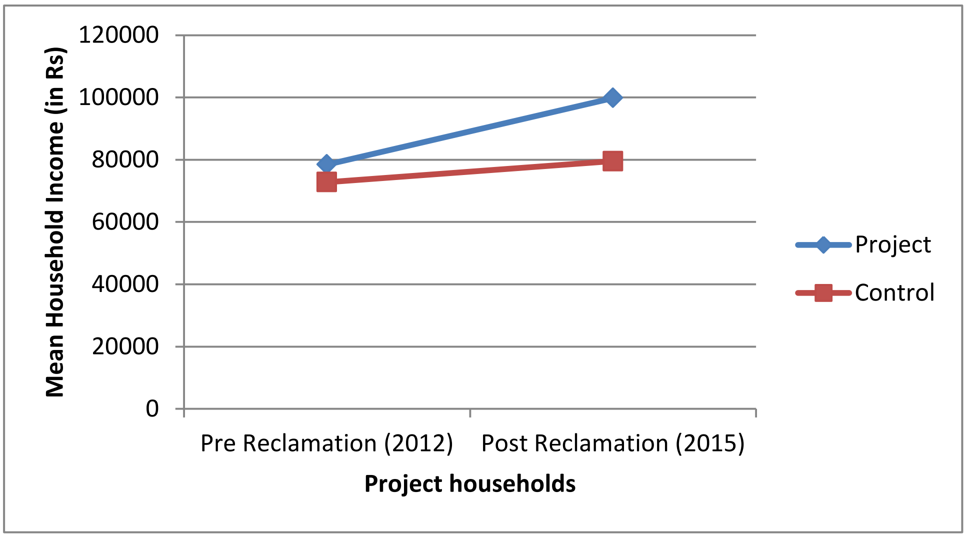


Figure 5.13 Total household income (in Rs)

5.3.9 Costs of degradation

The cost of degradation due to sodic soils can be understood as income foregone due to sodic soil, and was calculated by comparing the income from reclaimed land or project plots to the income obtained from non-reclaimed land or control plots. Cost of degradation can be defined as –

Equation 1: Cost of degradation = Gross Income from reclaimed land (project-post intervention) – Gross Income fromnon reclaimed land (control)

Using equation 1, cost due to degradation or loss of income from crops (rice and wheat) in each season was calculated for the sample control plots and total sodic area in the control villages, and is summarised in Table 5.14. A total annual loss of Rs.223.05 lakh is estimated for 4 selected control villages due to low productivity of rice and wheat, resulting from sodic soils.

Table 5.14 Cost of Degradation (annually)

	Actual Loss* (in Rs. per ha)		Total loss due to sodic soil ** (in lakh Rs.)	
	Rice	**Wheat**	**Rice**	**Wheat**
Slight	34,643.00	14,036.20	11.70	4.74
Moderate	52,389.80	36,725.00	13.62	9.55
Severe	60,513.00	36,215.00	114.76	68.68
Total Cost	49,181.93	28,992.07	140.08	82.97

*estimated for sampled Plots (in Rs. per ha); **estimated for control villages

5.4 Scenario development for 2030

For the State of Uttar Pradesh, we project the area likely to be impacted by salinity/ alkalinity in 2030 utilising data from 2003/ 05 and 2011/ 2013 of the Space Applications Centre. We then use these estimates to determine the costs of reclamation of saline/ alkaline for the State of Uttar Pradesh in 2030. The extent of salinity/ alkalinity in 2030 is shown in Table 5.15. We project two scenarios for salinity/ alkalinity. The data follows a linear trend ($y = -328631x + 964833 R^2 = 1$) and salinity/ alkalinity impacted land is projected to drop to 0 in 2019 itself. Therefore in 2030, Uttar Pradesh would have no alkaline land and all land would be reclaimed by 2019 (Fig 5.14). Hence no costs of reclamation in 2030 would be applicable. However, given that this scenario appears to be a bit optimistic, we generate a second scenario where the degraded area decreases proportionally every eight years (Fig 5.15).The costs of reclamation of alkaline/ saline land is Rs 60000 per ha in 2016 prices[44]. Therefore, the cost of reclaiming lands degraded by salinity alkalinity in Scenario 2 in 2030 is Rs 3199 million in 2016 prices.

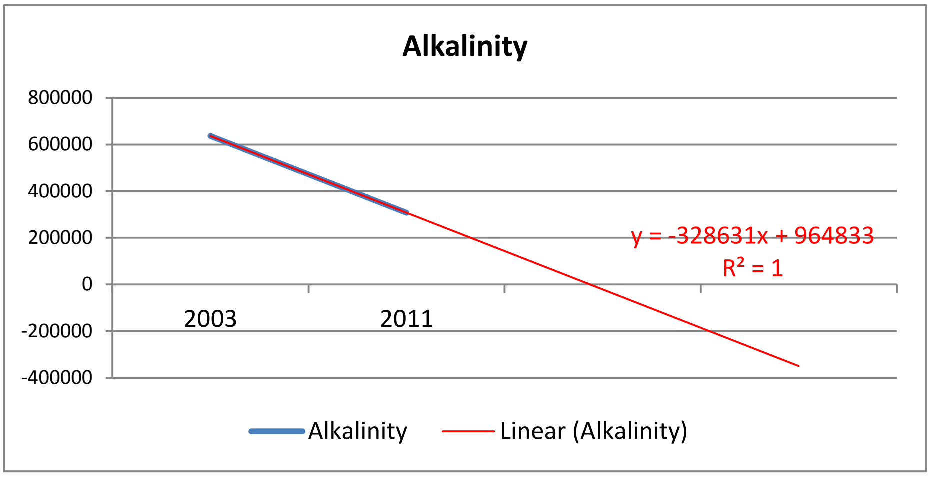


Figure 5.14 Linear decline in salinity for Uttar Pradesh (1st scenario)

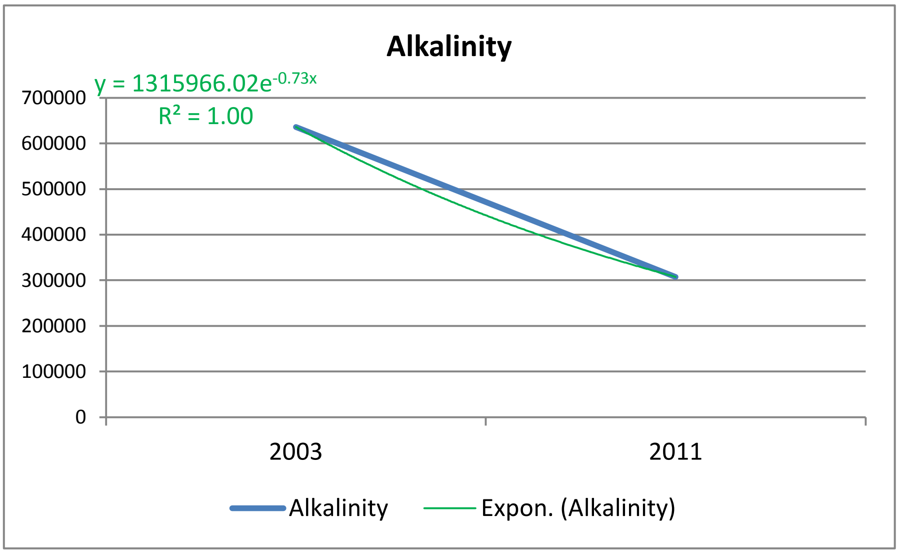


Figure 5.15

[44] http://agricoop.nic.in/sites/default/files/rps_guidelines%20(2).pdf

Proportional decline in salinity for Uttar Pradesh (2nd scenario)

Table 5.15 Projected extent of salinity/alkalinity in 2030

Extent of Salinity/Alkalinity (in ha)					
Year	2003	2011	2019	2027	2030
Scenario 1	636202	307571	0	-	-
Scenario 2	636202	307571	148695	71886	53320

5.5 Conclusion and Recommendations

UPSLRIIIP has had a remarkable impact on crop productivity and farm incomes. The productivity of all the three categories of land showed improvement. The study showed that it is possible to reclaim even highly deteriorated sodic land, by way of application of gypsum followed by improved drainage. The intervention had a significant positive impact on severely sodic land which prior to reclamation was left fallow, but could bear two crops a season post reclamation. Higher crop productivity post-reclamation was probably due to better soil condition for crop production. Several studies have indicated that the application of gypsum decreases Na toxicity and improves soil structure which significantly contributes to crop productivity improvements (Chhabra, 1996; Rasouli *et al.*, 2013). Therefore, soil reclamation appeared to play an important role in augmenting rice and wheat yields from previously degraded sodic soils. The intervention, in addition to, improved soil health has resulted in greater farm productivity, thereby augmenting farm income.

The cost of degradation was estimated as the difference between the gross income from reclaimed land and gross income from non- reclaimed land. The annual cost of degradation is assessed at INR 49,181.93/ ha for rice and INR 28,992.07/ ha for wheat.This study underlines the feasibility of reclaiming sodic soils resulting in positive benefits per year of Rs 78,147 per ha.

We develop two scenarios for the area under salinity/ alkalinity in Uttar Pradesh in 2030. In one scenario, salinity/ alkalinity impacted land is projected to drop to 0 in 2019 itself. Therefore in 2030, Uttar Pradesh would have no alkaline land and all land would be reclaimed by 2019. Hence no costs of reclamation in 2030 would be applicable. However, given that this scenario appears to be a bit optimistic, we generate a second scenario where the degraded area decreases proportionally every eight years.The cost of reclamation norms for alkaline/ saline land is Rs 60000 per ha in 2016 prices[45]. Therefore, the cost of reclaiming lands degraded by salinity/ alkalinity in Scenario 2 in 2030 is Rs 3199 million in 2016 prices.

Based on field observations, the results of this study and interaction with experts, summarised below are few recommendations to address the challenges of sodic soil reclamation.

Successful reclamation of sodic soils in Uttar Pradesh warrant studies to determine the reasons for success and their application in other states impacted by salinity such as Punjab.

[45] http://agricoop.nic.in/sites/default/files/rps_guidelines%20(2).pdf

Although, application of gypsum is a feasible approach for overcoming the structural and nutritional constraints in sodic soils, reduced availability and quality of agricultural-grade gypsum has been reported (Sharma et al., 2016). Thus, there is a need to identify other low-cost alternatives to reduce the pressure on limited gypsym reserves.

In addition, resodification of the previously gypsum-amended sodic lands has also increased. Resodification, refers to the reappearance of sodic patches resulting in stunted crop growth and low yields in a sizeable area of the land. The results of a study conducted by Yadav et al. (2010)*46*, to assess the sustainability of sodic land reclamation in Etawah district of Uttar Pradesh using remote sensing and ground truth data, showed that out of the total (3,905 ha) reclaimed area, about 27% had relapsed showing the signs of deterioration after a period of improvement. The study further identifies poor on-farm water management, including factors, such as, nearness to canal, poor drainage system and sallow water tables, to be perilous to resodifiction in Uttar Pradesh. This point towards the need to develop strategies to use marginal quality saline and sodic water in soil reclamation, enhancement of water drainage system and sensitization of farmers to adopt water management practices.

Lastly, experiments on land reclamation using phytoremediation, through salt-tolerant cultivars in field crops and sodic tolerant fruit crop should be conducted. These cultivars available in different field and horticulture crops also give stable yield with reduced or no amendments, especially in partially reclaimed soils.

[46] Yadav MS, Yadav PPS, Yaduvanshi M, Verma D and Singh AN (2010) Sustainability assessment of sodic land reclamation using remote sensing and GIS. Journal of Indian Society of Remote Sensing. 38: 269-278.

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Chapter 6. Economic benefits of addressing soil and water salinity through sub-surface drainage: A case study from the coastal croplands of Andhra Pradesh

6.1 Introduction

Soil degradation due to salinity adversely affects the production of agricultural and horticultural crops in several parts of India. Saline soils are found in almost all agro climatic zones. Barring a few cases that are of natural origin, formation of the majority of the saline soils in India can be attributed to anthropogenic factors. Introduction of canal irrigation, over-irrigation, use of saline water for irrigation, and large scale use of fresh water or ground water for intensive agriculture has led to the accumulation of soluble salt on the surface of land, thus increasing the salinity of surface soil.

It is estimated that nearly 6.7 million ha (Mha) land in India is affected by soil salinity and sodicity, (Mondol et al., 2010), of which about 1.7 Mha is waterlogged (ISRO, 2009) and 1.2 Mha is coastal saline soil (CSSRI, 2012). India has a long coastline (~7500 km), and saltwater intrusion can pose serious problems in coastal areas. The factors which contribute significantly to the development of saline soil in the coastal areas are tidal flooding during the wet season, direct inundation by saline water, and upward or lateral movement of saline ground water during the dry season. As a result of the high salinity of ground water, coastal saline soils are highly under-utilized for crop production. At present, the entire coastal area is mostly mono-cropped with rice grown during the monsoon. The land remains fallow during the rest of the year due to high soil salinity and the lack of good quality irrigation water. Apart from the constraint of irrigation, agricultural development in the coastal saline belt is impeded by several other factors, which include the low fertility status of most saline soils in respect to organic matter content, nitrogen, phosphorus and micronutrients like zinc and copper and the resulting low crop yields. Variable rainfall and risk of drought also affect cultivation since a heavy monsoon in some years delays the planting of a dry season crop, resulting in crop losses due to higher soil salinity during the summer. Further, a considerable area of the Indian coastal area is within polders of different types. Perennial water-logging due to inadequate drainage and faulty operation of sluice-gate facilities restrict potential land use of the low lands within poldered areas. However, saline agriculture can potentially play a vital role in coastal areas with suitable application of technologies and techniques. Besides growing salt-tolerant rice genotypes during the wet season, other interventions to improve the productivity of cropland during the dry season, include the following;

1. ***Protective embankment:*** protects the land from inundation of saline water through establishment of embankments of suitable size[47] (Prasetya, 2007).
2. ***Provision of sluice gate on the embankment:*** Sluice gate or flap-gate in the embankment system helps to remove excess water from the field during low tide.
3. ***Levelling of land:*** Slight variations in the micro-relief may lead to salt accumulation in the raised spots. Properly levelling of land can prevent the accumulation of water

[47] The recommended height is 1m above the sea level

in low-lying patches with shallow ground water tables and facilitate uniform drainage of excess water (Gehad, 2003). .

4. ***Storage of excess rainwater for irrigation:*** Storage of rain water in ponds/ water tanks in coastal areas during the monsoon can provide much-needed fresh water during the dry season.
5. ***Keeping land covered in the winter and summer:*** Ground water is saline and present at a shallow depth (about 1.0 meter) in coastal areas. Keeping lands fallow leads to high salinity in the soil due to evaporation of excessive soil moisture. Therefore, the cultivation of salt tolerant crops/ nitrogen-enriching crops during the dry season is recommended in order to avoid keeping the land under fallow (Islam, 2006).
6. ***Fertilization of crops:*** Since saline soils with high sodium (Na) content, have low fertility with low organic matter content, application of appropriate fertilizers is necessary to boost crop production. Potash fertilizers are advantageous to saline soils and help lower Na uptake by plants while increasing potassium (K) uptake. This increased K fertilization protects crops from the harmful effects of Na (Islam, 2006).
7. ***Sub-surface drainage:*** Sub-surface drainage (SSD) reduces salinity by leaching out the salts from soil, lowers the water table and maintains it below a critical depth (< 1m) to prevent salinity from affecting crops. Broadly, there are two types of drainage systems, surface drainage[48] and sub-surface drainage. Essentially, a SSD system (Wright and Sands, 2009) operates through a series of underground pipes which does not affect agricultural activity above ground and is more effective than surface drainage system in the long-term (Kumar et al., 2009). The SSD consists of a surface outlet and a system of sub-surface main drains and laterals. The laterals are perforated pipes placed parallel to each other and perpendicular to the main drain. The main drain is connected perpendicularly to a collection drain, from where the water is pumped out of the field through the surface outlet.

Sub-surface drainage has been one of the important interventions to deal with soil salinity. In this study, we examine the benefits of sub-surface drainage in salinity-affected areas in coastal Andhra Pradesh. Before, delving into the case study, we set the context in the next section by discussing the issues around soil salinity in the state of Andhra Pradesh.

6.2 Land degradation and salinity in Andhra Pradesh

More than 20% of the total degraded land due to waterlogging is present in Andhra Pradesh (Table 6.1). Saline soil area extends to about 0.12 Mha in the state (ISRO, 2016). The salinity affected soil area of the state is the fourth largest in India (after Gujarat, Rajasthan and Uttar Pradesh). Most of the saline soils in the State belong to the coastal saline soil category (CSSRI, 2012). Area under coastal saline soils (77568 ha) in the State is the fourth largest in India (After Gujarat, West Bengal and Odisha) (CSSRI, 2012). Salt-affected soils exist in

[48] Surface drainage operates through shallow ditches, also called open drains. These ditches discharge into larger and deeper collector drains. In order to facilitate the flow of excess water toward the drains, the field is given an artificial slope by means of land grading. However, surface drainage may be associated with soil erosion and might not be a long term solution. Additionally, deep trenches developed under the surface drainage system reduce the movement of agricultural machinery vis-à-vis reduces the effective area under cultivation (Kumar et al., 2009).

narrow patches between coastal sands and uplands in the districts of Nellore, Prakasam, Guntur, Krishna, and West Godavari and local patches alongside natural streams in almost all districts (ISRO, 2016). Soils with salinity levels as high as 101 $dS\,m^{-1}$ are found in Prakasam district (Swarajyalakshmi et al., 2003).

The major portion of the areas under coastal saline soils of Andhra Pradesh (particularly in the Krishna-Godavari deltaic region) is of the deltaic alluvium type (Swarajyalakshmi et al., 2003). This soil is relatively heavy textured, rich in clay and clay-loam and grouped under entisols and vertisols. Soils of the deltaic region have high cation exchange capacity (CEC), neutral to alkaline pH, moderate to poor drainability, soil exchangeable sodium percentage (ESP) > 15, and dominant salts are chlorides and sulphates of Na^{+} followed by those of Mg^{2+} and Ca^{2+}. Soil salinity varies from low to very high according to season and location.

Table 6.1 Statewise status of Desertification/Land Degradation (ha) Source: ISRO, 2016

State	Vegetation degradation		Water erosion		Wind erosion		Salinity		Water logging		Forest Shattering	
	2011-13	2003-05	2011-13	2003-05	2011-13	2003-05	2011-13	2003-05	2011-13	2003-05	2011-13	2003-05
Andhra Pradesh	1164257	1162447	789433	783830	3986	4722	117952	121239	132334	125755		
Arunachal Pradesh	120449	107845									20186	19072
Assam	471958	322540	31424	31424					186667	193669		
Bihar	242525	255073	321175	304364					106628	78450		
Chhattisgarh	1348089	1348122	783645	770387								
Delhi	9980	9980							347	347		
Goa	138172	132301	33889	33892					9005	9003		
Haryana	41411	40514	13568	13568	151797	148151	27841	27841	12530	8822		
Gujarat	2319826	2255417	3859497	3788099	1177105	1179548	2645405	2643828	3375	3375		
Himachal Pradesh	1790803	1582938	268261	233990							332423	322417
Jammu & Kashmir	1951000	1907187	145932	110222	1670244	1650577			70563	46548	2968279	2750257
Jharkhand	1379038	1307162	4036785	4037261								
Karnataka	1712386	1704569	5043041	5059629	2159	2159	86740	86582				

State	Vegetation degradation		Water erosion		Wind erosion		Salinity		Water logging		Forest Shattering	
	2011-13	2003-05	2011-13	2003-05	2011-13	2003-05	2011-13	2003-05	2011-13	2003-05	2011-13	2003-05
Kerela	337613	328638							11989	12906		
Madhya Pradesh	2523801	2514983	1125418	1120221					7788	7788		
Maharastra	4884005	4890778	8060753	7622800			29089	30054				
Manipur	575603	574706	8070	8070					5026	5026		
Meghalaya	435527	414659	53149	54046					1548	5881		
Mizoram	167050	81854	8119	7444								
Nagaland	778421	637957										
Odisha	745122	752929	4409413	4442526					36439	36439		
Punjab	32561	18705	14116	1897								
Rajasthan	2606221	2596003	2116314	2116082	15197874	15332054	363768	365666	18421	18421		
Sikkim	74318	74205									3730	3730
Tamilnadu	1385478	1368330	6411	6411	30429	30429	9878	9878				
Telengana	541145	538533	2854285	2951871			86514	81917				
Tripura	236374	125058	186900	189533								
Uttar Pradesh	413476	414176	586961	610989			307571	636202	33620	33907		

State	Vegetation degradation		Water erosion		Wind erosion		Salinity		Water logging		Forest Shattering	
	2011-13	**2003-05**	**2011-13**	**2003-05**	**2011-13**	**2003-05**	**2011-13**	**2003-05**	**2011-13**	**2003-05**	**2011-13**	**2003-05**
Uttarakhand	606616	545610	11943	11943							13786	13786
West Bengal	265277	264325	1329539	1299542					17627	13261		
Total	**29298553**	**28283544**	**36099042**	**35610069**	**18233594**	**18347639**	**3674759**	**3999206**	**653908**	**599597**	**3338404**	**3109262**

Andhra Pradesh is the third largest rice producing (13.03 Mt) state of India (MoA, 2015). Rice is the staple food in Andhra Pradesh and the major crop in coastal Andhra Pradesh (2.2 Mha) covering more than 82% of total rice cropping area of Andhra Pradesh. The Krishna-Godavari delta area in the coastal Andhra Pradesh is one of the major rice growing areas of the state (Figure 6.1).

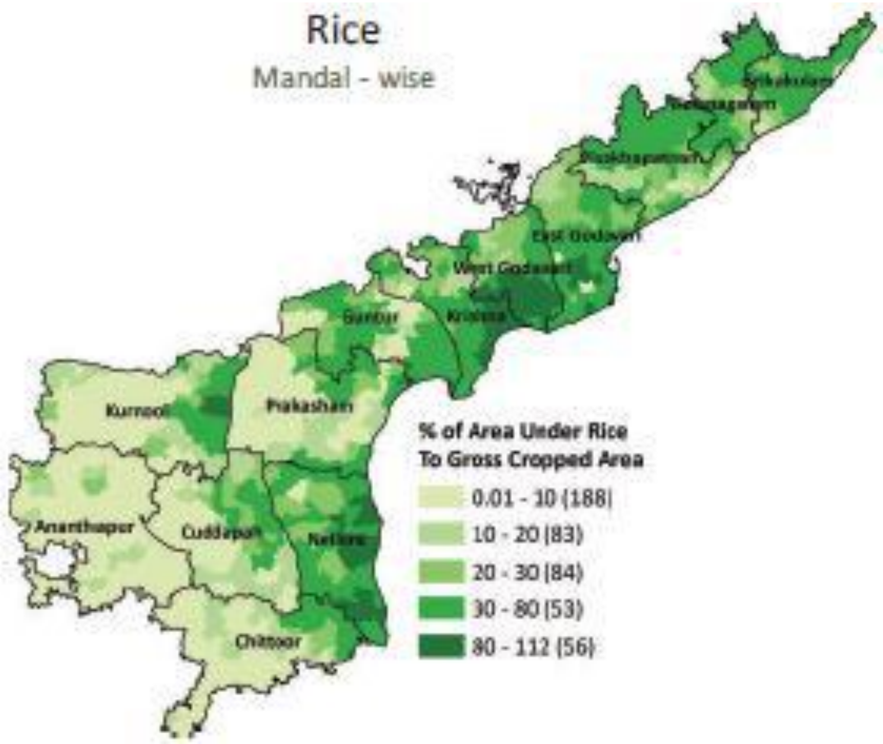


Figure 6.1 Block wise rice cropping area in Andhra Pradesh during 2014. (Govt. of Andhra Pradesh, 2016)[49]

About 1307 m^3 of water is required to produce 1 ton of rice (Chakraborty et al., 2014). Most of it is used for soil preparation during the initial 60 days period of rice cultivation (Chapagain and Hoekstra, 2011). The rice crop is sensitive to a salinity (threshold 3 $dS\ m^{-1}$) particularly during the seedling stage of crop growth (FAO, 2002). Therefore, the area under rice cultivation mostly depends on the monsoon pattern and availability of fresh water. In the coastal districts of India, the area under rice and rice productivity are declining because of increase in aquaculture (Cheralu, 2011) and intrusion of sea water (Redfern et al., 2012). Rice farmers in the coastal Andhra Pradesh are adopting improved varieties of rice to increase production (Cheralu, 2011). However, the recommended input packages for rice varieties provide inadequate attention to the correction of soil and, nutritional deficiencies and water management. As one of the highest fertilizer (NPK: 2366 thousand ton) (FAI, 2011) and pesticide (9289 t) (MoA, MoSPI, 2012) using states in India, there is no further scope to improve rice productivity in the coastal districts of Andhra Pradesh using these inputs. Further, in addition to the requirement of fresh water for rice cropping, an efficient drainage system is also required to regulate the groundwater table and to remove the pool of surface water formed after the saturation of the soil pores with irrigation or rain water. In addition water use efficiency in the coastal districts also needs to be improved in order to make rice farming more profitable (Cheralu, 2011).

[49] Andhra Pradesh State Portal. http://www.ap.gov.in/

A few projects have been implemented in Andhra Pradesh to manage soil salinity and water logging in croplands due to irrigation water and intrusion of marine water in groundwater. The major initiative to control the salinity of the vast crop land of Andhra Pradesh was started in the year 2004 as the Andhra Pradesh Water Management (APWAM). As part of this project sub-surface drainage systems were introduced. Details of this project are provided in the next section.

The objective of this case study was to evaluate the economic and social benefits of sub-surface drainage. The area falls in the lower Godavari Delta area where soil salinity is mainly due to intrusion of the sea water through the tidal rivers and withdrawal of water from the fresh water lakes for aquaculture. The analysis was based on a comparison of agricultural productivity and profits in areas with SSD and those without, using structured questionnaire-based interviews. We hypothesize that the benefits of SSD will show up in the form of increased agricultural productivity and/ or enhanced incomes for households in the intervention areas as compared with the control group (those without access to SSD). We assume that these benefits represent the foregone benefits (conversely the costs of degradation) of coastal salinity intrusion in the absence of SSD interventions.

In the next section, we describe our site selection methodology, the main project and intervention studied and our data collection approach.

6.3 Methodology

6.3.1 Case study site selection

District selection in Andhra Pradesh

The share of each class of Andhra Pradesh (old, new and Telengana) in the degradation of the total area of AP was determined from the harmonised atlas (ICAR, 2010). Category 1 (water erosion), 2 (water erosion under open forests) and 12 (waterlogged saline soils) of the state (current AP) accounted for 83.2%, 11.4% and 0.3% of the state (Table 6.2). However, Andhra Pradesh was selected for its waterlogged saline soils since water erosion is being assessed in Madhya Pradesh and saline soils in Gujarat. When the analysis was repeated on a district basis, East Godavari and Krishna districts contributed 41.2. % and 52.9 % to waterlogged saline soils (category 12) (Table 6.3). We therefore selected a site lying at the border of these districts as the case study area.

Figure 6.2 District map of Andhra Pradesh showing potential case study areas

Table 6.2 Share of class in degraded area of Andhra Pradesh

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Share of class in total degraded area of the state																		
OLD ANDHRA PRADESH																		
87.6	8.9	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.2	1.7	0.4	0.0	0.0	0.0	0.4	0.2
CURRENT ANDHRA PRADESH																		
83.2	11.4	0.0	0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.0	0.3	2.6	0.7	0.0	0.0	0.0	0.4	0.3
TELANGANA																		
95.2	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0

1 Exclusively water erosion (>10 tonnes/ha/yr);
2 Water erosion under open forest;
3 Exclusively acid soils (pH <5.5);
4 Acid soils under water erosion;
5 Acid soils under open forest;
6 Exclusively wind erosion;
7 Exclusively saline soils;
8 Eroded saline soils;
9 Acid saline soils;
10 Saline soils under wind erosion;
11 Saline soils under open forest;
12 Waterlogged saline soils;
13 Exclusively sodic soils;
14 Eroded sodic soils;
15 Sodic soils under wind erosion;
16 Sodic soils under open forest;
17 Eroded sodic soils under open forest;
18 Mining/Industrial waste;
19 Waterlogged area (Permanent)

Source: ICAR-NAAS (2010)

Table 6.3 Share of district in state-wise degradation by class (%)

Category	1	2	7	8	12	13	14	17	18	19
Adilabad	9.7	1.5	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0
Anantapur	9.9	4.1	0.0	0.0	0.0	9.1	46.2	0.0	7.7	0.0
Chittoor	7.8	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cuddapah	12.3	19.8	0.0	0.0	0.0	0.6	17.9	100.0	5.1	0.0
East Godavari	1.8	2.2	35.7	0.0	41.2	0.0	0.0	0.0	2.6	26.3
Guntur	2.9	5.3	10.7	0.0	0.0	21.4	12.8	0.0	2.6	0.0
Karimnagar	3.7	7.2	0.0	0.0	0.0	0.0	0.0	0.0	12.8	0.0
Khammam	4.4	3.2	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0
Krishna	0.5	0.0	46.4	0.0	52.9	0.0	0.0	0.0	5.1	31.6
Kurnool	6.6	0.2	0.0	0.0	5.9	3.9	0.0	0.0	28.2	0.0
Mahbubnagar	4.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medak	3.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nalgonda	2.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0
Nellore	1.7	5.5	0.0	0.0	0.0	27.3	2.6	0.0	0.0	15.8
Nizamabad	4.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prakasam	5.2	12.5	0.0	0.0	0.0	37.7	20.5	0.0	7.7	5.3
Rangareddi and Hyderabad	4.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0
Srikakulam	2.3	3.1	3.6	100.0	0.0	0.0	0.0	0.0	0.0	10.5
Vishakhapatnam	4.0	19.3	0.0	0.0	0.0	0.0	0.0	0.0	2.6	5.3
Vizianagaram	4.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0
Warrangal	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0
West Godavari	1.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	2.6	5.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

6.3.2 The Andhra Pradesh Water Management Project

The major initiative to control the salinity of the vast crop land of Andhra Pradesh was started in the year 2004 as the Andhra Pradesh Water Management (APWAM) Project. The APWAM project was initiated with a grant of over a billion rupees from the Food and Agricultural Organization (FAO) to improve agricultural water use efficiency in the State. The grant was awarded to Acharya N G Ranga Agricultural University (ANGRAU), Hyderabad, in technical collaboration with the International Institute for Land Reclamation and Improvement and Wageningen Agricultural University, Netherlands.

The entire state of Andhra Pradesh (before 2014) was divided into 8 agro-climatic zones under the APWAM project (Figure 6.3). Different water management projects were undertaken in different agroclimatic zones under 10 different centres. Five sub surface drainage (SSD) pilot areas were developed in farmers' fields under all over the state. These include, i) Konaki Pilot area (Nagarjuna Sagar Project), ii) Endakuduru pilot area (Krishna Delta), iii) Uppugunduru pilot area (Krishna Delta), iv) Kovelamudi pilot area(Krishna Delta) and v) Kalipattanam pilot area (Godavari Delta) (Satyanarayana et al., 2006).

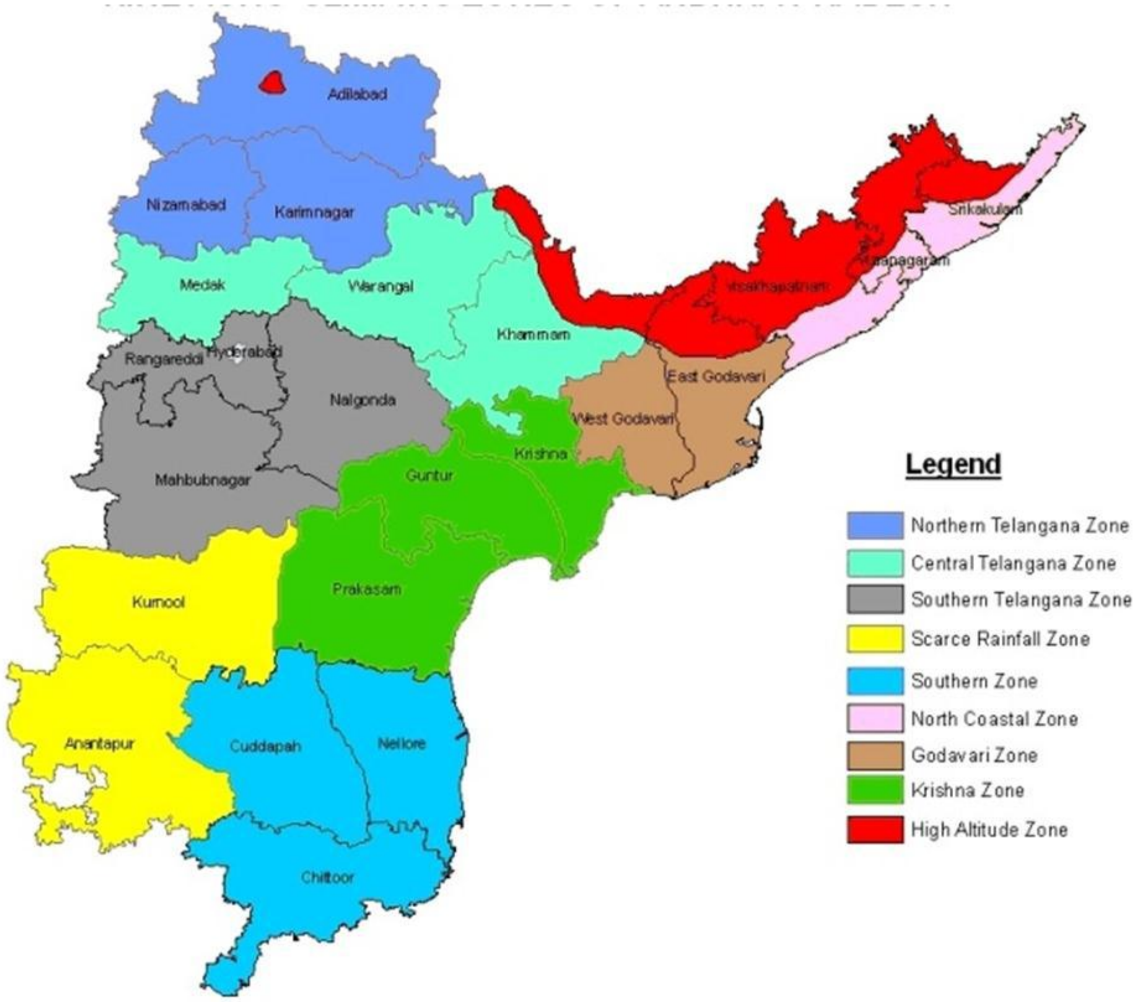


Figure 6.3 Different agroclimatic zones in Andhra Pradesh (before 2014). Under the APWAM project Northern Telengana Zone and Central Telengana zone were merged as Northern Telengana Zone. (Saytanarayana et al., 2006)

Soil salinity in the lower Godavari Delta area is mainly due to intrusion of sea water through tidal rivers and withdrawal of water from fresh water lakes for aquaculture (Satyanarayana et al., 2006). In this study, we evaluate the economic and social benefits of SSD implemented under the APWAM project through a case study in the Kalipattanam area of the Godavari delta.

6.3.3. About the selected site

The Kalipatnam pilot area is located in the Godavari Delta area near Bhimavaram town of Mogalturu thesil in West Godavari district (Figure 6.4). Soils of the area are highly saline with high sodium absorption ratio (SAR) and exchangeable sodium percentage (ESP) values. In these soils water-soluble salts smother the sodium, which explains the recorded lower pH values. The soils have high Mg/ Ca ratio (>1) (Schulte and Kelling, 1993). Soil textures vary from loamy sand (12% clay) to clay (66%). A soil and water analysis carried out by Sreedevi et al., (2008a) revealed the following:

- EC: 2.0–27.0 dS $m^{-1,}$, ESP: 15.5–23.0 and SAR: 14.9–21.1
- Hydraulic conductivity between 0.01 to 1.5 m day^{-1} which clearly indicates that the soil texture of the pilot area varies widely.
- The EC of the groundwater varied from 4.8 to 43 dS m^{-1}.

The principal cropping pattern is rice–rice–-fallow. The area obtains a fresh water supply from the Dowleswaram Barrage (Rajhamundry) through the Kalipatnam extension channel. The water table depth varies from 0 to 1.0 m from the ground level. The Upputeru River in the southern side of the Kalipatnam Pilot area (Figure 6.5) originates from the Kolleru lake which spans into two districts – i) Krishna and ii) West Godavari. The lake is located within 40 km from the sea shore. Kolleru lake is the largest (90,100 ha) fresh water lake in India (Ramsar, 2002). Major fresh water inputs to the lake are Ramileru, Tammileru, Budameru, Polaraj drains located in the northern side of the lake. Upputeru river is the primary outflow of the Kolleru lake to the Bay-of-Bengal. During the last few decades of the last century, thousands of aquaculture ponds were built around the Kolleru lake. About 42% of the lake area was occupied by an aquaculture pond during 2004 (UNEP, 2010).

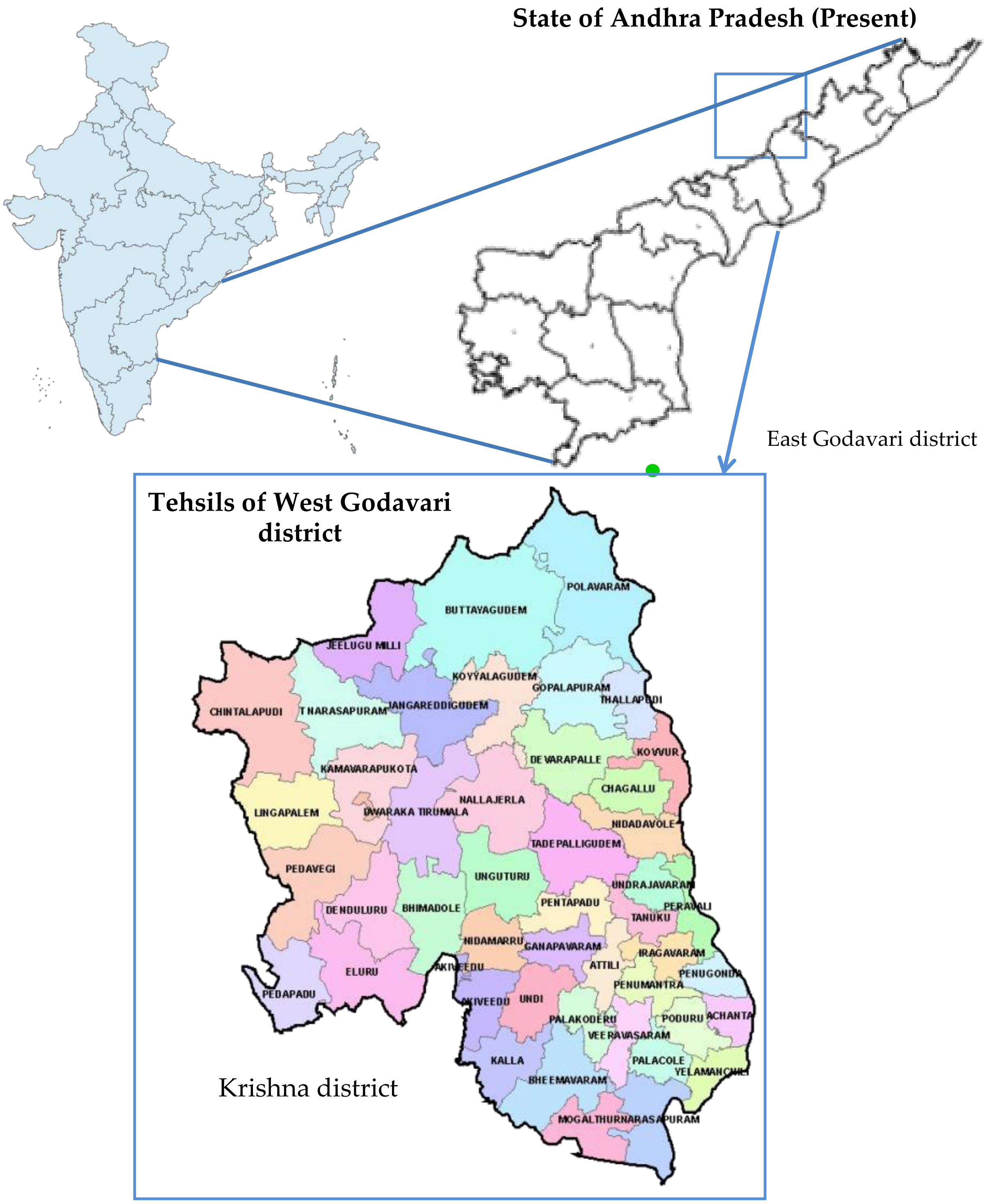


Figure 6.4 Location of the study area. ● Kalipatanam pilot area

These fish tanks draw fresh water from the lake and releases their effluents to the lake. This has a large impact on the water quality and water level in the lake. The decrease in the water level in the lake has increased the back slush of saline marine water to the lake through the Upputeru river and ground water seepage (Harikrishna et al., 2012). The decrease of the fresh water inflow to the Upputeru river from the lake has increased the salinity of the river water and consequently the salinity of the ground water in the flood plain. Thus worries in the Upputeru river basin grow as the Kolleru shrinks.

Agriculture in the Upputeru river basin has been severely affected due to an increase in the salinity level of the ground water and consequently of soil (Rao et al. 2006). Apart from agriculture, drinking water supply to the area has been also affected (Rao et al., 2006). The tailing of the Kalipattanam extension channel supplies fresh water to the Kalipatnam area. However, the lower surface level of the Kalipatnam area as compared to the Upputeru river allows the river water to enter the crop land through ground seepage. Farmers of the Kalipatnam Pilot area grow two rice crops, one during the dry season (locally called *Dalva*: December to March) and the other in the wet season (called *Saarva*: June to November). The rice cropping during *Dalva* has been severely affected due to increase in the salinity level of the Upputeru river (Sreedevi et al., 2008a).

Under the APWAM project, flap gates bar the entry of saline water from the Upputeru river into the cropland and prevent it from mixing with the fresh water of the Kalipatnam extension channel. A SSD system was built in the area to restrict the mixing of the irrigation water with the saline ground water. The design of the SSD system in the Kalipatnam pilot area was based on the recommendations formulated for different soil types in Andhra Pradesh under an Indo-Dutch Network Project (INDP, 2002).

In May 2005, 36 ha of salt-affected crop land of about 60 farmers of Kalipattanam village were adopted under the APWAM project. Initially flap gates were installed in the fields to prevent the fresh water of the Kalipatnam extension channel from mixing with the saline water of the Upputeru river (Sreedevi et al., 2008b). Subsequently, a SSD system was installed in an area of 18 ha with drains spaced at 50 m. Thus the 36 ha land area was divided into flap gate (referred as Intervention 1 or Int_1) and flap gate + SSD (henceforth referred as Intervention 2 or Int_2) (Figure 6.5). At the downstream end of the collector line from the Int_2 crop land the drainage effluent was pumped into the Upputeru river. Thus it was assured that both control area and pilot area farmers receive fresh water supply from the irrigation canal.

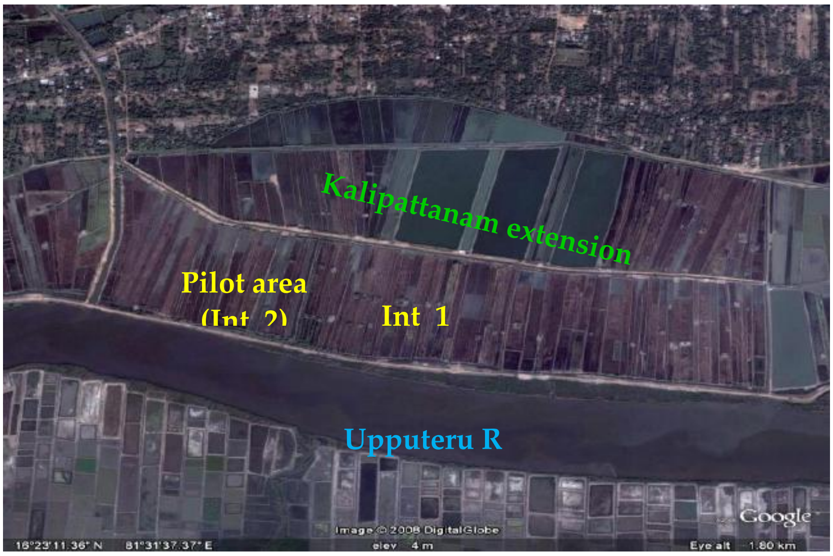


Figure 6.5 Kalipatnam pilot area. Int_1: Flap gate only; Int_2 Flap gate + SSD.

Source: Google Earth

6.3.4 Survey design

A survey was conducted among farmers of the Kalipatnam pilot area using a structured questionnaire. The questionnaire is provided in Appendix 6.1. The questionnaire was divided into the following five sections: (i) household identification, (ii) land holdings and operational area (iii) cropping pattern and crop production (iv) Soil conservation practices and benefits derived from SSD and flapgate interventions and (v) Socio-economic information about households (income, literacy, livestock holdings, cooking fuel usage and collection of firewood). All farmers (59) from the APWAM Kalipatnam pilot area were included in the study-the intervention group. Among these farmers, 29 were from the project control area with only flap gate installed as an intervention (Int-1) and 30 were from the pilot area where both flap gate and SSD were installed (Int-2). Additional, 110 farmers' plots from the upstream and downstream area to the Kalipatnam pilot area were included in the present study as control area (outside the Kalipatnam pilot area of APWAM project) (Figure 6.6). While selecting the control cropland area, we ensured that the croplands have the same source of irrigation water as the intervention group i.e. the tail of the Kalipatnam extension canal. The survey was conducted during the months of May-June, 2016.

Figure 6.6 Study area in the Kalipattanam village.

Source: Google Earth.

6.3.5 Questions addressed in the case study

We attempted to answer three questions in this study:

1. Is there a significant difference in crop productivity among the intervention and non-intervention groups (including between the two interventions)? If so, which variables most influence this difference in crop productivity?

2. Is there is significant variation in the net annual cost of cultivation among different groups?

3 Is there is significant variation in the net annual profit among different groups? If so, which are the important variables in determining the net annual profit of the croplands of the study area?

SPSS 23 was used to analyse the dataset collected from the field. All dataset related to crop land was converted to Mg ha^{-1} for better comparison. Univariate analysis was conducted to assess the role of Int_1 and Int_2 on profitability of farmlands from agriculture activities and on socio-economic status of farmers compared to the control area farmers. Tukey's HSD test was employed to test for differences amongst groups (control, Int_1 and Int_2). Linear regression analysis was employed to understand the influence of various variables on crop productivity and net annual profit of the farmers. We used the Darbin-Watson constant to test for auto correlation among variables. If the Darbin-Watson constant indicated an auto correlation, then the strength of the correlation was determined using a Pearson's correlation. P values ≤ 0.05 were considered significant.

6.4 Results and Discussion

6.4.1 Socioeconomic status of farmers

Most the surveyed farmers are Hindu (95.2% of sample) and belong to the general caste (69.9% of farmers surveyed) (Figure 6.7). Christians make up a tiny proportion of the populations (4.2%). However, the percentage of OBC farmers (62.1%) was higher within the Int_1 group followed by control (13.8%) and Int_2 (6.7%) group.

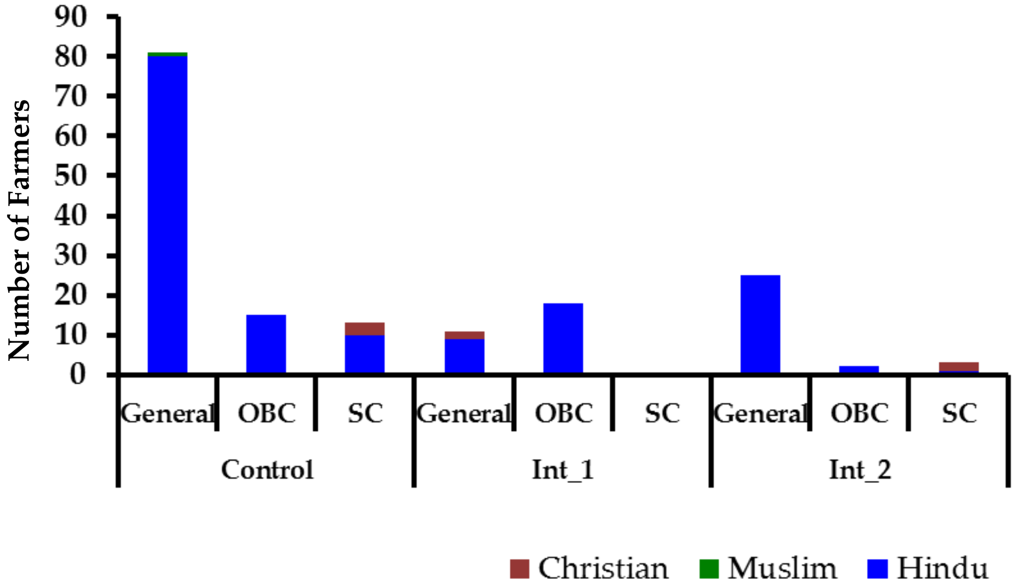


Figure 6.7 Distribution of farmers based on caste and religion

The types of houses constructed by the farmers were of four different types: a) Mud houses, b) mixed (mud and brick) houses, c) Brick houses with tiled roofs d) Brick houses with concrete roofs. There was no mud house among the farmers from the intervention group (Figure 9). However, more than 16% farmers from the control group had mud houses. The study indicates that more brick houses with concrete roofs belong to the intervention group farmers (Figure 6.8). The percentage of brick houses with concrete roofs was highest amongst the Int_2 group of farmers (46.6%). This could suggest that Int_2 farmers were better placed financially to adopt the intervention given that their lands could not be utilised during the construction of the SSD intervention. Alternatively, this could also suggest that higher revenues resulting from increased yields post soil-salinity removal led people to invest in more permanent structures.

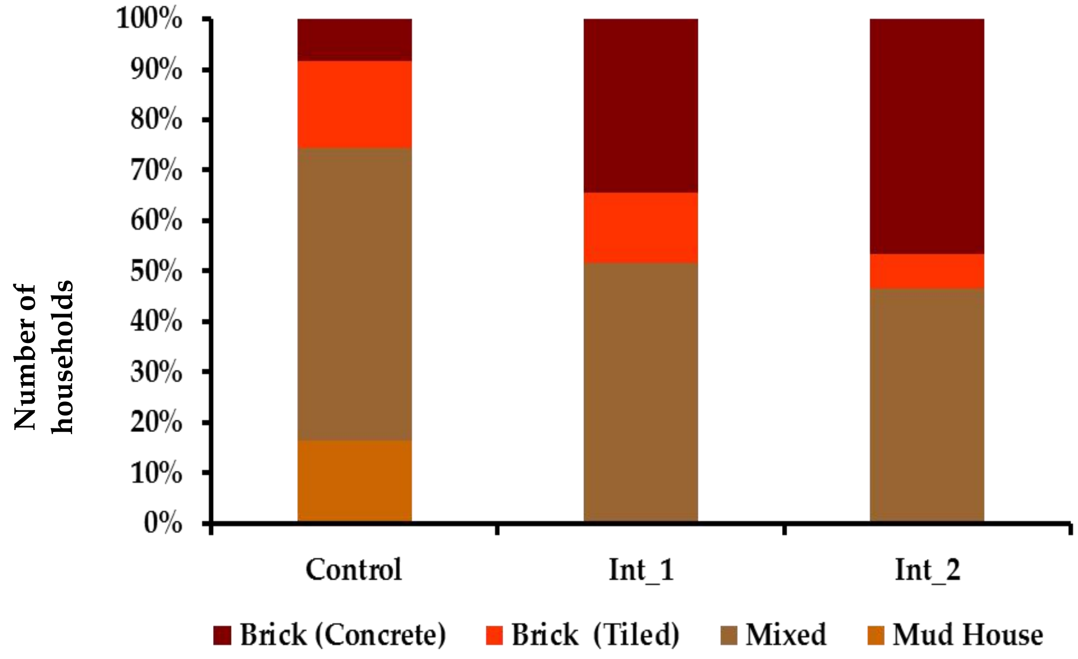
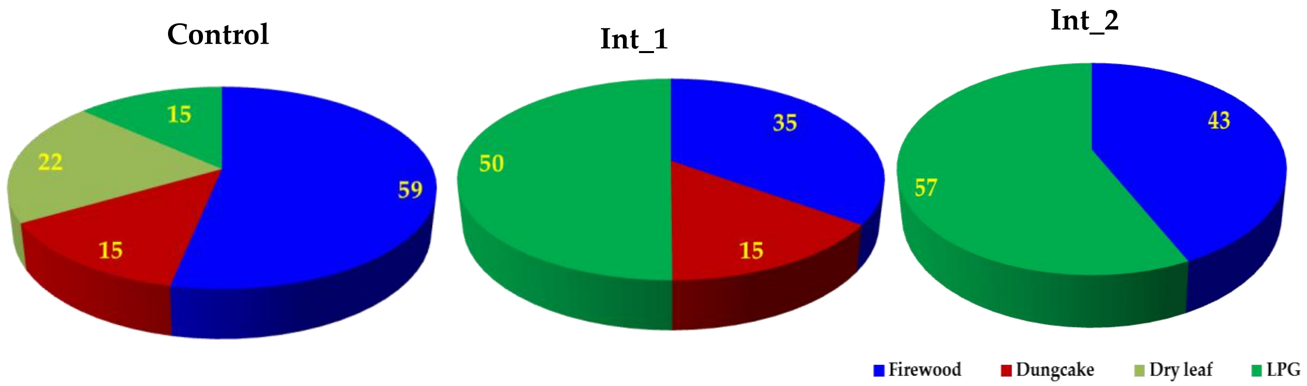


Figure 6.8 Distribution of household types among different groups of farmers in the study area during 2016.

All households in the village were electrified. Farmers use firewood, dry crop residues, dung cake and liquid petroleum gas (LPG) for household cooking. LPG usage was significantly higher among households of in the Int_2group (Figure 6.9).



Int_1: Flap gate; Int_2: Flap gate + SSD

Figure 6.9 Percentage distribution of sample households using various types of fuel.

The land area of the farmers in the intervention area was in the range of 0.40 to 4.45 ha (average 0.64 ha) while land area of farmers in the control area was in the range of 0.12 to 1.82 ha (average 0.51 ha). There is higher variation in the land area of farmers belonging to the Int_2 group. However, these differences are not significant (Table 6.4).

Table 6.4 Analysis of variation of land area among different group of farmers

Site	Area (ha)	
	Mean	Range
Control	0.5[a] (0.3)	1.7
Int_1	0.6[a] (0.4)	1.9
Int_2	0.8[a] (0.7)	4.2

Values in parenthesis indicate standard deviation of the mean. Similar alphabets (a) indicate that the means are not significantly different by Tukey' HSD test

Int_1: Flap gate; Int_2: Flap gate + SSD

6.4.2 Role of the intervention in reducing soil salinity

Comparing the surveyed soil salinity of the intervention croplands with the soil salinity data recorded before the implementation of interventions in 2005 (ANGRAU, 2008), suggests that both interventions have significantly reduced soil salinity (Figure 6.10).

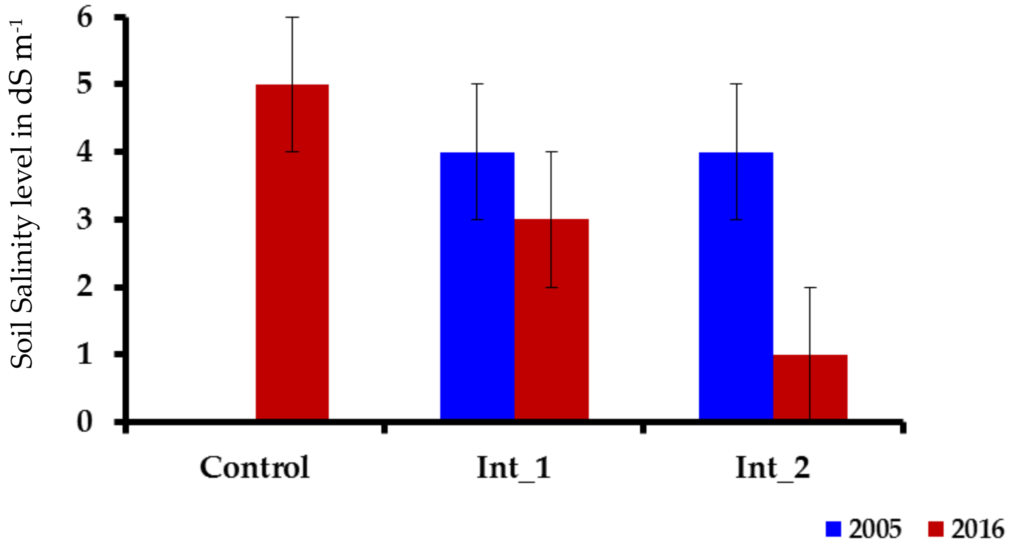


Figure 6.10 Mean soil salinity level of plots pre (2004) and post project (2016) implementation).

Int_1: Flap gate; Int_2: Flap gate + SSD.

Based on the soil salinity of the crop lands in the area, crop lands were classified into five different classes a) not saline (< 3.0 dS m^{-1}), b) Moderately saline (2.1 to 4.5 dS m^{-1}), c) Saline (4.6 to 6.0 dS m^{-1}), d) Highly saline (6.1 to 8.0 dS m^{-1}) and e) extremely saline (> 8.0 dSm^{-1}).

Survey results indicate that the croplands of more than 92% of the farmers in the control group were extremely saline while about 8% were highly saline (Figure 6.11). In contrast for the intervention group the cropland soils were not saline or moderately saline or saline. Only a limited number of plots were very saline and none were extremely saline. Figure 6.11 indicates that the soil salinity of Int_2 plots was significantly lower compared to that of the Int_1. Thus the SSD provided additional benefits in terms of reduced salinity vis-à-vis jus the flap gates.

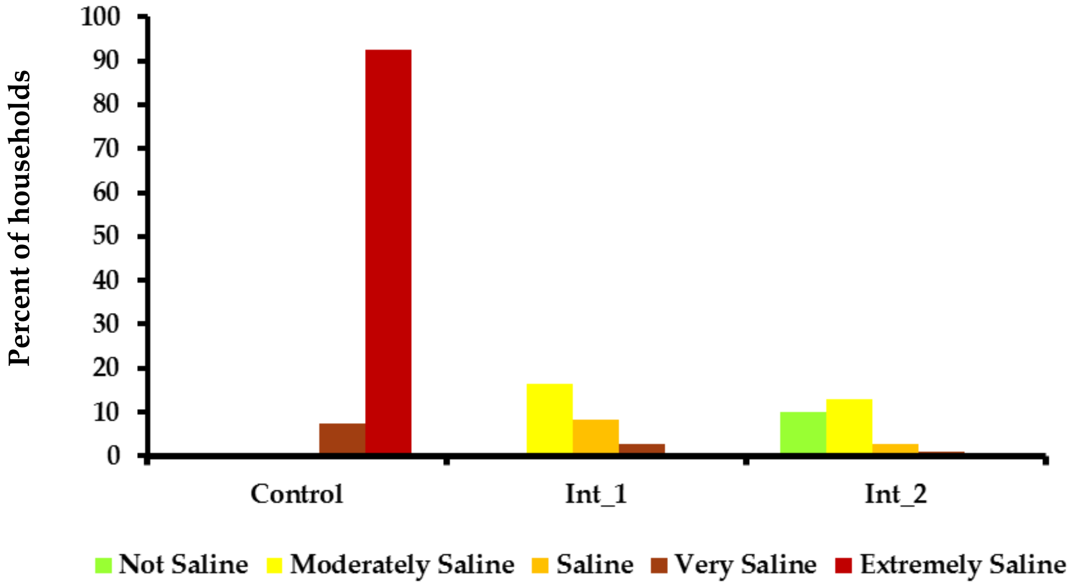


Figure 6.11 Percentage distribution of different levels of soil salinity of crop land among intervention and non-intervention (Control) groups. Int_1: flap gate ; Int_2: Falp gate + SSD

6.4.3 Seasonal variation in crop productivity

The productivity of the rice crop during *Dalva* (dry) and *Saarva* (wet) seasons varied widely among the control and intervention croplands. The mean crop productivity was significantly higher during *Saarva* season in both control and intervention cropland (Table 2). However, earlier studies report higher productivity of rice grain during the dry (*Dalva*) season (Datta et al., 2013a; Datta and Adhya 2014). They attribute the higher crop productivity to higher photosynthesis rates in the dry season. However, salinity of the soil remains higher during the dry season compared to the wet season due to lack of water availability. Higher soil salinity in the dry season consequently reduces rice production in the dry season in coastal rice ecosystems (Datta et al., 2013b) which accounts for our results of higher production in the wet season. However, the productivity of the intervention croplands was significantly higher compared to the control in both seasons (Table 6.5). However, no significant differences were found in the productivity of Int_1 and Int_2 croplands (Table 6.5). Thus while Int_2 has a more significant impact on soil salinity than Int_1, this does not appear to translate into higher productivity gains. This suggests there is a threshold of salinity below which crop productivity is no longer enhanced. Moreover, other factors also influence crop productivity in addition to soil salinity.

Table 6.5 Seasonal difference of crop productivity (Mg ha^{-1}) in the control and intervention cropland.

Season	Control	Int_1	Int_2	*F (Calc)*	*F(Crit)*
Dalva	3.1^{a}A (2.2)	9.0^{a}B(4.5)	8.9^{a}B(4.0)	*60.0*	*2.9*
Saarva	11.4^{b}A(6.3)	17.1^{b}B(10.3)	17.5^{b}B(8.1)	*12.0*	*2.9*
F (Calc)	*159.8*	*15.5*	*25.5*		
F(Crit)	*3.9*	*4.0*	*4.0*		

Mean of all samples after removing the outliers.

Values in the parenthesis indicates standard deviation of mean.

In a column mean followed by a common alphabet are not significantly different by Tukey's test at $p < 0.05$.

A row mean followed by a common upper case alphabet indicates that they are not significantly different by Tukey s test at $p < 0.05$.

F (Calc.): Calculated F-value of crop productivity during Dalva and Saarva seasons.

F (Crit.): Critical F-value from the F-table at group specific denominator and numerator degree of freedom.

The study indicates significantly lower rice productivity in soils with salinity levels higher than 10 dS m^{-1} (Figure 6.12). However, apart from soil salinity, soil fertility levels, fertilizer application, other soil parameters, total land area of the farmer and presence of the intervention might also affect the productivity of rice.

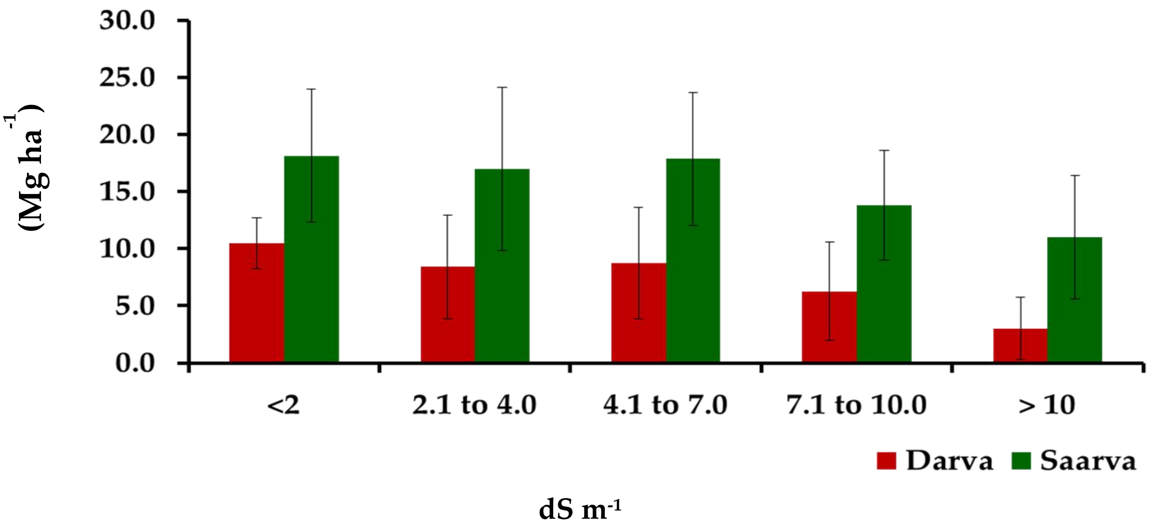


Figure 6.12 Seasonal variation of crop productivity in different cropland categorized based on their soil salinity level.

Bars indicate mean of all observations

Error bar indicates standard deviation of mean.

Mean followed by a common alphabet are not significantly different by Tukey s test ($p < 0.05$)

The soil fertility level of crop land was calculated by the factorial analysis of soil N, P, K level and organic carbon level of the soil. Table 6.6 indicates that among different independent variables that potentially influence crop productivity, soil salinity and the interventions (Control, Int_1 and Int_2) play a significant role in influencing rice productivity. Partial correlation analysis indicates a significant correlation between soil salinity level and the interventions ($r^2 = 0.88$), so they were not considered together as independent variables in the regression analysis. Additionally, there was a significant partial correlation ($r^2 = 0.85$) between productivity and land area of individual farmers indicating that the size of farm also influences productivity.

The results thus indicate that the interventions by reducing soil salinity also influence crop productivity. However, both interventions have similar impacts on productivity even though the SSD has a stronger impact on soil salinity (Table 6.6).

Table 6.6 Regression analysis of annual crop productivity (Mg ha^{-1}) based on intervention and soil parameters as independent variable.

Independent variables	Beta coefficient					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
(Constant)	32.65 (2.25)	36.95 (2.52)	16.58 (3.72)	15.04 (0.90)	17.61 (1.24)	7.42 (4.39)
Intervention				6.74** (0.96)	4.07** (0.94)	3.60** (1.14)
Soil salinity level	-3.56** (0.53)	-3.82** (0.53)	-1.97** (0.58)			
Area (ha)		5.72** (1.68)	0.58		5.43** (1.66)	0.06
Soil fertility level		0.02	0.74		0.027	0.02
Soil Depth		0.06	0.12		0.10	0.02
Average cost of cultivation (Mg ha^{-1})			0.39			0.37
Adj-R^2	0.58	0.75	0.85	0.59	0.65	0.79
F-regression	44.03	29.15	39.14	49.34	22.40	38.14
F-crit	2.70	2.70	2.70	2.70	2.70	2.70

**** Significant at $p<0.001$ Values in the parenthesis indicates standard error of the beta value**

6.4.4 Variation of the net annual cost of rice cultivation among different groups

The net annual cost of cultivation is significantly higher (INR 66357.6 ha^{-1}) in the Int_2 group compared to the other two groups (Figure 6.13). Net annual cost of cultivation was significantly lowed in the control (INR 36958.7 ha^{-1}) group (Figure 6.13).

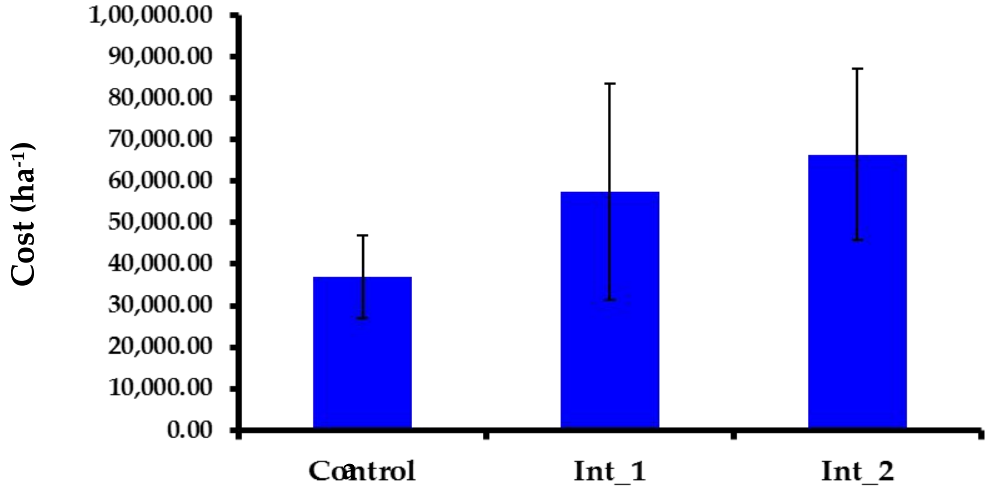


Figure 6.13 Variation of net annual cost of cultivation among different groups.

Bars indicate mean of all observations. Error bars indicate standard deviation of mean.

In a particular cost parameter mean followed by a common alphabet are not significantly different at $p<0.05$ by Tukey s HSD test.

Most of the control group farmers (>75%), did not grow any crops during the Dalva season due to high soil salinity. So, the net annual cost of cultivation for the control group is generally the cost of cultivation during the Saarva season. The farmers of the intervention group grow both Dalva and Saarva season crops and hence incur higher annual cultivation costs.

There was no significant difference in the net annual costs of seeds, water and diesel between the control and intervention groups (Figure 6.13). However, the net annual cost of labour was significantly higher in the Int_2 group. In the non-intervention area, severe seedling damage occurs due to high soil salinity in the Dalva season, thus labour costs incurred are lower for this group. Additionally, farmers of the Int_2 group pay additional labours cost for the maintenance and operation of the SSD system which might account for the significantly higher labour costs of Int_2 farmers. The total cost of fertilizers and pesticides are significantly higher in the control group due to enhanced inputs (especially N fertilizer) required in highly saline soils. Jibrin et al. (2008) also report higher fertilizer application in more saline soils. Higher application of nitrogen fertilizers, however, increases pest infestation (Zehnder, 2015), which might increase the pesticide application rate and consequently the costs. The control group has significantly higher annual costs of pesticide (INR 5595.9 ha^{-1}) followed by Int_1 (INR 4955.0ha^{-1}) and Int_2 (INR 4468.9 ha^{-1}).

6.4.5 Factors influencing the net annual profit from the cropland

The net annual profits vary from INR 6987.9 ha^{-1} (control) to INR 191812.8 ha^{-1} (Int_2). Average net annual profit of Int_2 group (INR 197268.7 ha^{-1}) was significantly higher than the control (INR 100075.7 ha^{-1}) (Figure 6.15). However, there was no significant variation of net annual profit between the two intervention groups. The study indicates that the intervention leads to an average 69% higher profit over the control.

The role of different soil parameters in influencing the annual profit was determined through a step-wise, forward linear regression. Among three independent soil variables, net annual profit was found to vary significantly and negatively with the soil salinity level (Table 6.7). The intervention also significantly and positively affects the net annual profit.

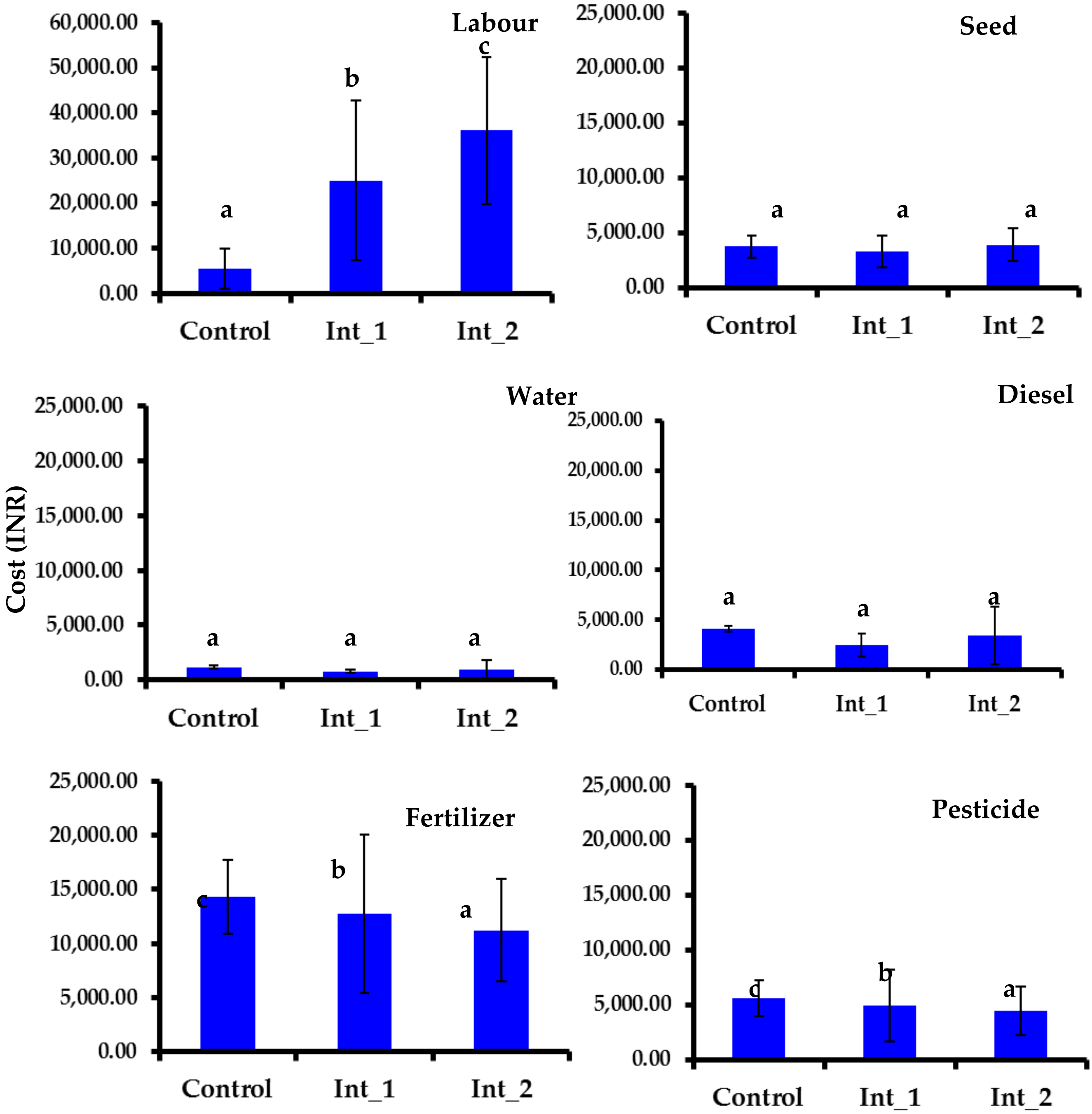


Figure 6.14 Variation of different cost of cultivation among different groups.

Bars indicate mean of all observations. Error bars indicate standard deviation of mean.

In a particular cost parameter mean followed by a common alphabet are not significantly different at $p<0.05$ by Tukey s HSD test.

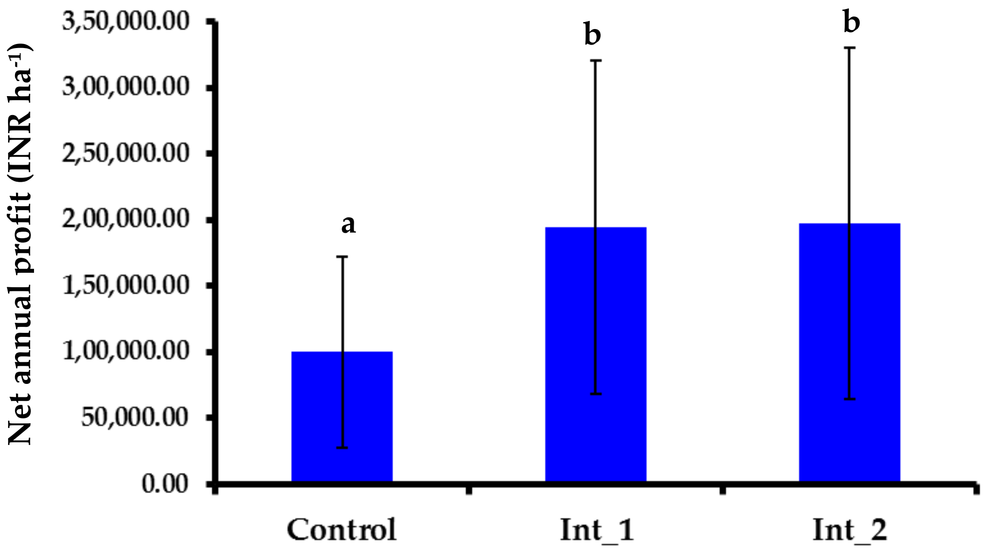


Figure 6.15 Variation of net annual profit among the intervention and control group.

Bars indicate mean of all observations. Error bars indicate standard deviation of mean.

Bar followed by a common alphabet are not significantly different at $p<0.05$ by Tukey s HSD test.

Model 4 predicts 76% variability in the net annual profit from crop land and suggests a minimum increase of annual profit of INR 34494.6 ha^{-1} with the adaptation of interventions (Table 6.7). Model 2 predicts 73% of variability in the net annual profit and suggests one level increase of soil salinity level (from not saline to extremely saline) might decrease the annual profit by INR 10045.1 ha^{-1} (Table 6.7).

Table 6.7 Stepwise linear regression analysis of net annual profit (INR ha^{-1})

Independent variable	Beta coefficient			
	Model 1	**Model 2**	**Model 3**	**Model 4**
Constant	12232.7 (11846.0)	98251.7 (30080.4)	488220.9 (14615.4)	92308.9 (23547.3)
Intervention			19827.8** (8574.8)	34494.6** (10482.8)
Productivity (Mg ha^{-1})	6525.25** (548.3)	5609.9** (612.5)	5541.6** (613.4)	5930.6** (626.9)
Soil salinity		-10045.1** (4742.8)		

Independent variable	Beta coefficient			
	Model 1	**Model 2**	**Model 3**	**Model 4**
Soil depth		-0.04		0.29
Soil fertility		0.08		0.61
Average cost (Mg ha^{-1})		-0.15		-1.06**(0.4)
Adj- R^2	0.67	0.73	0.71	0.76
F-regression	141.6	80.8	57.1	47.9

**** significant at $p < 0.001$**

values in the parenthesis indicates standard error of the respective beta value.

6.5 Scenario development for 2030

For the State of Andhra Pradesh, we project the area likely to be impacted by waterlogging erosion in 2030 utilising data from 2003/ 05 and 2011/ 2013 of the Space Applications Centre. We then use these estimates to determine the costs of reclamation of waterlogged areas for the State of Andhra Pradesh in 2030. The extent of water logging in 2030 is shown in Table 6.8. The extent of waterlogging in the State shows an increasing linear trend based on available data ($y = 6579x + 119176$; $R^2 = 1$) (Fig 6.16). In the XII th plan the cost of land reclamation for waterlogged areas using SSD is Rs 50,000 per ha. Using this value, the cost of reclaiming lands degraded by waterlogging in Andhra Pradesh in 2030 is Rs 7439 million at 2013 prices.

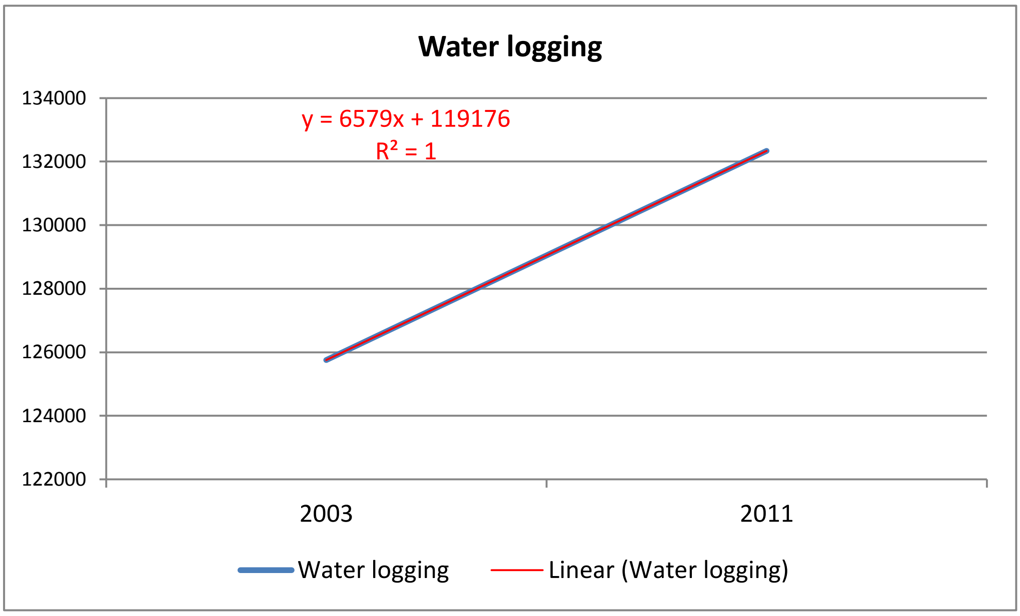


Figure 6.16 Projected extent of waterlogging in the Sate (till 2030)

Table 6.8 Projected extent of waterlogging in the State of Andhra Pradesh in 2030

Extent of water erosion					
Year	2003	2011	2019	2027	2030
Waterlogging (in ha)	125755	132334	138913	145492	148782

6.6 Conclusion and recommendations

The study was conducted by comparing the present farm productivity and agricultural profitability as well as the socioeconomic status of farmers of the intervention croplands with those of the farmers of the control area. The study indicates that the average net annual profit of the farmers of the intervention croplands was significantly higher than the control group of farmers. This supports the hypothesis that the intervention implemented ten years ago continues to be effective in significantly improving crop productivity and the social status of the farmers in the area. Further, social indicators like house type and cooking fuel type also indicate significant difference among the intervention and control group of farmers, although it is not clear if this is the reason for why the farmers adopted the SSD or whether it is the result of the intervention. Given that ten years have elapsed since initiation and the substantial enhancements wrought in productivity and profits, it is likely to be the latter. However, we assume that there was no difference in soil salinity before the implementation of the intervention in control and intervention areas. It is, however, beyond the scope of the present study to test this assumption.

Introduction of flap gate + SSD system has significantly reduced the soil salinity over flap gate only and control area. Each level increase of salinity reduces the net annual profit of farmers' by about INR10045 ha-1. However, there was no significant difference in crop (rice) productivity in the land area under flap gate only and flap gate+SSD area.

Farmers in the intervention area believe that sub-surface drainage has greatly improved the crop productivity of their land both in the Dalva and Saarva seasons. Farmers from the Int_1 area (flap gates) also want to implement SSD on their lands, but require governmental support for the implementation process. However, as indicated above, the present study suggests that there was no significant difference in net annual profits between the Int_1 (flap gates) and Int_2 (SSD) groups. Moreover, flap gates appeared to be sufficient to reduce soil salinity to a level that supports productive agriculture. ***These interesting results suggest that flap gates may be sufficient to enhance productivity and net annual profits for farmers. This must be kept in mind while initiating other such programmes since this could significantly reduce costs. Moreover, this result needs to be tested in other sites as well to see if it holds true in a range of environmental conditions.***

Given that the results show that flap gates reduce salinity thereby, enhancing rice productivity, it is important to create flap gates in all the crop lands along the Upputeru river to effectively control land degradation as well as enhance rice productivity from salinity reductions.

Moreover, our results suggest the need to restore waterlogged areas. The projected extent of waterlogged areas in the State in 2030 is 148782 ha and the cost of their reclamation is Rs 7439 million at 2013 prices.

Photo 6.1 Soil Salinity in the crop lands of the study area during Dalva (Dry) Season

Photo 6.2 Cropland with the Sub-surface drainage system during the dry season

Photo 6.3 In field:farmers' workshop before survey initiation-1

Photo 6.4 In field: Farmers' workshop before before survey initiation-2

Photo 6.5 Control area field during the Salva (Wet) season.

Photo 6.6 SSD implemented area during the Salva (Wet) season.

Photo 6.7 Left side of the field is a control cropland and on the right the SSD intervention cropland in the Salva (Wet) season

Photo 6 8 Farmers survey

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Chapter 7. Foregone agricultural benefits due to wind erosion: The case of shelterbelt plantations in Jaisalmer, Rajasthan.

7.1 Introduction

Desertification, as defined by United Nations Environment Programme (UNEP) in 1992 and adopted by United Nations Convention to Combat Desertification (UNCCD 1996), is 'land degradation in arid, semiarid and dry sub humid areas resulting from various factors, including climatic variations and human activities'. A large part of north-western India can be classified as desert. The western part of Rajasthan is clothed in rolling dunes for almost its whole expanse. The annual precipitation is between 200 and 300mm. Daily potential evaporation rises to 12 mm in the summer, and high temperatures, wind speeds and frequent dust storms combined with low humidity, make conditions unfavourable (Dev et al. 2015). Due to the inhospitable climate the people of the area earn their livelihoods primarily with pasture animals and on one crop per year, but sustenance is difficult. The agricultural productivity in the region remains limited due to an unconducive environment, limited choice of crops and aberrant weather conditions (Sharma, 2001). Agriculture is impeded by strong wind speeds in the desert (Mertia et al., 2006). Besides brutal environmental conditions, people living in the approximately 500 scattered villages have no means to communicate with outside world except for minimal roads. A significant area of the country-18.23 m ha (5.55 % of the geographical area of the country) is affected by wind erosion, a drop of 0.12 m ha from 2003/ 05 (SAC, 2016). In this study, we determine the costs of wind erosion for agricultural productivity. We do this by ascertaining enhancements in agricultural productivity brought about by shelterbelt interventions that reduce wind erosion. These foregone benefits are proxies for the costs of wind erosion.

Spatial distribution of the area affected by wind erosion places most of the severely and very severely affected areas in western Rajasthan (Kar, 1996; Narain and Kar, 2006). Direct economic costs of wind erosion include the loss of productivity in land while indirect impacts include siltation and effects on human health and ecosystems from dust storms. Wind erosion control is usually undertaken by reducing the impact of high wind speeds at the ground level by increasing plant cover, installing wind breaks, irrigation and planting shrubs for sand dune stabilization, and by increasing organic matter in the soil to increase soil cohesion. The Central Arid Zone Research Institute (CAZRI) has developed vegetative methods for sand dune stabilization including shelterbelt plantations (Bhimaya and Kaul, 1960).

Studies at CAZRI have revealed that the major physical manifestation of desertification in western Rajasthan is wind erosion/ deposition, followed by water erosion, as well as water logging and salinity (Ghose et al., 1977). Mapping of desertification in different land uses in the arid western part of Rajasthan reveals that approximately 76% area of western Rajasthan is affected by wind erosion, encompassing all major land uses, but mostly cropland and sandy areas (Kar, 1996; Narain and Kar, 2006). With time, industrial effluents and mining are also gradually becoming important factors of desertification; mismanagement of land is a major cause of the problem (Kar, 1996; Narain and Kar, 2006, Kar et al., 2009). Overall, 30% of the area of western Rajasthan is slightly affected by desertification, while 41% is moderately affected, 16% severely, and 5% very severely impacted. Increasing desertification has started threatening the existence of many villages- more than 60% area of western Rajasthan requires intensive management to contain desertification (MoEF & CC, 2001).

There are 12 districts in Rajasthan that are categorized as arid. Rainfall in this region is temporally scattered and drought like conditions prevail. The main crops grown in the region are pearl millet (*Pennisetum glaucum*), moong (*Vigna radiata*), and guar (*Cyamopsis tetragonoloba*) as *kharif* (monsoon) crops which are affected by drought and rain distribution. Rabi (winter) crops like wheat, barley, gram, pulses, oil seeds and mustard are also impacted as the available moisture and temperature are not favourable to cropping. Several interventions have been undertaken to control the direct and indirect impacts of wind erosion. One such intervention is shelterbelts in western Rajasthan. Shelterbelt plantations by reducing wind speeds also reduce erosion which in turn benefits agriculture. In this case study we assess shelterbelt impacts on agriculture to understand the economics of land degradation from wind erosion.

7.2 Activities to combat desertification in Rajasthan

Action to combat desertification has been a priority for the Government of India as well as the Government of Rajasthan. The Rajasthan State Forest Policy (2010) emphasizes the need to (i) undertake massive afforestation on government and community-owned wasteland and privately-owned agriculture and non-farm lands, to expand the vegetal cover of the state both in rural and urban areas, and simultaneously meet the timber, fuel wood and non-timber product demands of the society (Article 3.1.2), (ii) increase the productivity of forests through appropriate management interventions and use of modern technology to meet the needs of the present as well as future generations (Article 3.1.3), and (iii) combat desertification (through shelterbelt plantations, block plantations, sand dune stabilization and agro-forestry in desert areas) and to prevent all kinds of land degradation (Article 3.1.4).

One such effort undertaken by the government of Rajasthan is the Indira Gandhi Nahar Project (IGNP). IGNP is the largest irrigation project in the world (Sharma 2001). It is a comprehensive regional development project which aims at actualization of infrastructure, increase and stabilization of income, making available basic amenities to people and thus improving their living conditions. The Indira Gandhi Nahar Canal provides a stable water supply that can be used for irrigation, plantation, road construction and drinking purposes, thus improving living conditions. With the advent of this project, the life of people living in the area has changed dramatically and has also enabled migrants to earn their livelihood from new sources, including agriculture (Refer to Table 7.1).

Table 7.1 Land Use Statistics in the arid region of Rajasthan during 1957-58 to 2010-11

Land Use	**1957-58**	**1997-98**	**2001-02**	**2005-06**
Reporting area (m ha)	20.8	20.8	20.8	20.8
Agricultural land use (% of reporting area)				
Total cropped area	36.1	64.5	61.0	61.1

Land Use	1957-58	1997-98	2001-02	2005-06
Net sown area	35.5	52.3	52.4	51.2
Area sown more than once	0.7	12.2	8.6	9.9
Total irrigated area	2.6	11.3	11.2	18.1
Other fallows	14.2	7.1	7.9	8.2
Non- agricultural land use (% of reporting area)				
Culturable waste	24.2	19.3	18.5	17.7
Permanent pasture	2.3	3.9	3.9	3.9
Forest	0.7	2.0	2.1	2.1
Barren and uncultivated	11.2	4.9	4.8	4.8
Current fallows	9.1	5.9	6.4	7.4

(Source: Ram, 2009)

The Indira Gandhi canal has enabled a change in vegetation. Tree plantations carried out when the canal was constructed now act as shelterbelts against wind erosion. This has made it possible to cultivate the land on the eastern side of the canal. These shelter belts can be seen on the stretch between Mohangarh and Nachna in Jaisalmer district. The plantations are on the either side of lift canal channels. Shelterbelt or windbreaks are an array of plantations usually made up of one or more rows of trees or shrubs to provide a shield from wind, and to protect the soil from erosion. These barriers of trees or shrubs reduce wind velocities and, as a result, reduce evapotranspiration and prevent wind erosion. They provide direct benefits to agricultural crops, resulting in higher yields, and provide shelter to livestock, grazing lands, and farms. The shelter belts change the soil profile over time. They add to the leaf litter and increase the level of humus. Inhabitants of the region were traditionally dependent on animal husbandry and mostly rainfed agriculture wherever possible; now there is extensive agriculture with the help of irrigation. This change in vegetation profile can be attributed to the canal itself but before the shelterbed plantations, agriculture was not possible since the sandy soil would turn into quicksand due to excessive water. These plantations have helped to maintain a ground water profile that is favourable to cultivation, and their presence has enabled a change in the soil characteristics to support agriculture.

The dual benefits of IGNP including shelterbelts plantations and availability of irrigation for the fields has therefore impacted yields: Shelterbelts have numerous potential benefits for farm productivity. Apart from providing protection to crops and pastures from drying winds they help in preventing salinity and soil erosion.

7.3 Objectives of the Study

This study aims to analyse the foregone benefits due to wind erosion in terms of enhanced agricultural productivity and additional income derived from shelterbelt plantations. Shelterbelt plantation occurred under phase II of the IGNP. Shelterbelt plantations reduce wind speed, control sand drift/ sand movement, improve air quality, habitat condition and livelihood status in arid western Rajasthan. We hypothesize that these benefits will be evident in the form of increased agricultural productivity and/ or enhanced incomes for households with the intervention (the intervention group) as compared with the control group (those without shelterbelt interventions). Improved land conditions and enhanced incomes might also impact other facets of life such as livestock rearing.

7.4 Methodology

7.4.1 Case study selection

As discussed in Chapter 1 Volume II, the project followed a three-tier system to select the site for a micro-economic assessment. The first criterion for site selection was to identify states lying within the drylands. The second tier for site selection was to include those states most impacted by land degradation as well as those encompassing the major processes of land degradation (water, wind, salinity/ alkalinity, vegetal). Wind erosion as mentioned in the introduction is an important causal mechanism for land degradation in our country and 62.5% of Rajasthan is degraded of which wind erosion accounts for 44.4% of the area degraded (SAC 2016). Rajasthan is also the state with highest area under desertification/ land degradation with respect to the country's Total Geographical Area (TGA) and the second highest area under desertification/ land degradation with respect to state TGA. Hence Rajasthan was selected to understand the costs of wind erosion in the country.

7.4.2 District selection in Rajasthan

Because the updated desertification/ land degradation atlas for the country (SAC, 2016) was not available at the time of district selection, we utilised the harmonised atlas (ICAR, 2010) to understand the share of Rajasthan in the country-wide area affected by class of degradation. According to this atlas, Rajasthan accounted for as much as 99.9% of the country-wide area affected by category 6 or exclusively wind erosion (Table 7.2). The share of each class of degradation in the total area of Rajasthan was found to be 55.91% for exclusively wind erosion. When the analysis was repeated on a district basis, Jaisalmer contributed 24.1% to the state-wise area affected by wind erosion (Table 7.3, Fig 7.1) and hence was selected as the case study area.

Table 7.2 Share of Rajasthan in the country-wide area affected by degradation and share of class in degraded area of Rajasthan

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Share of Rajasthan in the country-wide area affected by the class of degradation																		
10.05	**12.87**	**0.00**	**0.00**	**0.00**	**99.99**	**2.81**	**20.00**	**0.00**	**100.00**	**0.00**	**0.00**	**4.14**	**2.45**	**100.00**	**5.00**	**80.00**	**0.00**	**0.00**
Share of class in total degraded area of Rajasthan																		
36.41	**5.86**	**0.00**	**0.00**	**0.00**	**55.91**	**0.36**	**0.04**	**0.00**	**0.54**	**0.00**	**0.00**	**0.53**	**0.13**	**0.15**	**0.00**	**0.08**	**0.00**	**0.00**

1 Exclusively water erosion (>10 tonnes/ ha/ yr);	11 Saline soils under open forest;
2 Water erosion under open forest;	12 Waterlogged saline soils;
3 Exclusively acid soils (pH <5.5);	13 Exclusively sodic soils;
4 Acid soils under water erosion;	14 Eroded sodic soils;
5 Acid soils under open forest;	15 Sodic soils under wind erosion;
6 Exclusively wind erosion;	16 Sodic soils under open forest;
7 Exclusively saline soils;	17 Eroded sodic soils under open forest;
8 Eroded saline soils;	18 Mining/ Industrial waste;
9 Acid saline soils;	19 Waterlogged area (Permanent)
10 Saline soils under wind erosion;	

Source: ICAR-NAAS (2010)

Table 7.3 Share of district in state-wide degradation by class (%)

	1	2	6	7	8	10	13	14	15	16	17
Ajmer	3.70	0.00	0.01	0.00	37.50	0.00	3.70	11.54	0.00	0.00	0.00
Alwar	4.81	8.53	0.00	0.00	12.50	0.00	10.19	23.08	0.00	0.00	0.00
Banaswara	5.20	6.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baran	6.46	7.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barmer	0.00	0.00	16.71	0.00	0.00	9.09	1.85	0.00	6.67	0.00	0.00
Bharatpur	3.99	0.25	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00
Bhilwara	7.42	1.59	0.00	0.00	0.00	0.00	4.63	3.85	0.00	0.00	0.00
Bikaner	0.01	0.00	18.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bundi	6.02	7.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	1	2	6	7	8	10	13	14	15	16	17
Chittorgarh	6.27	13.96	0.00	0.00	0.00	0.00	8.33	11.54	0.00	0.00	0.00
Churu	0.00	0.00	11.79	0.00	0.00	31.82	0.00	0.00	0.00	0.00	0.00
Dausa	1.80	0.25	0.00	1.35	0.00	0.00	4.63	0.00	0.00	0.00	0.00
Dholpur	3.40	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dungarpur	4.80	0.00	0.00	0.00	0.00	0.00	0.00	7.69	0.00	0.00	0.00
Hanuman garh	0.00	0.00	2.80	35.14	0.00	47.27	1.85	0.00	0.00	0.00	0.00
Jaipur	2.89	3.43	0.00	12.16	50.00	0.00	0.93	0.00	0.00	0.00	0.00
Jaisalmer	0.00	0.00	24.11	13.51	0.00	0.91	5.56	0.00	6.67	0.00	0.00
Jalore	0.05	0.00	2.14	1.35	0.00	0.91	6.48	0.00	3.33	0.00	0.00
Jhalawar	6.74	5.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jhunjhunu	0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jodhpur	0.00	0.00	10.82	1.35	0.00	4.55	0.00	0.00	0.00	0.00	0.00
Karauli	4.75	6.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kota	5.61	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nagaur	0.09	0.00	6.44	33.78	0.00	5.45	0.00	0.00	0.00	0.00	0.00
Pali	0.28	0.25	0.01	0.00	0.00	0.00	1.85	0.00	0.00	0.00	0.00
Rajsamand	3.70	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sawai Madhopur	3.54	1.00	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00
Sikar	0.00	0.00	3.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sirohi	4.07	8.78	0.00	1.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sri Ganaganagar	0.00	0.08	1.70	0.00	0.00	0.00	49.07	0.00	80.00	0.00	0.00
Tonk	5.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Udaipur	9.13	25.67	0.00	0.00	0.00	0.00	0.00	42.31	0.00	100.00	100.00
Total	100	100.00	100.00	100.00	100.00	#####	100.00	100.00	100.00	100.00	100.00

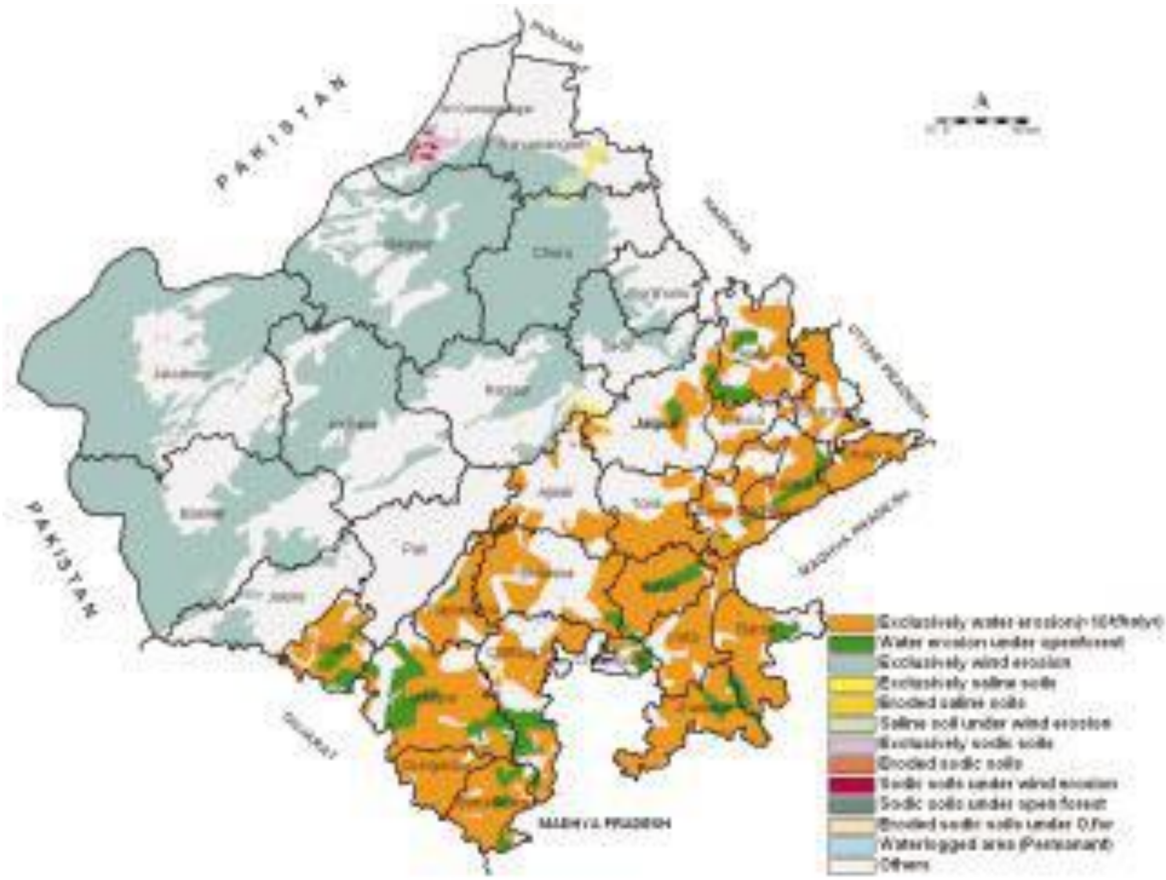

Figure 7.1 Degraded land and wastelands of Rajasthan

7.4.3 Field surveys

Based on consultations with experts from CAZRI, the forest department and a literature review, it was decided to select villages in this district where shelterbelts had been used for soil stabilisation. This case study aims to assess the benefits from shelterbelts in terms of increased productivity attributed to planting of shelterbelts. Sampling was carried out in the villages of Nachana and Mohangarh of Jaisalmer district. A detailed household survey was carried out and one hundred and fifty farmers (n=150) living in the command area of IGNP were interviewed about their available resources, incomes, crop production and livelihood sources. Sixty two households that have shelterbelt interventions (intervention group), and 88 households without the intervention (the control group) were surveyed.

Structured interviews were conducted using a questionnaire. The questionnaire is provided in Appendix 7.1. The questionnaire was divided into the following five sections: (i) household identification, (ii) land holdings and operational area (iii) cropping pattern and crop production (iv) Soil conservation practices and benefits derived from shelterbelt plantations, and (v) Socio-economic information about households (income, literacy, livestock holdings, cooking fuel usage and collection of firewood). The questionnaire was designed to gauge the impact of shelterbelts on agricultural productivity by assessing production levels and other benefits derived from plantations. The hypothesis tested in this study is that households with shelter beds on their agricultural fields have better output and monetary benefits than the farmers without shelterbelts, *ceteris paribus*.[50]

The efficacy and economic value of shelterbelts can be viewed in terms of (i) change in the crop yield (ii) change in the area under production (iii) change in the cost of cultivation and (iv) change in the value of produce. But, how these variables are altered also depends on the existing socio-economic conditions of the farmers and region under consideration (Kumar 2007).

7.4.4 Description of Site

The study area is located in Jaisalmer district of Rajasthan. The stretch from Nachna village to Mohangarh village is one of the areas where shelter belts have been planted in an arid region prone to wind erosion and has seen transformation over the years with the development of irrigation through the IGNP and agriculture proliferation. The district of Jaisalmer falls largely under the western sandy plains physiographic division. The land utilisation pattern is presented in Table 7.4. The climate of the area is dry and arid characterised by extreme temperatures and erratic rainfall. According to CAZRI, the most common vegetation in the region includes species like Khejadi (*Prosopis cineraria*), the exotic invasive Baval (*Prosopis juliflora*), *Tecomella undulata* (Rohida), Neem (*Azadirachta indica*), Babul (*Acacia nilotica*) and several others. Agricultural crops in *kharif* include jowar, bajra, tur, moong, moth, urad, chowla, ground nut, sesame, soyabean, guar and in *rabi* season include maize, wheat, barley, gram, masoor, matar, mustard and caster seeds. The economy of the district is largely dependent on tourism and particularly desert tourism in the Desert National Park. Another traditional occupation is animal husbandry.

Table 7.4 Land utilization pattern of Jaisalmer district

Land Utilization pattern	**2000-01 (in ha)**		**2010-11 (in ha)**		**Percentage (increase/decrease)**
	Area	**Percentage**	**Area**	**Percentage**	
Total Geographical area	3839154	100	3839154	100	0
Total reported area for the land utilization	3839154	100	3839154	100	0
Forest	23277	0.61	44873	1.17	0.56
Not available for cultivation	112023	2.92	147437	3.84	0.92
1) Area put to Non-agricultural use	371077	9.67	363715	9.47	-0.19
2) Barren & uncultivable land					
Total Non-cultivable land excluding follow land	2682452	69.87	2451331	63.85	-6.02
Fallow land	164850	4.29	106113	2.76	-1.53

[50] All else being equal.

Land Utilization pattern	2000-01 (in ha)	2010-11 (in ha)		Percentage (increase/decrease)	
	Area	Percentage	Area	Percentage	
Net sown area	485475	12.65	725685	18.90	6.26
Area sown more than once	55646	1.45	151900	3.96	2.51
Gross cropped area	541121	14.09	877585	22.86	8.76

Source: Socio-economic abstract of Jaisalmer district

7.5 Results and Discussion

7.5.1 Socio-economic profile of households

As per census data (Census, 2011), Jaisalmer district has a population of 672008, with 363346 males and 308662 females. The sex ratio is 849 females for every 1000 males. The district has a population density of 17 inhabitants per sq. km. The population growth rate for the decade 2001-11 was 32.22%. The overall literacy rate of the district according to the 2011 census was 58.04%. The literacy rate of rural and urban areas was 56.61 and 78.91%, respectively.

The survey results indicated that the household size ranged between 2 and 13 adults, with an average of 5 people per household. The age of the head of households ranged from 25 years to 70 years, with an average of 44 years. Out of 150 household heads survey under this study[51], 87 heads said they are educated and have received some years of education. Of these 87 household heads, 30% received an average 8 years of formal education and only 1 respondent had an average 14 years of formal education.

The three main sources of household income are crop production, livestock rearing and off-farm income. Livestock include bullocks, cows, buffaloes, calves, goats and sheep. Off-farm income generating activities included income derived from salaries and wage labour, remittances, and income from other sources (rent from leased-out land/ room, business, and pension). People with shelterbelts appear to have better access to public distribution systems (PDS); 84% of the intervention group have access compared with 69% of the control group. Overall a majority of households in both the groups use the PDS. Almost the same number of households have access to electricity in both the groups. Liquefied petroleum gas, as cooking fuel is used by the farmers in both groups; 45 % of households with shelterbelts and 41% of those without, use LPG. As depicted in Fig 7.2, the number of households with BPL (below poverty line) cards are lower (5%) in the intervention group as compared to 14 % in the non-intervention group. Overall, however, the results are not significantly different indicating that both those with the intervention and those without share a similar socio-economic profile.

[51] Household head as used in the study refers to the senior-most member of the family, who makes key decisions and whose authority is recognized among all other members of the household

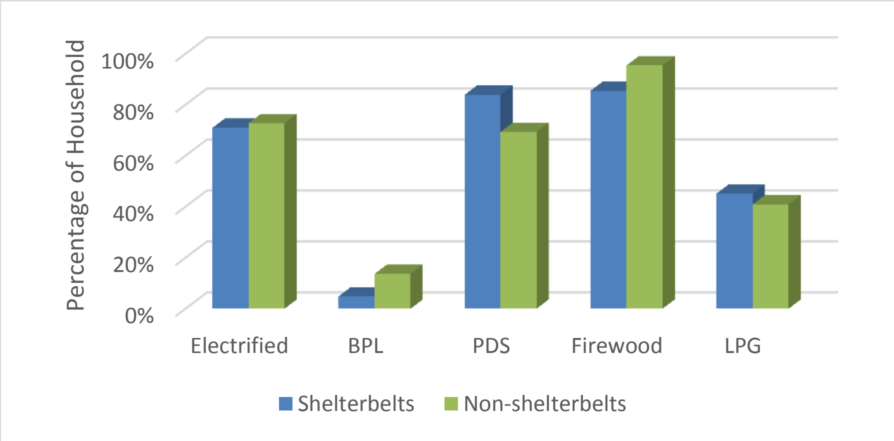

Figure 7.2 Socio-economic information about intervention group and control group

Soil conservation practices under shelterbelts have impacted the households in a variety of ways. All the respondents reported that plantation of shelterbelts have not only helped in anchoring the sand dunes in the area but also proved beneficial in providing fuel wood, livestock fodder and timber, while reducing wind speed. Approximately 84% farmers report additional benefits such as better ground water availability and improved soil texture for production.

7.5.2 Change in irrigated area

Most of the ground water in the area is saline and unfit for use. Since rainfall is scanty, the seasonal fluctuations in water table are not significant. With the introduction of irrigation, the water table has risen. Out of 62 households with the intervention, approximately 80 percent are no longer dependent on rain for irrigating their fields. Of the households without shelterbelts, only 23% are rain fed and the rest are dependent on irrigation. Canal irrigation quite naturally is a preferable option for the farmers in both the groups.

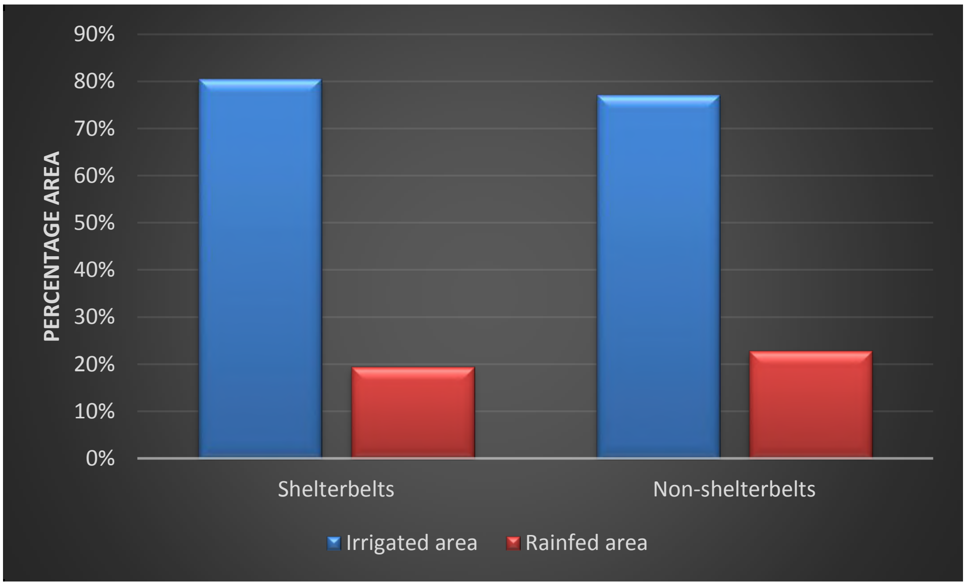

Figure 7.3 Area under rain-fed and irrigated agriculture in the intervention and control group

One of the major findings of the study is that over time with the plantation of shelterbelts, the productivity for the farmers with trees on their fields has increased substantially. This has improved their income by way of improved profits but also has proved advantageous in terms of reduced cost (Fig 7.4).

Figure 7.4 Flowchart representing the impact of shelterbelts

This chain of events has been experienced in our study. With the presence of shelterbelts the farmers have higher production for two major crops, *Guar* (cluster bean, *Cyamopsis tetragonoloba*) and *Chana dal* (*Cicer arientum*) (Fig 7.5). The productivity of Guar on average is approximately eight quintals more per ha in shelterbelts fields relative to non-shelterbelt areas. The same is true for *Chana* which is the second most important crop grown in the study area. Farmers with plantations on average reap six additional quintals of Chana per ha (Fig 7.5). For each additional (on average) input used, the production of Chana with shelterbelts is 61 quintals as compared to non-shelterbelts which yields 55 quintals. Figure 7.5 depicts the crop wise productivity which is ratio of output per unit of area, i.e. quintals per hectare.

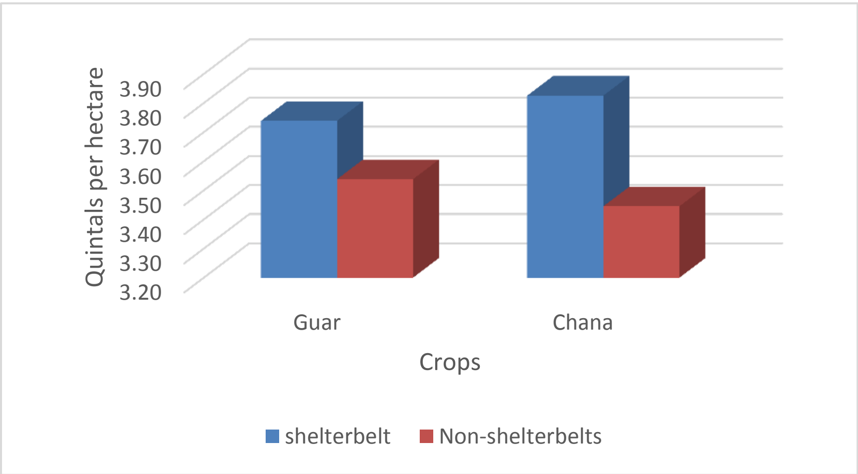

Figure 7.5 Crop-wise productivity, with and without shelterbelts

As indicated in Fig 7.6, input costs are also less for both crops in the intervention areas. For *Guar*, the total cost for shelterbelt farmers is Rs. 1756.39 per hectare as compared to non-shelterbelts *Guar* farmers (Rs 2464.7 per hectare). In case of *Chana*, farmer input costs on average are Rs 2000 lower for those with shelterbelts. Total revenues that farmers get by selling their produce in the market are higher in case of shelterbelts (Fig 7.6). Decreased costs and increased revenues imply higher profit margins for farmers.

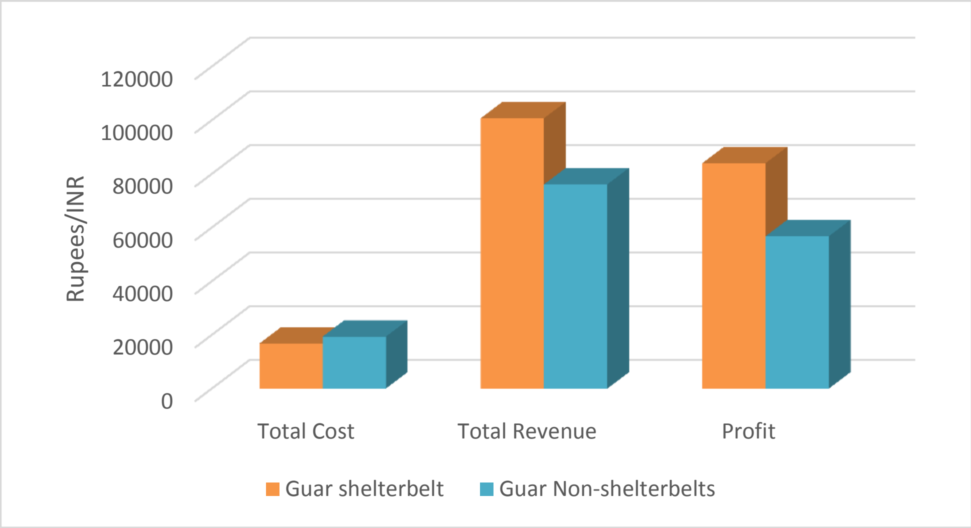

Figure 7.6 Crop-wise total revenue, total cost and profits of *Guar*

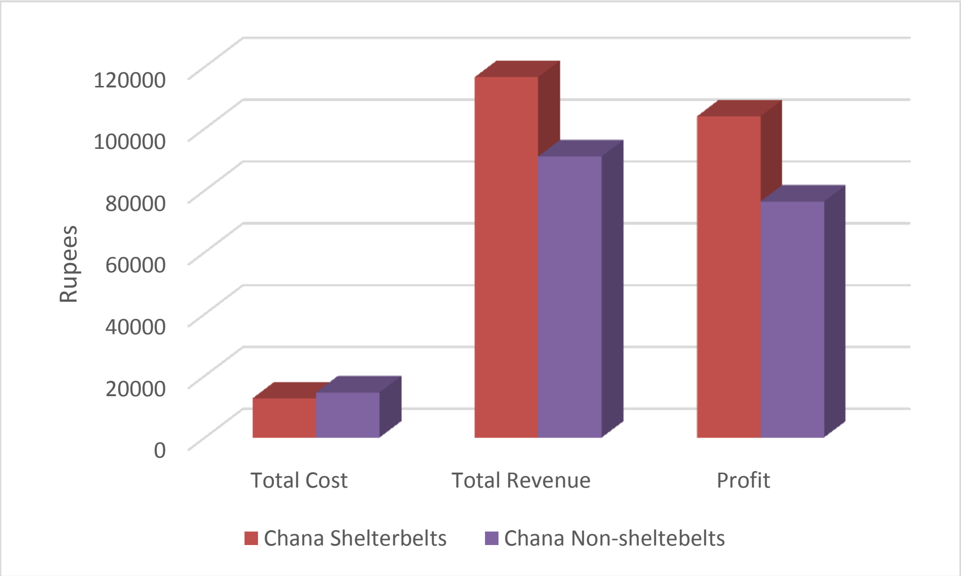

Figure 7.7 Crop-wise total revenue, total cost and profits of *Chana*

Farmers with shelterbelts had higher per hectare profits in the case of both major crops as depicted in Fig. 7.8. Increased profits have benefitted the farmer not only on the economic front but also in promoting crop diversification. Profits per hectare for *guar* farmers with the intervention are INR 8800 while the value is INR 7225 for those without the intervention. Similarly, chana crop has yielded a better return of INR 10891 for those with the intervention compared with INR 9725 for the control group.

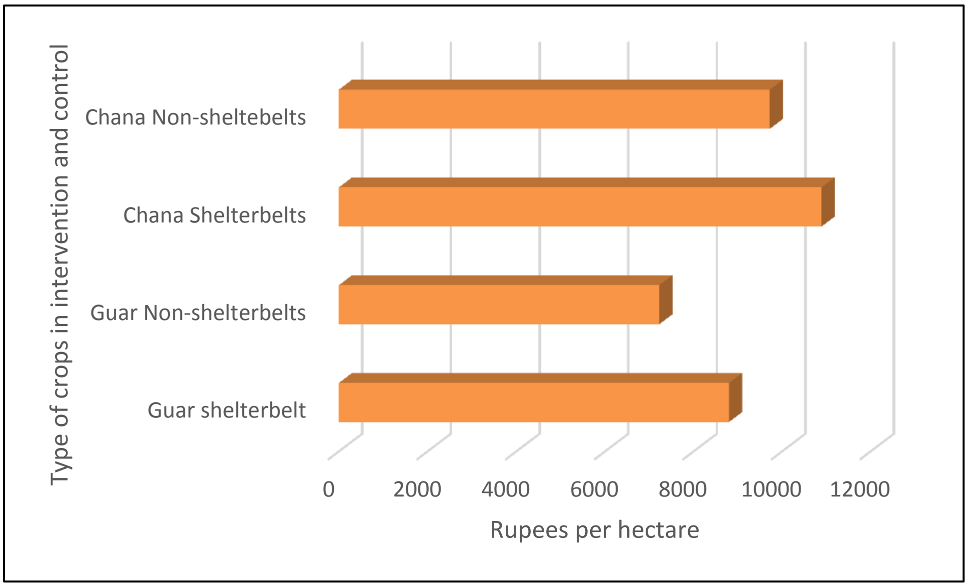

Figure 7.8 Crop-wise profit per hectare

This increase in revenue coupled with reduced costs has a beneficial impact on the income of the farmers as shown in the Fig 7.9. The proportion of total income derived from agriculture has increased for those with the intervention. Income of respondents (both overall income and agriculture income) with shelterbelts is higher as compared to the control group without shelterbelts.

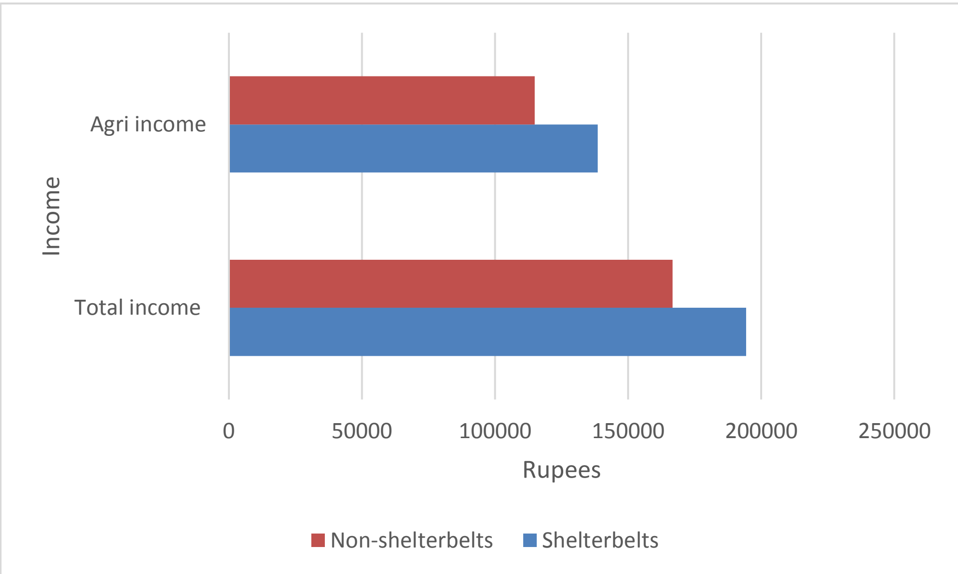

Figure 7.9 Agriculture income and overall income for the intervention and control group

These results suggest that tree plantations on the fields act as a boon for the farmers in earning them additional revenues. A regression analysis to study the effect of shelterbelts on productivity, after controlling for other factors (labour, other inputs and crop diversification) confirms that the presence of shelterbelts is significant and positively associated with productivity (Table 7.5).

Table 7.5 Regression of Shelterbelt adoption (dependent variable is total productivity)

Variable name	Coefficient	Standard Error	P-value
Total labour cost	-0.000361	0.0001966	0.068**
Total other input cost	0.0002408	0.0001483	0.107***
Shelterbelts dummy	0.2066144	0.098292	0.037*
Crop diversification	-0.0995923	0.0400024	0.014*
Average literacy rate	0.0282235	0.0147912	0.058**
Constant	1.218465	0.1491784	0.000*

***Significant at 0.05 level**

**** Significant at 0.10 level**

***** Significant at 0.01 level**

7.6 Scenario development for 2030

For the State of Rajasthan, we project the area likely to be impacted by wind erosion in 2030 utilising data from 2003/ 05 and 2011/ 2013 of the Space Applications Centre. We then use these estimates to determine the costs of reclamation of wind-eroded areas for the State of Rajasthan in 2030. The extent of wind erosion in 2030 is shown in Table 7.6. The extent of wind erosion in the State shows a decreasing linear trend based on available data (y = -134180x + 15466234 R^2 = 1). The norms for reclamation of wind eroded lands according to Chouhan (2005) are Rs 11000/ ha respectively for arid and semi-arid areas and Rs 12,000 per ha for sub-humid areas. Utilising the highest value of Rs 12,000 per ha and adjusting it to 2014/ 2015 prices using WPI, the cost of reclaiming lands degraded by wind erosion in Rajasthan in 2030 is Rs 309323.9 million at 2014/ 2015 prices.

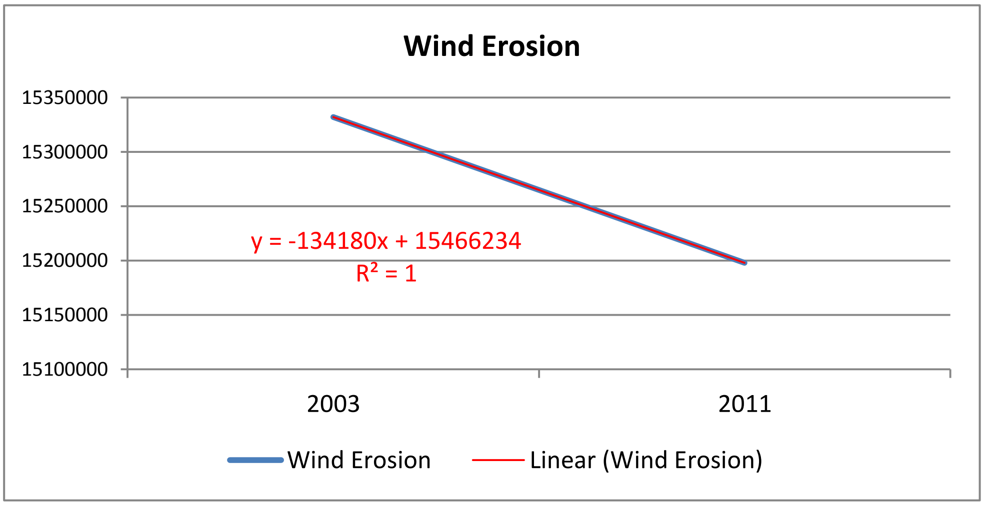

Figure 7.10 Projected trend for wind erosion in the State of Rajasthan (till 2030)

Table 7.6 Projected extent of wind erosion in the State of Rajasthan in 2030

Extent of wind erosion					
Year	2003	2011	2019	2027	2030
Wind erosion (in ha)	15332054	15197874	15063694	14929514	14862424

7.7 Conclusion and recommendations

Shelterbelts are seen as a long-term and important intervention to minimize wind erosion hazards and increase farm productivity. The planting of trees near fields reduces soil particle movement by reducing wind speeds during cultivation and harvesting, thus facilitating higher and healthier produce. In this study, we estimate the impact of shelterbelts on crop productivity and income of respondents residing in Jaisalmer district of Rajasthan. These impacts are equivalent to the foregone benefits or costs of degradation in areas without the shelterbelt intervention.

Our survey-based comparative assessment of areas with and without shelterbelts in Western Rajasthan shows that areas with shelterbelts had higher productivity, lower costs and higher profits (considering *guar* and *chana)* as compared to areas without shelterbelts. The positive association between shelterbelts and productivity is confirmed using a regression analysis which shows that the introduction of a shelterbelt increases productivity by 20% for *guar* and 38% for *chana*.

Our findings are in line with other research on the impact of shelterbelts. For example, a study in SE Australia finds that shelterbelts has led to an increase in the yield of oats by 22% and wheat by 47%. Another study conducted on assessing the impact of shelterbelts in Jaisalmer district has revealed an increase of 430.8 % increment in net returns due to presence of shelterbelt plantation (Gajja et al. 2008).

Our analysis thus supports the creation of shelterbelts to augment farm incomes through higher agricultural productivity in areas prone to wind-erosion.

The extent of land that is projected to degrade in 2030 shows a downward trend (14862424 ha). The cost of reclaiming this degraded land in 2030 is Rs 309323.9 million at 2014/ 2015 prices.

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Appendix 1.1 People interviewed/Institutions visited as part of the study

State	Names/Designations	Institutions visited
Madhya Pradesh	Mr. Vikas Verma, DFO and staff	Forest Department, Indore Division
	Range officer Mhow and her staff	Forest Department Mhow
	Mr. Vivek Dave, Joint Commissioner	Rajiv Gandhi Watershed Mission, Bhopal
	Mr. Jamal Ahmed Khan	District Watershed Development Center, Indore
Gujarat	Dr. Pankaj Joshi, Dr. Ramesh Bhatti, Ms. Mamta Patel, Dr. Jayahari K M, Ms. Punita Patel, Mr. Hanif, Mr. Imran,	Sahjeevan, Bhuj
	Dr. Ankila Hiremath, Dr. Abi Tamim Vanak, Dr. Dinakaran J, Mr. Chetan Misher	ATREE (Ashoka Trust for Research in Ecology and the Environment, New Delhi
	Mr Kabul	RAMBLE (Research and Monitoring in the Banni Landscape, Banni)
	Dr. CP Geevan, Dr. Arun Mani Dixit	CESC (Centre for Environment & Social Concerns, Ahmedabad)
	Dr. Deepa Gavali	GES (Gujarat Ecology Society, Vadodara)
	Dr Anjan Kumar Prusty, Senior Scientist , Environmental Impact Assessment	GUIDE (Gujarat Institute of Desert Ecology),
	Shri Hasmukh Shah	GES (Gujarat Ecology Society, Vadodara)
	Bhavin Vyas. DFO, Kutch	Kutch
	C K Aervadia, Asst Conservator of Forests, Kutch	Kutch
	Dr Vijay Kumar , Joint Director	GUIDE (Gujarat Institute of Desert Ecology)
	D. R. Patel, Dept. Commissioner,	Gujarat Groundwater Dev. Corporation

State	Names/Designations	Institutions visited
	Mr Thakkar	Salinity Intrusion and Investigation Circle (Shaar Niyantarn)
	Pratik Mebara,	Kharas niyantran office (Rapar Block), Bhuj
	P P Patel, Range Forest Officer	Rapar Block
	Bharat Waghela	RFO Office, Rapar
	V.A. Joshi	RFO Office, Rapar
	Devraj Vaniya, Farmer	Fatehgarh
	Dr. Sandeep Virmani, Board Member	Sahjeevan, Bhuj
	Dr. Jayahari KM, Director	Sahajeevan
	Dr Devi Dayal, Head and PS,	Regional Research Station, Kukuma (Bhuj), CAZRI
	Dr Yogesh Jadeja	Arid Communities and Technologies
	Shailesh Vyas	SATVIK
	J.P. Wagamshi, Secretary,	Director of Agriculture, Jila Parisad Building
	Dr. Sipai	KVK Bachau
	Dr Tank	KVK Mundra
	Mr. S.P. Dimar	Akhra Shakha; Statistics deptt; Govt. of Gujarat, Jila Panchayat Office; Bhuj
	Dr Haresh Thakkar	Livestock deptt
	Mr. G D Pathak	, Kutch Irrigation Circle, Bhuj
	Dr M.G. Thakkar, Additional Assistant Engineer	I/ C Registrar and HoD Geology, Kachchh University 9879121777
	Mr. Velji Gordiya	Parab water Management Private Limited
Uttar Pradesh	Mr S K Jain, Additional PCCF	Uttar Pradesh Forest Department
	Mr Navin Chaturvedi, Senior Manager	UP Bhumi Sudhar Nigam

State	Names/Designations	Institutions visited
	Mr B P Singh, District Programme Manager	UP Bhumi Sudhar Nigam
Andhra Pradesh	Dr T.V. Satyanarayana, Registrar	Andhra Pradesh Rice Research Institute and Regional Research Centre, Maruteru
	Dr. A. Vishnu Vardhan Reddy, Associate Director	Andhra Pradesh Rice Research Institute and Regional Research Centre, Maruteru
	Dr. Ch. Sreenivas, Senior Scientist,	Andhra Pradesh Rice Research Institute and Regional Research Centre, Maruteru
	Registrar	Acharya N G Ranga Agricultural University, Hyderabad
	Mr. Nagendra Rao	Agricultural Research Station, Machilipattanam
	Dr. Anuradha	Agricultural Research Station, Machilipattanam
		Directorate of Rice Research, Hyderabad
Rajasthan	Dr. C B Pandey, Head, Natural Resources and Environment Division	Central Arid Zone Research Institute, Jodhpur
	Dr. Mahesh Gaur, Senior Scientist (Geography)	CAZRI
	Dr. Priyabrata Santra, Senior Scientist (Soil Physics)	CAZRI
	Dr. Genda Singh, Scientist G, Forest Ecology Divison	Arid Forest Research Institute, Jodhpur
	Mr. D R Saharan	CF, Department of Forests, Jodhpur Division
	Mr. Badri Prasad	Nachna Village
Uttarakhand	Dr P Dogra	Indian Institute of Soil and Water Conservation Dehradun, ICAR
	Dr Mondal	Indian Institute of Soil and Water Conservation Dehradun, ICAR
	Dr. B L Dhyani, Principal Scientist of the	ICAR- Indian Institute of Soil and Water Conservation, Dehradun

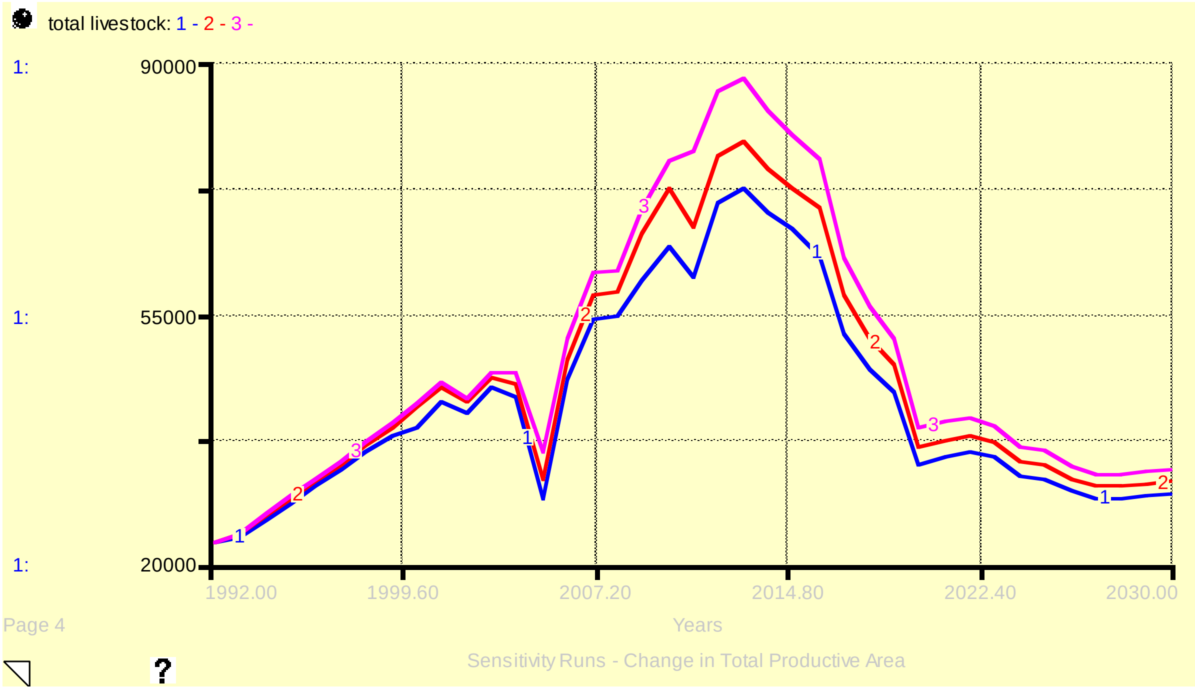
State	Names/Designations	Institutions visited
	Dr Dheeraj Pande,	Divisional Forest Officer, Dehradun
	Mr Sanjay Sondhi	Titli Trust
Karnal	Dr. R. K. Yadav, Principal Scientist and Head	Central Soil Salinity Research Institute, Karnal
	Dr. Thinampa, Agricultural Economist	Central Soil Salinity Research Institute, Karnal
	Dr. S. K. Kamra	Central Soil Salinity Research Institute, Karnal
	Dr. Madhurama Sethi	Central Soil Salinity Research Institute, Karnal
Cuttack		National Rice Research Institute, Cuttack
National/Regional Institutes	Dr V N Sharda	Indian Council for Agricultural Research (ICAR), Delhi

Appendix 2.1 Sensitivity Runs

The results of sensitivity runs are presented below. All the graphs show that the shape of change of variables remain the same with changes in parameter values. This consistency under changes of parameter values demonstrates the model's robustness.

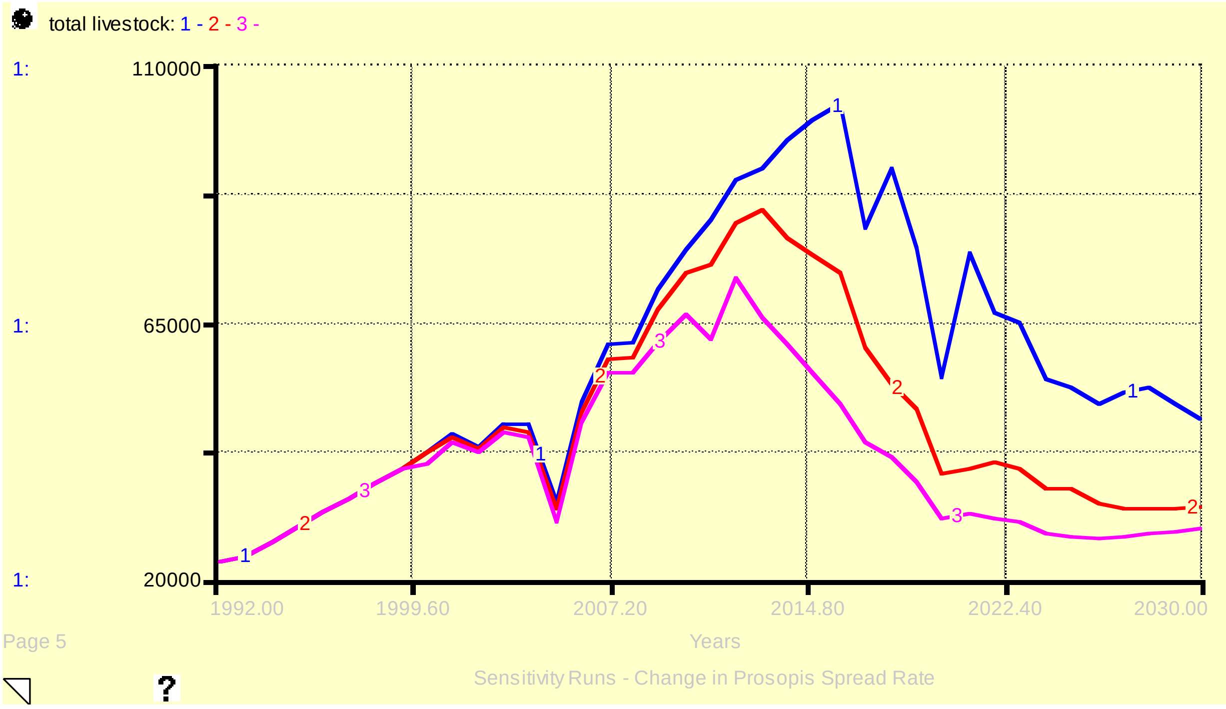
A. Parameter Changed: Total Productive Area

1. 2 lac hectare
2. 2.25 lac hectare
3. 2.5 lac hectare



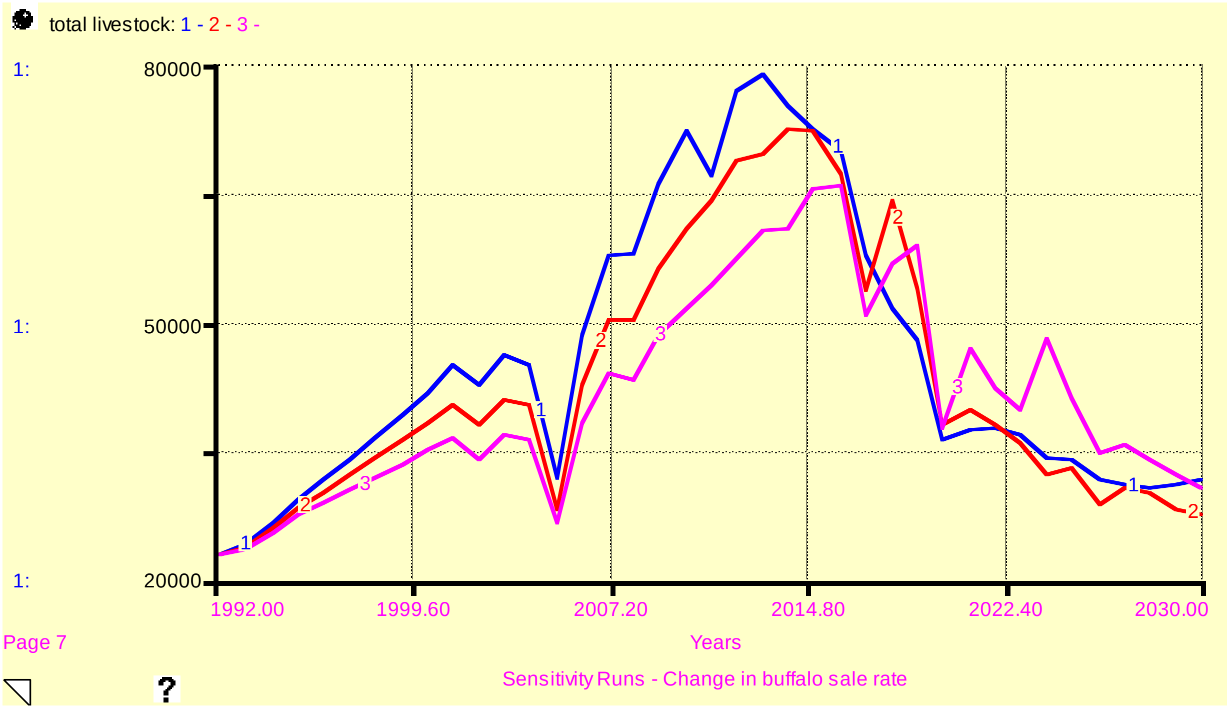
B. Parameter Changed: Prosopis Spread Rate

1. 0.06
2. 0.08
3. 0.10



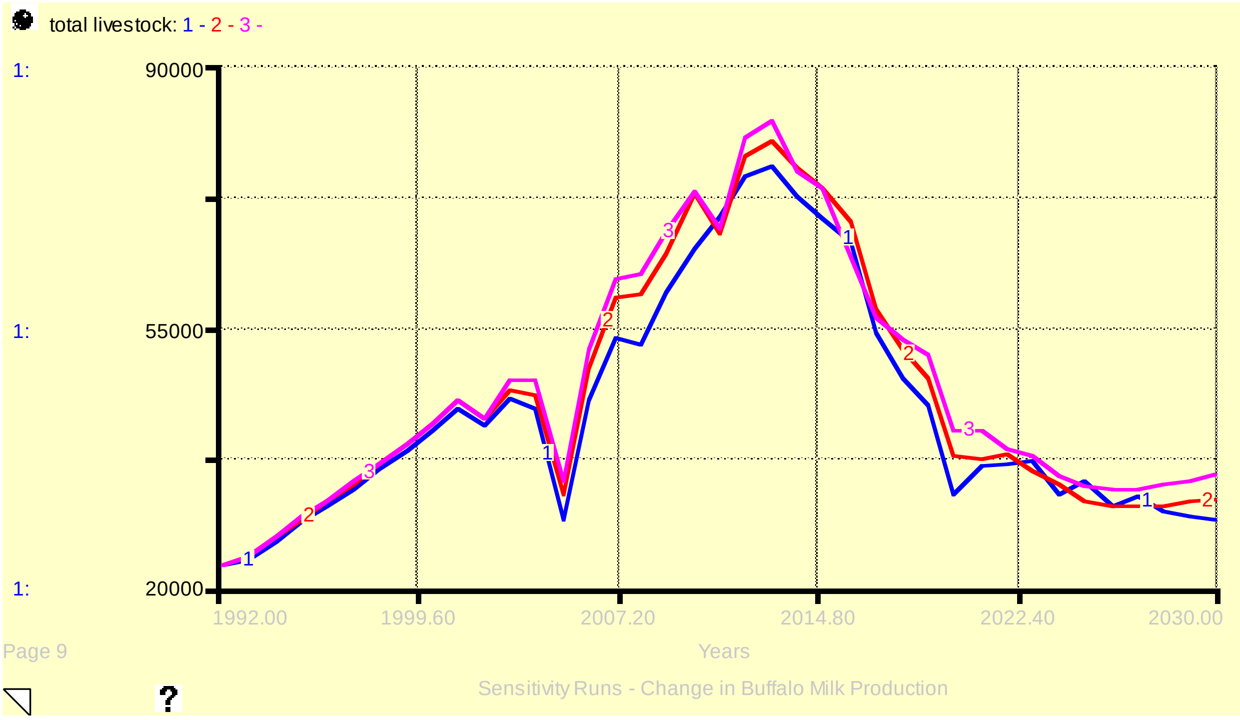
C. Parameter Changed: Buffalo Sale Rate

1. 0.01
2. 0.03
3. 0.05



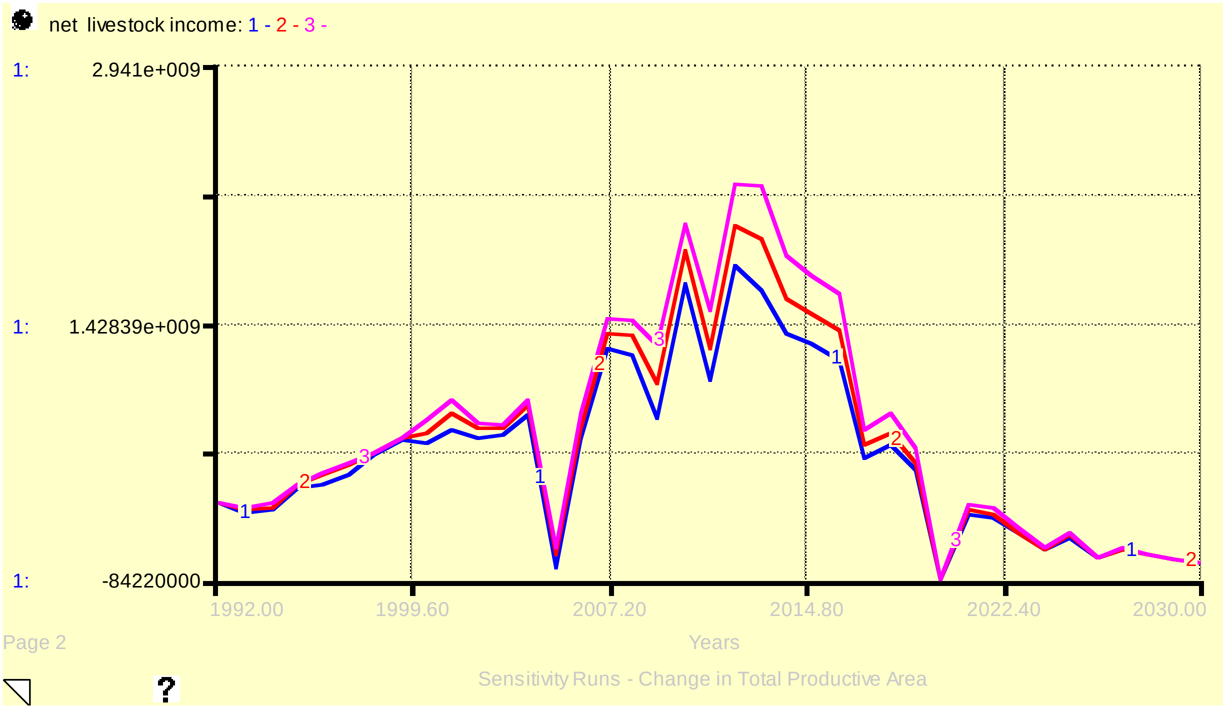
D. Parameter Changed: Buffalo Daily Milk Production

1. 10
2. 12.5
3. 15



E. Parameter Changed: Total Productive Area

1. 2 lac hectare
2. 2.25 lac hectare
3. 2.5 lac hectare



Appendix 2.2 Model Equations

Economy Dynamics

UNATTACHED:

income_from_dung_manure_sale = dung_manure__from_buffalo*rate_per_dung_truck_load

income_from_livestock_sale = income_from_buffalo_sale+income_from_kankrej_sale

income_from_milk = income_from_kankrej_milk+income_from_bufalo_milk

net_income_from_charcoal = charcoal_price*charcoal_production

DOCUMENT: Cost of making one sac (40 kgs) of charcoal is Rs. 100. At 6 rupees a kg one sac yields Rs. 300 revenue less cost Rs. 100 gives Rs. 200 per sac as net income. Around 5 rupees a kg.

net__livestock_income = (income_from_milk+income_from_dung_manure_sale+income_from_livestock_sale)-total_livestock_expenses

average_milk_production_per_buffalo_per_day = 12

UNITS: litres (l)

DOCUMENT: Milk production per buffalo ranges from 8 litres to 20 litres a day. Average taken as 12 litres a day.

average_milk_production_per_kankrej_per_day = 9

UNITS: litres (l)

DOCUMENT: Milk production per Kankrej cattle ranges from 6 to 14 litres a day. Average taken as 9 litres a day.

buffalo_milk_production = milk_producing_buffalo*average_milk_production_per_buffalo_per_day*275

UNITS: litres (l)

DOCUMENT: Milk production assumed for 275 days a year.

charcoal_price = 5000

UNITS: rupee/ ton

DOCUMENT: Rs. 5 per kg. Taken as constant

dung_manure__from_buffalo = (total_livestock/ 100)*24

UNITS: units (unit)

DOCUMENT: Let it be Banni pg 74. 15 days one truck load from 100 livestock

income_from_bufalo_milk = milk_price_per_litre_of_banni_buffalo_milk*buffalo_milk_production

UNITS: l-rupee/ litre

income_from_buffalo_sale = buffalo_sale_price*(Buffalos_Sold+buffalo_sale)

income_from_kankrej_milk = milk_price_per_litre_of_kankrej_milk*kankrej_milk_production

UNITS: l-rupee/ litre

income_from_kankrej_sale = (kankrej_calves_being_sold+Kankrej_Stress_Sales)*kankrej_sale_price

UNITS: rupee/ yr

per_day_milk_output = total_milk_production_per_annum/ 365

UNITS: litres (l)

input_costs_of_non_milking_buffalos = input_cost_for_milk_producing_buffalos/ 3

DOCUMENT: Non lactating buffalo feed expense is around 1/ 3rd of lactating buffalo.

kankrej_milk_production = milk_producing_kankrej*average_milk_production_per_kankrej_per_day*180

UNITS: litres (l)

DOCUMENT: Kankrej Milk production days assumed to be 180 days in a year.

kankrej_sale_price = 10000

UNITS: rupee/ unit

DOCUMENT: Average price varies from 12000 to 30000 for a pair of bullock. Taken as average Rs. 10000 per Kankrej. Let it be Banni, pg 65 milking_buffalo_feed_expenses = milk_producing_buffalo*input_cost_for_milk_producing_buffalos

non_milking_buffalo__expenses = input_costs_of_non_milking_buffalos*non_milk_producing_buffalo

profit_per_livestock = net__livestock_income/ total_livestock

rate_per_dung_truck_load = 1500

DOCUMENT: Kept constant at Rs. 1500 per truck load

total_livestock_expenses = milking_buffalo_feed_expenses+non_milking_buffalo__expenses

total_milk_production_per_annum = kankrej_milk_production+buffalo_milk_production

UNITS: litres (l)

total_net_income = net_income_from_charcoal+net__livestock_income

buffalo_sale_price = GRAPH(TIME)

(1992, 38197), (1993, 39152), (1994, 40131), (1995, 41135), (1996, 42163), (1997, 43217), (1998, 44297), (1999, 45405), (2000, 46000), (2001, 46000), (2002, 46000), (2003, 46000), (2004, 46000), (2005, 46000), (2006, 46000), (2007, 46000), (2008, 46000), (2009, 46000), (2010, 46000), (2011, 51520), (2012, 57702), (2013, 64627), (2014, 72382), (2015, 75000)

DOCUMENT: Current Buffalo price for year 2015 range from INR 50,000 to INR 3,00,000. Mode sale price taken as INR 75,000 and then normalized for the past years taking into consideration the rise in price due to Buffalo registration in year 2011.

input_cost_for_milk_producing_buffalos = GRAPH(fodder_deficit)

(0.00, 10000), (0.2, 20000), (0.3, 50000), (0.5, 70000), (0.7, 100000), (0.8, 120000), (1.00, 140000)

DOCUMENT: At 50% fodder deficit the cost of feed for milk producing buffalo is estimated to be Rs. 70,000/ - per annum. The numbers are adjusted to reflect fall and increase in fodder deficit and its corresponding impact on feed cost due to increase in supply. This table could be changed to do sensitivity or policy runs in the interface.

milk_price_per_litre_of_banni_buffalo_milk = GRAPH(TIME)

(1992, 19.0), (1993, 20.0), (1994, 20.0), (1995, 21.0), (1996, 22.0), (1997, 22.0), (1998, 23.0), (1999, 24.0), (2000, 26.0), (2001, 27.0), (2002, 27.0), (2003, 28.0), (2004, 29.0), (2005, 29.0), (2006, 30.0), (2007, 31.0), (2008, 32.0), (2009, 32.0), (2010, 33.0), (2011, 34.0), (2012, 35.0), (2013, 36.0), (2014, 38.0), (2015, 40.0)

UNITS: rupee/ litre

DOCUMENT: Historical Milk prices taken at 2015 constant values.

2015 milk price taken from personal interviews with Dairy.

2010 milk price taken from Let it be Banni, pg 71 footnote.

2000 milk price taken from Ecological Economic Analysis of Grassland Systems: Resource Dynamics and Management Challenges-Kachchh District (Gujarat), pg 56, table 6.9

1992 milk prices are assumed.

milk_price_per_litre_of_kankrej_milk = GRAPH(TIME)

(1992, 10.0), (1999, 13.0), (2007, 17.0), (2015, 18.0)

UNITS: rupee/ litre

DOCUMENT: Historical Milk prices taken at 2015 constant values. Current prices for 2015 taken from personal interview, while earlier prices are re-calculated to reflect 2015 constant values.

Livestock Dynamics

Adult_Buffalo(t) = Adult_Buffalo(t - dt) + (buffalo_calves_becoming_adult - retiring_buffalos - sale__of_buffalos - Adult_Buffalo_migration - buffalo_sale) * dt

INIT Adult_Buffalo = 16774*0.75

UNITS: units (unit)

DOCUMENT: 75% assumed to be adults.

Let is be Banni, pg 87 table 33

INFLOWS:

buffalo_calves_becoming_adult = Buffalo_Calves/ ageing_time

UNITS: unit/ yr

OUTFLOWS:

retiring_buffalos = (Adult_Buffalo+Adult_Buffalo_Migrated)/ buffalo_lifetime

UNITS: unit/ yr

sale__of_buffalos = buffalo_sale_multiplier_due_to_profitability*Adult_Buffalo

UNITS: unit/ yr

DOCUMENT: This is the flow of buffalo sale which happens during times of fodder stress.

Adult_Buffalo_migration = IF fodder_deficit>0.3 AND fodder_deficit<=0.5 THEN Adult_Buffalo*0.3 else IF fodder_deficit>0.5 THEN Adult_Buffalo*0.5 ELSE IF fodder_deficit<0.1 THEN -(Adult_Buffalo_Migrated*1) else 0

UNITS: unit/ yr

DOCUMENT: Livestock Migration takes place when fodder deficit exceeds 30%. A step increase in migration is given. When fodder deficit is between 30% and 50% the migration is 30%. When fodder deficit goes above 50% then 50% migration happens. While if fodder deficit is less than10% then the migrated stock comes back, shown as negative function.

buffalo_sale = IF TIME<2011 THEN Adult_Buffalo*normal_buffalo_sale_rate ELSE (Adult_Buffalo*normal_buffalo_sale_rate)/ 2

UNITS: unit/ yr

DOCUMENT: Before Banni buffalo registration happened the sale of buffalo is assumed to be relatively higher. Post registration due to increase in sale income the quantity of buffalo sold has come down due to higher sale price.

Adult_Buffalo_Migrated(t) = Adult_Buffalo_Migrated(t - dt) + (Adult_Buffalo_migration) * dt

INIT Adult_Buffalo_Migrated = 10

INFLOWS:

Adult_Buffalo_migration = IF fodder_deficit>0.3 AND fodder_deficit<=0.5 THEN Adult_Buffalo*0.3 else IF fodder_deficit>0.5 THEN Adult_Buffalo*0.5 ELSE IF fodder_deficit<0.1 THEN -(Adult_Buffalo_Migrated*1) else 0

UNITS: unit/ yr

DOCUMENT: Livestock Migration takes place when fodder deficit exceeds 30%. A step increase in migration is given. When fodder deficit is between 30% and 50% the migration is 30%. When fodder deficit goes above 50% then 50% migration happens. While if fodder deficit is less than10% then the migrated stock comes back, shown as negative function.

Adult_Kankrej(t) = Adult_Kankrej(t - dt) + (kankrej_calves__becoming_adult - kankrej_adult_deaths - adult_kankrej_calf_migration) * dt

INIT Adult_Kankrej = 6058*.75

UNITS: units (unit)

INFLOWS:

kankrej_calves__becoming_adult = Kankrej_Calf/ ageing_time_of_kankrej

UNITS: unit/ yr

OUTFLOWS:

kankrej_adult_deaths = (Adult_Kankrej+Adult_Kankrej_Migrated)/ kankrej_lifetime*impact_of_Prosopis_on_death_rate_of_Kankrej

UNITS: unit/ yr

adult_kankrej_calf_migration = IF fodder_deficit>0.3 AND fodder_deficit<=0.5 THEN Adult_Kankrej*0.3 else IF fodder_deficit>0.5 THEN Adult_Kankrej*0.5 ELSE IF fodder_deficit<0.1 THEN -(Adult_Kankrej_Migrated*1) else 0

UNITS: unit/ yr

DOCUMENT: Livestock Migration takes place when fodder deficit exceeds 30%. A step increase in migration is given. When fodder deficit is between 30% and 50% the migration is 30%. When fodder deficit goes above 50% then 50% migration happens. While if fodder deficit is less than10% then the migrated stock comes back, shown as negative function.

Adult_Kankrej_Migrated(t) = Adult_Kankrej_Migrated(t - dt) + (adult_kankrej_calf_migration) * dt

INIT Adult_Kankrej_Migrated = 10

INFLOWS:

adult_kankrej_calf_migration = IF fodder_deficit>0.3 AND fodder_deficit<=0.5 THEN Adult_Kankrej*0.3 else IF fodder_deficit>0.5 THEN Adult_Kankrej*0.5 ELSE IF fodder_deficit<0.1 THEN -(Adult_Kankrej_Migrated*1) else 0

UNITS: unit/ yr

DOCUMENT: Livestock Migration takes place when fodder deficit exceeds 30%. A step increase in migration is given. When fodder deficit is between 30% and 50% the migration is 30%. When fodder deficit goes above 50% then 50% migration happens. While if fodder deficit is less than10% then the migrated stock comes back, shown as negative function.

Buffalos_Sold(t) = Buffalos_Sold(t - dt) + (sale__of_buffalos - buffalo__sale_stock_normaliser) * dt

INIT Buffalos_Sold = 10

INFLOWS:

sale__of_buffalos = buffalo_sale_multiplier_due_to_profitability*Adult_Buffalo

UNITS: unit/ yr

DOCUMENT: This is the flow of buffalo sale which happens during times of fodder stress.

OUTFLOWS:

buffalo__sale_stock_normaliser = Buffalos_Sold

Buffalo_Calves(t) = Buffalo_Calves(t - dt) + (buffalo_births - buffalo_calves_becoming_adult - buffalo_calf_deaths - buffalo_calves_migration) * dt

INIT Buffalo_Calves = 16774*0.25

UNITS: units (unit)

DOCUMENT: 16774*0.25

INFLOWS:

buffalo_births = (Adult_Buffalo+Adult_Buffalo_Migrated)*birth_rate

UNITS: unit/ yr

DOCUMENT: Birth flows are a function of adult buffalos (migrated+local) multiplied by the birth rate.

OUTFLOWS:

buffalo_calves_becoming_adult = Buffalo_Calves/ ageing_time

UNITS: unit/ yr

buffalo_calf_deaths = Buffalo_Calves*buffalo_calf_death_rate

UNITS: unit/ yr

buffalo_calves_migration = IF fodder_deficit>0.3 AND fodder_deficit<=0.5 THEN Buffalo_Calves*0.2 else IF fodder_deficit>0.5 THEN Buffalo_Calves*0.5 ELSE IF fodder_deficit<0.1 THEN -(Buffalo_Calves_Migrated*1) else 0

UNITS: unit/ yr

DOCUMENT: Livestock Migration takes place when fodder deficit exceeds 30%. A step increase in migration is given. When fodder deficit is between 30% and 50% the migration is 30%. When fodder deficit goes above 50% then 50% migration happens. While if fodder deficit is less than10% then the migrated stock comes back, shown as negative function.

Buffalo_Calves_Migrated(t) = Buffalo_Calves_Migrated(t - dt) + (buffalo_calves_migration) * dt

INIT Buffalo_Calves_Migrated = 10

INFLOWS:

buffalo_calves_migration = IF fodder_deficit>0.3 AND fodder_deficit<=0.5 THEN Buffalo_Calves*0.2 else IF fodder_deficit>0.5 THEN Buffalo_Calves*0.5 ELSE IF fodder_deficit<0.1 THEN -(Buffalo_Calves_Migrated*1) else 0

UNITS: unit/ yr

DOCUMENT: Livestock Migration takes place when fodder deficit exceeds 30%. A step increase in migration is given. When fodder deficit is between 30% and 50% the migration is 30%. When fodder deficit goes above 50% then 50% migration happens. While if fodder deficit is less than10% then the migrated stock comes back, shown as negative function.

Kankrej_Calf(t) = Kankrej_Calf(t - dt) + (kankrej_births + male_calves__being_purchased - kankrej_calves__becoming_adult - calf_deaths - kankrej_calves_being_sold - stress_sale__of_kankrej - kankrej_calf_migration) * dt

INIT Kankrej_Calf = 6058*0.25

UNITS: units (unit)

DOCUMENT: 16774*0.24

INFLOWS:

kankrej_births = kankrej_birth_rate*(Adult_Kankrej+Adult_Kankrej_Migrated)

UNITS: unit/ yr

male_calves__being_purchased = Kankrej_Calf*average_male_kankrej_purchase_rate

UNITS: unit/ yr

OUTFLOWS:

kankrej_calves__becoming_adult = Kankrej_Calf/ ageing_time_of_kankrej

UNITS: unit/ yr

calf_deaths = Kankrej_Calf*kankrej_calf_death_rate*impact_of_Prosopis_on_death_rate_of_Kankrej

UNITS: unit/ yr

kankrej_calves_being_sold = Kankrej_Calf*average_kankrej_calf_sale_rate

UNITS: unit/ yr

stress_sale__of_kankrej = Kankrej_Calf*kankrej_sale_multiplier_due_to_profitability

UNITS: unit/ yr

kankrej_calf_migration = IF fodder_deficit>0.3 AND fodder_deficit<=0.5 THEN Kankrej_Calf*0.3 else IF fodder_deficit>0.5 THEN Kankrej_Calf*0.5 ELSE IF fodder_deficit<0.1 THEN -(Kankrej_Calf_Migrated*1) else 0

UNITS: unit/ yr

DOCUMENT: Livestock Migration takes place when fodder deficit exceeds 30%. A step increase in migration is given. When fodder deficit is between 30% and 50% the migration is 30%. When fodder deficit goes above 50% then 50% migration happens. While if fodder deficit is less than10% then the migrated stock comes back, shown as negative function.

Kankrej_Calf_Migrated(t) = Kankrej_Calf_Migrated(t - dt) + (kankrej_calf_migration) * dt

INIT Kankrej_Calf_Migrated = 10

INFLOWS:

kankrej_calf_migration = IF fodder_deficit>0.3 AND fodder_deficit<=0.5 THEN Kankrej_Calf*0.3 else IF fodder_deficit>0.5 THEN Kankrej_Calf*0.5 ELSE IF fodder_deficit<0.1 THEN -(Kankrej_Calf_Migrated*1) else 0

UNITS: unit/ yr

DOCUMENT: Livestock Migration takes place when fodder deficit exceeds 30%. A step increase in migration is given. When fodder deficit is between 30% and 50% the migration is 30%. When fodder deficit goes above 50% then 50% migration happens. While if fodder deficit is less than10% then the migrated stock comes back, shown as negative function.

Kankrej_Stress_Sales(t) = Kankrej_Stress_Sales(t - dt) + (stress_sale__of_kankrej - kankreaj__sale_normaliser) * dt

INIT Kankrej_Stress_Sales = 10

INFLOWS:

stress_sale__of_kankrej = Kankrej_Calf*kankrej_sale_multiplier_due_to_profitability

UNITS: unit/ yr

OUTFLOWS:

kankreaj__sale_normaliser = Kankrej_Stress_Sales ageing_time = 3

UNITS: years (yr)

DOCUMENT: Taken as 3 years. Data coming from Personal Interview with experts and pastoralists.

ageing_time_of_kankrej = 3

UNITS: years (yr)

DOCUMENT: Taken as 3 years. Data coming from Personal Interview with experts and pastoralists.

average_kankrej_calf_sale_rate = 0.6

UNITS: Unitless

DOCUMENT: Taken as 0.6. Data coming from Personal Interview with experts and pastoralists.

average_male_kankrej_purchase_rate = 0.25

UNITS: Unitless

DOCUMENT: Taken as 0.25. Data coming from Personal Interview with experts and pastoralists.

birth_rate = 0.50*0.50

UNITS: Unitless

DOCUMENT: Personal Interviews.

50% born are females. Approx. 50% of the total adult stock would give birth every year.

buffalo_calf_death_rate = 0.2

UNITS: units (unit)

DOCUMENT: Taken as 20%. Data coming from Personal Interview with experts and pastoralists.

buffalo_lifetime = 20

UNITS: years (yr)

DOCUMENT: Taken as 20 years excluding 3 years as calve. Total age 23 years. Data coming from Personal Interview with experts and pastoralists.

fodder_requirement__for_buffalo = (Adult_Buffalo*fodder_requirement_per_adult_buffalo_per_day)+(Buffalo_Calves*fodder_requirement_per_buffalo_calf_per_day)*300

UNITS: kilogram

fodder_requirement__for_kankrej = (Kankrej_Calf*fodder_requirment_per_kankrej_calf_per_day)+(Adult_Kankrej*fodder_requirement_per_kankrej_adult_per_day)*300

UNITS: kilogram

fodder_requirement_per_adult_buffalo_per_day = 30

UNITS: kilogram/ unit

DOCUMENT: Taken as 30 kgs a day based on personal interveiws with experts and pastoralists.

fodder_requirement_per_buffalo_calf_per_day = 7.5

UNITS: kilograms/ unit

DOCUMENT: Taken as 7.5 kgs a day based on personal interveiws with experts and pastoralists.

fodder_requirement_per_kankrej_adult_per_day = 15

UNITS: kilogram/ unit

DOCUMENT: Taken as 15 kgs a day based on personal interveiws with experts and pastoralists.

fodder_requirment_per_kankrej_calf_per_day = 5

UNITS: kilogram/ unit

DOCUMENT: Taken as 5 kgs a day based on personal interveiws with experts and pastoralists.

fraction_of_milk_producing_buffalos = 0.5

UNITS: Unitless

DOCUMENT: Assumed to be 50% of the adult buffalo stock.

fraction_of_milk_producing_kankrej = 0.5

UNITS: Unitless

DOCUMENT: Taken as 0.5 assuming that 50% of the cows are lactating since 50% reproduce every year. Data coming from Personal Interview with experts and pastoralists.

kankrej_birth_rate = 0.5

UNITS: Unitless

DOCUMENT: Taken as 0.5. Data coming from Personal Interview with experts and pastoralists.

kankrej_calf_death_rate = 0.2

UNITS: Unitless

DOCUMENT: Taken as 0.2. Data coming from Personal Interview with experts and pastoralists.

kankrej_lifetime = 12

UNITS: years (yr)

DOCUMENT: Taken as 12 years excluding 3 years as calves. Total age 15 years. Data coming from Personal Interview with experts and pastoralists.

milk_producing_buffalo = Adult_Buffalo*fraction_of_milk_producing_buffalos

UNITS: units (unit)

milk_producing_kankrej = Adult_Kankrej*fraction_of_milk_producing_kankrej

UNITS: units (unit)

non_milk_producing_buffalo = Adult_Buffalo-milk_producing_buffalo

normal_buffalo_sale_rate = 0.01

UNITS: Unitless

DOCUMENT: Personal Interview.

This is the fraction which is sold outside Banni.

total_livestock = Adult_Buffalo + Adult_Kankrej + Buffalo_Calves + Kankrej_Calf

UNITS: units (unit)

buffalo_sale_multiplier_due_to_profitability = GRAPH(profit_per_livestock)

(-5000, 0.3), (-4500, 0.208), (-4000, 0.136), (-3500, 0.104), (-3000, 0.0781), (-2500, 0.061), (-2000, 0.0419), (-1500, 0.0305), (-1000, 0.0216), (-500, 0.00889), (0.00, 0.00)

DOCUMENT: It is assumed that buffalo sale would get amplified during times of losses. As losses go up the sale amplification also goes up.

impact_of_Prosopis_on_death_rate_of_Kankrej = GRAPH(Prosopis_area_against_total_productive_area)

(0.1, 1.00), (0.2, 1.23), (0.3, 1.39), (0.4, 1.56), (0.5, 1.67), (0.6, 1.79), (0.7, 1.89), (0.8, 1.96), (0.9, 2.00), (1.00, 2.00)

kankrej_sale_multiplier_due_to_profitability = GRAPH(profit_per_livestock)

(-5000, 0.2), (-4500, 0.15), (-4000, 0.121), (-3500, 0.103), (-3000, 0.0838), (-2500, 0.061), (-2000, 0.0419), (-1500, 0.0305), (-1000, 0.0216), (-500, 0.00889), (0.00, 0.00)

DOCUMENT: It is assumed that Kankrej sale would get amplified during times of losses. As losses go up the sale amplification also goes up, but less as compared to Buffalo sale.

Prosopis and Grassland Dynamics

Area_under_Prosopis(t) = Area_under_Prosopis(t - dt) + (Prosopis_area_increasing - Prosopis_area_reducing) * dt

INIT Area_under_Prosopis = 41180

UNITS: hectares (ha)

DOCUMENT: Birds of Banni, GUIDE 2016, Pg 20

INFLOWS:

Prosopis_area_increasing = proposip_actual_spread_rate*Area_under_Prosopis*(1-(Area_under_Prosopis/ total_productive__land_area))

UNITS: hectares/ yr

OUTFLOWS:

Prosopis_area_reducing = IF TIME>=2004 AND TIME <=2008 THEN DELAY1(step_for_ban_on__Prosopis_cutting,1) ELSE MIN((Area_under_Prosopis*Prosopis_removal_multiplier),Area_under_Prosopis)

UNITS: hectares/ yr

DOCUMENT: Since Maldharis only use above ground wood of Prosopis for charcoal making it does not reduce the area under Prosopis. Only when the ban on charcoal making was lifted the Prosopis was being excavated. The second condition for Prosopis excavation would be under a policy for Prosopis removal.

UNATTACHED:

charcoal_production = IF time<=2004 then ((charcoal_produced_per_day*240)/ 1000)/ 2 else if time >=2004 AND TIME <=2008 then ((charcoal_produced_per_day*240)/ 1000)*5 ELSE if TIME >=2008 then (charcoal_produced_per_day*240)/ 1000 else 0

DOCUMENT: 240 days of charcoal production takes place. Before ban was lifted (i.e. before 2004) the production was half of what is is now (i.e. after 2008). While ban was lifted the charcoal production become 10 times of what it was before the ban (2004-2008).

UNATTACHED:

grassland_biomass = grass_productivity*area_under_grassland

DOCUMENT: This is the annual flow of grass biomass which grows in Banni.

area_under_grassland = total_productive__land_area-Area_under_Prosopis

UNITS: hectares (ha)

DOCUMENT: Birds of Banni, GUIDE 2016, Pg 20

Total grassland area is considered as total_productive__land_area less Area_under_Prosopis

charcoal_produced_per_day = IF TIME>2015 then (4800*40)*impact_of_profit_per_livestock_on_charcoal_production else 4800*40

UNITS: kilograms (kg)

DOCUMENT: 4800 sacs@40 kgs each produced per day. This rate of production goes up to compensate for loss of profitability from Livestock.

fodder_deficit = if fodder_surplus_or_deficit<0 THEN (fodder_surplus_or_deficit/ fodder_requirement)*-1 ELSE 0

DOCUMENT: Fodder deficit is shown as the ratio between deficit and fodder requirement. It is multiplied with -1 to maintain positive number

fodder_requirement = fodder_requirement__for_buffalo + fodder_requirement__for_kankrej

UNITS: kilogram

DOCUMENT: This is the total annual fodder requirement of Livestock in Banni.

fodder_surplus_or_deficit = grassland_biomass-fodder_requirement

UNITS: kilograms (kg)

proposip_actual_spread_rate = Prosopis_normal_spread_rate*impact_of_livestock_on_proposis_spread_rate

UNITS: units (unit)

DOCUMENT: Spread rate after taking into account the increase in spread rate due to livestock.

Prosopis_area_against_total_productive_area = Area_under_Prosopis/ total_productive__land_area

DOCUMENT: This is the extent of area under Prosopis cover.

Prosopis_normal_spread_rate = 0.085

UNITS: Unitless

DOCUMENT: ABOVE GROUND BIOMASS AND CARBON STOCK ESTIMATION

FROM PROSOPIS JULIFLORA IN BANNI GRASSLAND USING

SATELLITE AND ANCILLARY DATA

Vineet Vaibhava, Arun B. Inamdarb* and Divya N. Bajaja, pg 3

Prosopis_removal_fraction = STEP(0.2, 2016)

DOCUMENT: It is assumed that 20% of the Prosopis land area would be cleared every year from year 2016 as a policy.

Prosopis_removal_multiplier = IF Prosopis_removal_policy=1 THEN DELAY1(Prosopis_removal_fraction,3) else 0

DOCUMENT: It is assumed that 20% of the Prosopis land area would be cleared every year as a policy. But there would be a delay of a year for the policy to take full effect.

Prosopis_removal_policy = 0

DOCUMENT: 0=Policy not in action

1=Policy in action

step_for_ban_on__Prosopis_cutting = STEP(10240,2004)

DOCUMENT: 2400*40 kgs of charcoal produced before 2004 when the ban was there. From 2004 to 2008 when ban was lifted this went up by 10 times.3 kgs of Prosopis wood is requried to make 1 kg charcoal. Hence, 2400*40*10*3 is the total Prosopis wood consumed. To convert it into hectares of land equivalent we use 750 trees @90 kgs each per hectare.

total_productive__land_area = (184062+65938)*0.9

UNITS: hectares (ha)

DOCUMENT: Birds of Banni, GUIDE 2016, Pg 20

Includes land with mixed vegetation and salinity. It is assumed that 10% of the land is waste land where neither Prosopis nor grasses can grow.

grass_productivity = GRAPH(Rainfall)

(100, 100), (178, 200), (256, 400), (340, 620), (411, 700), (489, 700), (567, 600), (644, 500), (722, 400), (800, 300)

DOCUMENT: Grassland productivity taken as 620 kgs per hectare per year for 340 mm of rainfall for the whole of Banni area. The productivity figures are adjusted for different rainfall numbers. Ref. Let it be Banni, pg 76.

impact_of_livestock_on_proposis_spread_rate = GRAPH(total_livestock)

(25000, 1.00), (40000, 1.15), (55000, 1.50), (70000, 1.85), (85000, 2.00), (100000, 2.00)

UNITS: units (unit)

DOCUMENT: Parameterised through sensitivity runs.

impact_of_profit_per_livestock_on_charcoal_production = GRAPH(profit_per_livestock)

(-5000, 2.00), (-4500, 1.96), (-4000, 1.92), (-3500, 1.85), (-3000, 1.76), (-2500, 1.66), (-2000, 1.49), (-1500, 1.32), (-1000, 1.21), (-500, 1.10), (0.00, 1.00)

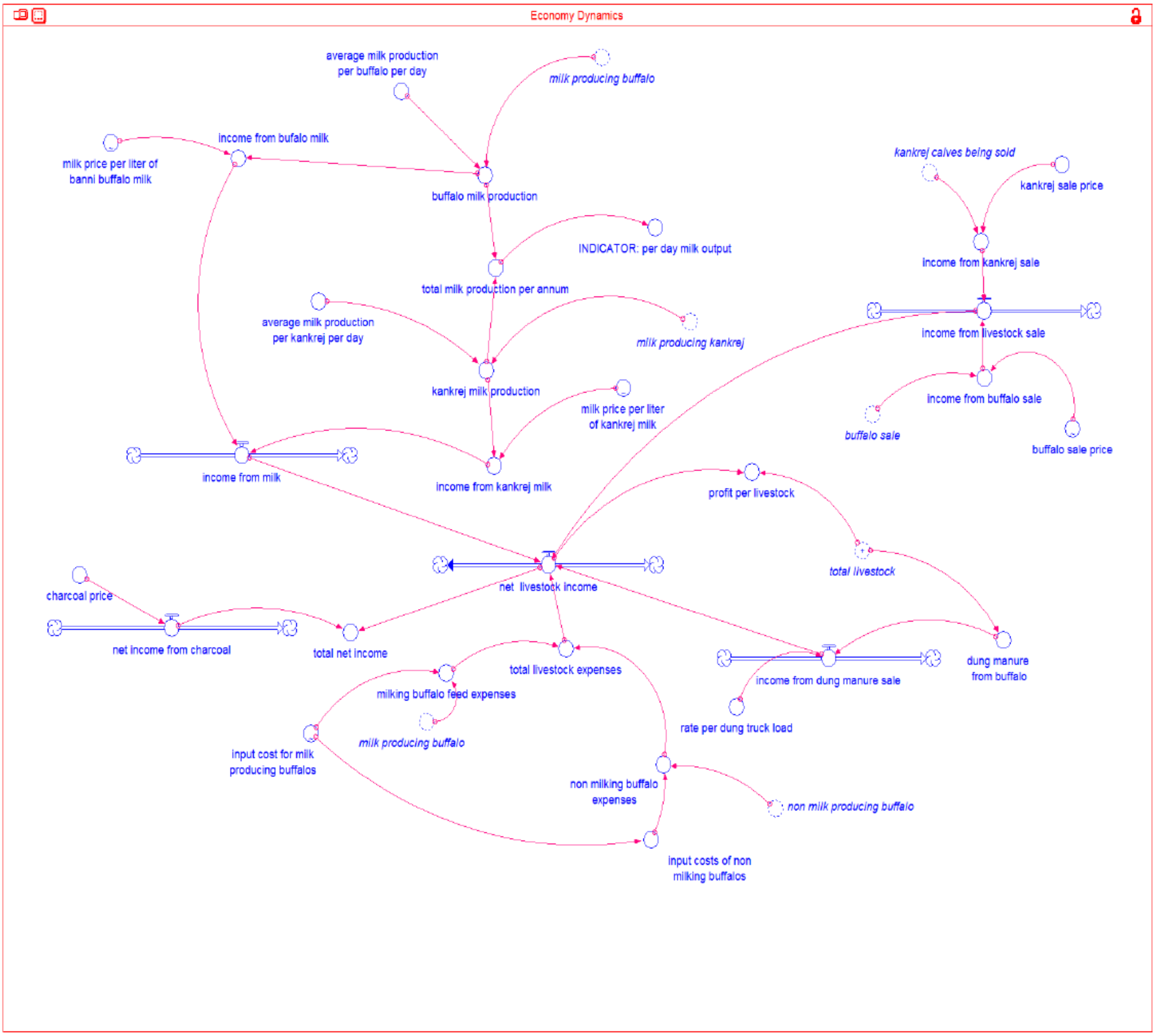
DOCUMENT: As profit per livestock falls people increase charcoal production to compensate for the losses. Numbers are assumed and estimated through sensitivity runs.

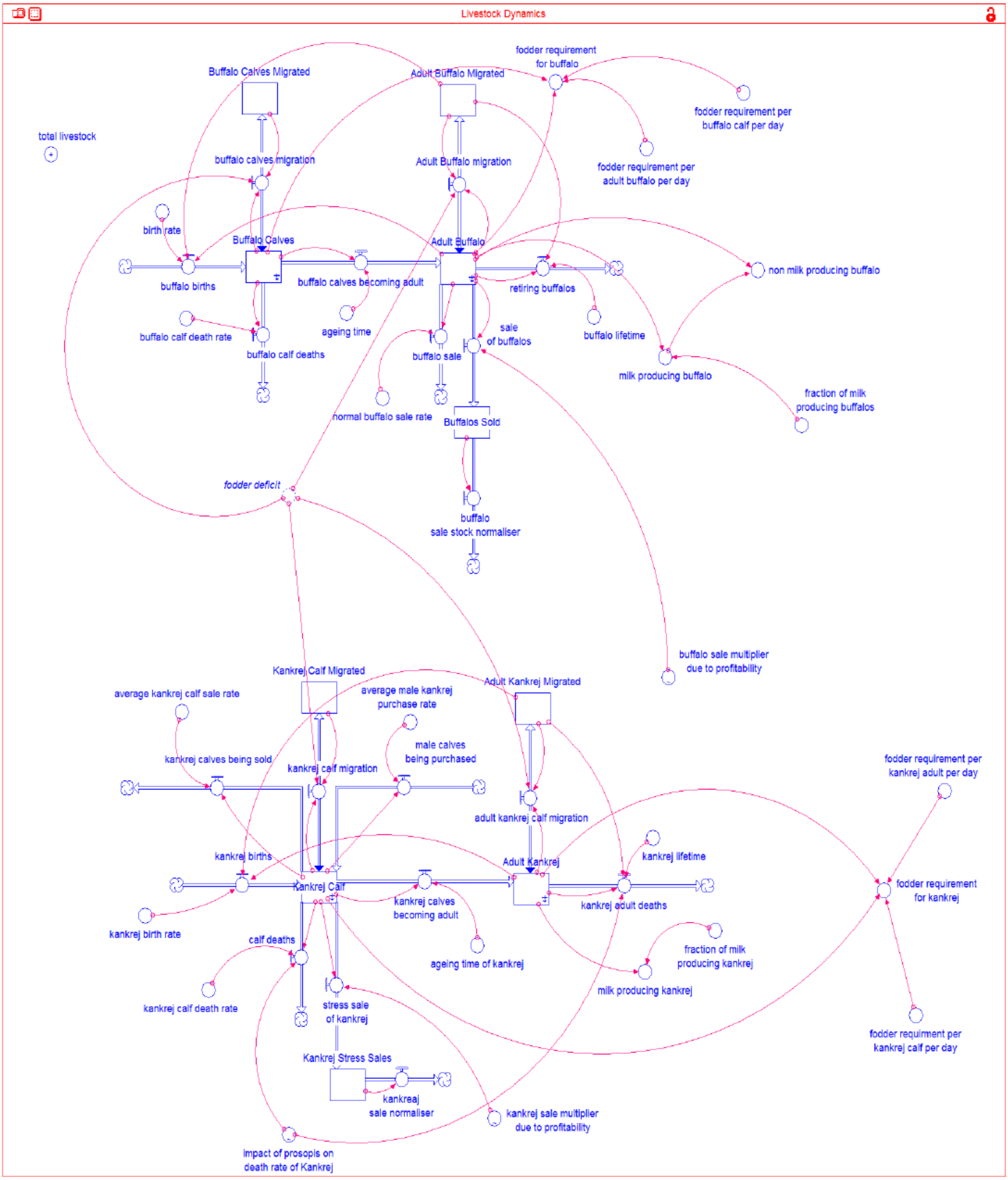
Rainfall = GRAPH(TIME)

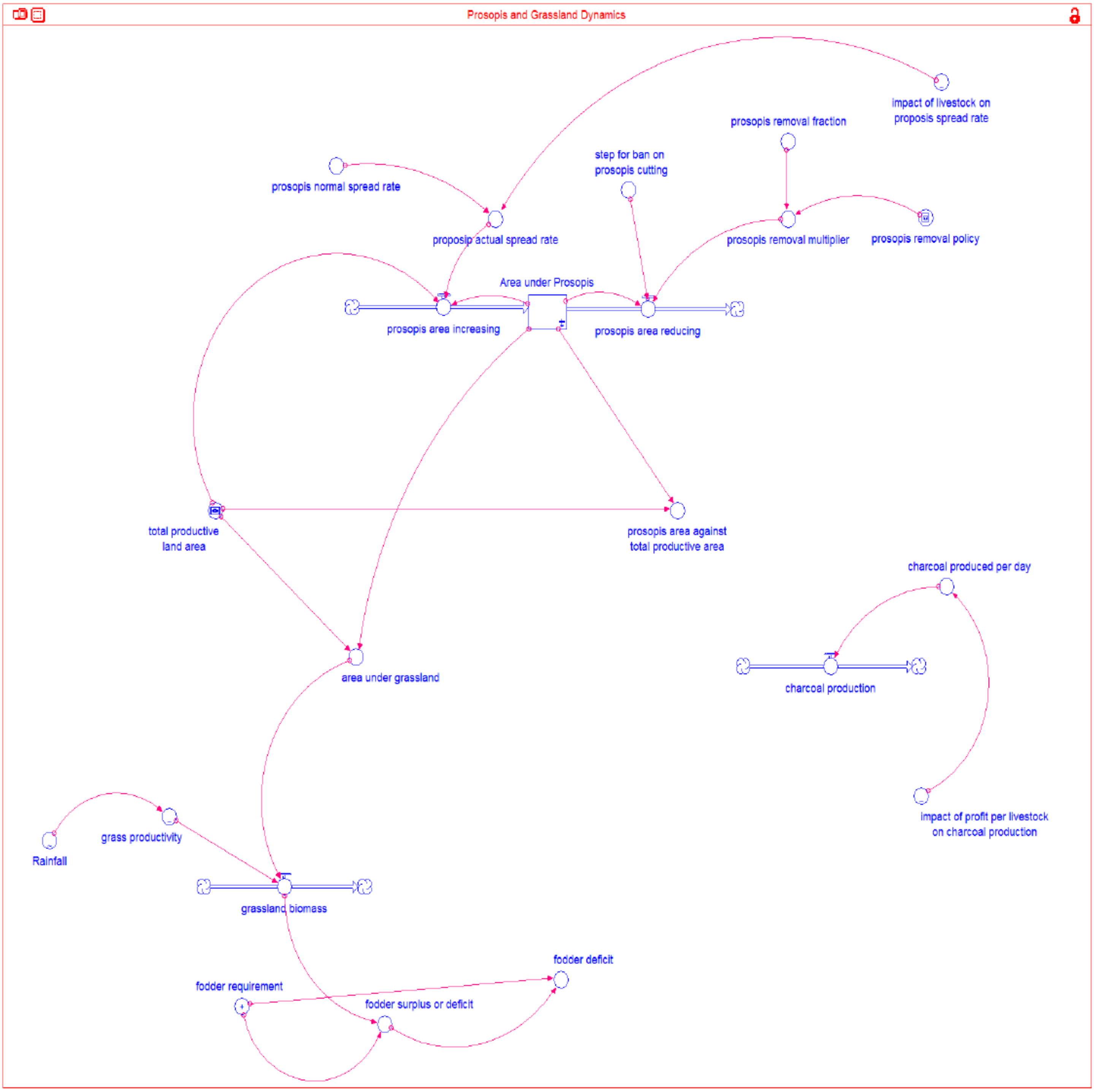
(1992, 507), (1993, 106), (1994, 729), (1995, 326), (1996, 174), (1997, 259), (1998, 464), (1999, 450), (2000, 195), (2001, 540), (2002, 110), (2003, 700), (2004, 147), (2005, 139), (2006, 485), (2007, 641), (2008, 177), (2009, 370), (2010, 655), (2011, 650), (2012, 350), (2013, 652), (2014, 291), (2015, 450), (2016, 540), (2017, 110), (2018, 700), (2019, 147), (2020, 139), (2021, 485), (2022, 641), (2023, 177), (2024, 370), (2025, 655), (2026, 650), (2027, 350), (2028, 652), (2029, 291), (2030, 450)

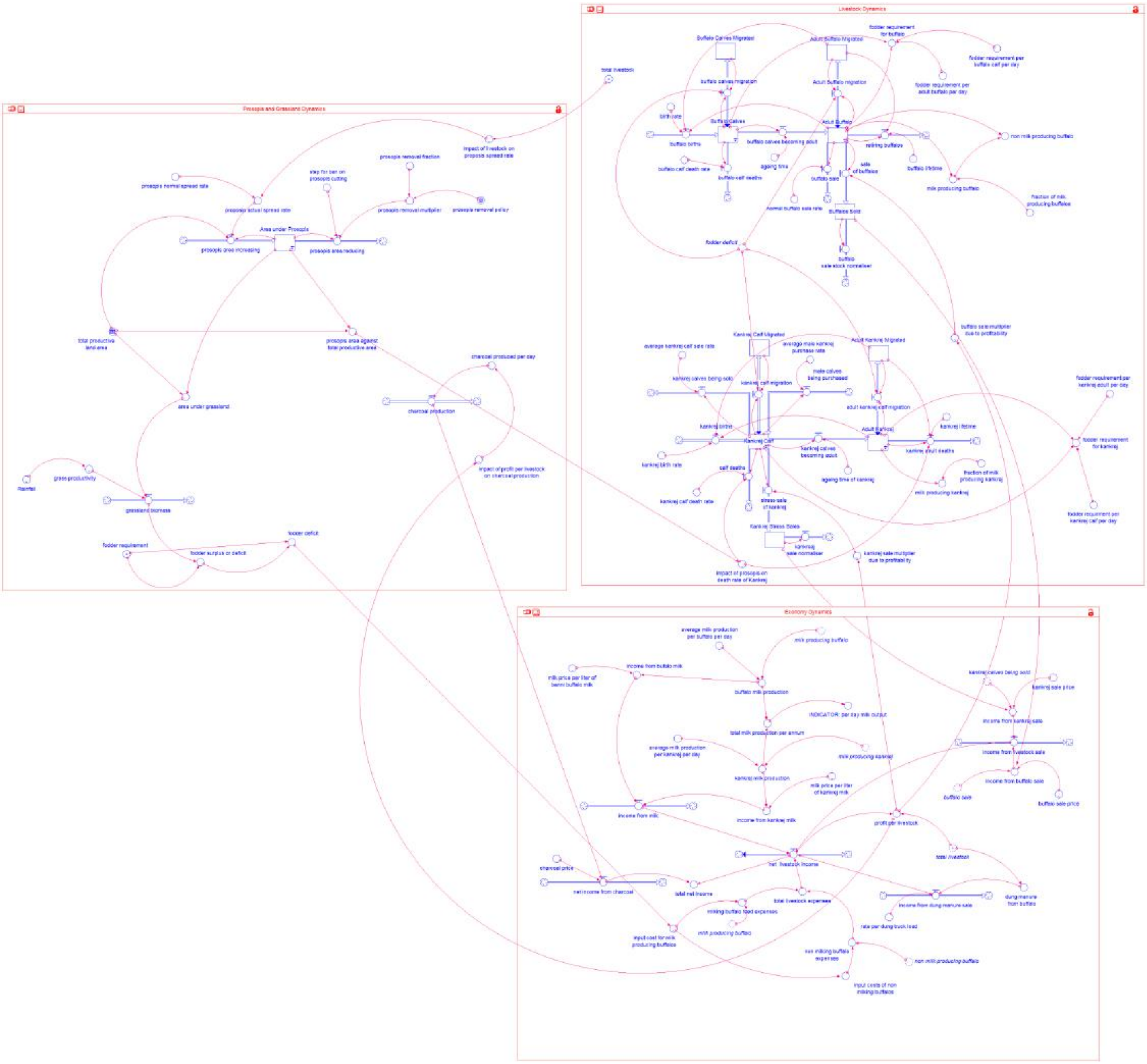
DOCUMENT: Rainfall from 2015-2030 assumed to be the same as from 1999-2014. Rainfall data for 1992-2010 taken from Let it be Banni, pg 143, for year 2011-12 taken from Vegetation dynamics in Banni grasslands under the influence of changing climate, GES 2015, pg 5 and for 2013-14 taken from IMD website for Kachchh district from http://hydro.imd.gov.in/hydrometweb/(S(lmae0jvse31sb045m2gxd5i1))/DistrictRaifall.aspx

Appendix 2.3 Full Model Structure




Livestock Dynamics
total livestock
Buffalo Calves Migrated
Adult Buffalo Migrated
fodder requirement for buffalo
fodder requirement per buffalo calf per day
fodder requirement per adult buffalo per day
buffalo calves migration
Adult Buffalo migration
birth rate
Buffalo Calves
Adult Buffalo
buffalo births
buffalo calves becoming adult
retiring buffalos
non milk producing buffalo
buffalo calf death rate
ageing time
sale of buffalos
buffalo lifetime
buffalo calf deaths
buffalo sale
milk producing buffalo
normal buffalo sale rate
Buffalos Sold
fraction of milk producing buffalos
fodder deficit
buffalo sale stock normaliser
buffalo sale multiplier due to profitability
Kankrej Calf Migrated
average kankrej calf sale rate
average male kankrej purchase rate
Adult Kankrej Migrated
male calves being purchased
kankrej calves being sold
kankrej calf migration
fodder requirement per kankrej adult per day
adult kankrej calf migration
kankrej lifetime
kankrej births
Adult Kankrej
Kankrej Calf
fodder requirement for kankrej
kankrej calves becoming adult
kankrej adult deaths
kankrej birth rate
calf deaths
fraction of milk producing kankrej
ageing time of kankrej
milk producing kankrej
kankrej calf death rate
stress sale of kankrej
fodder requirment per kankrej calf per day
Kankrej Stress Sales
kankreaj sale normaliser
kankrej sale multiplier due to profitability
impact of prosopis on death rate of Kankrej


Prosopis and Grassland Dynamics
impact of livestock on proposis spread rate
prosopis removal fraction
step for ban on prosopis cutting
prosopis normal spread rate
proposip actual spread rate
prosopis removal multiplier
prosopis removal policy
Area under Prosopis
prosopis area increasing
prosopis area reducing
total productive land area
prosopis area against total productive area
charcoal produced per day
area under grassland
charcoal production
impact of profit per livestock on charcoal production
grass productivity
Rainfall
grassland biomass
fodder deficit
fodder requirement
fodder surplus or deficit


Prosopis and Grassland Dynamics
Livestock Dynamics
Economy Dynamics
Area under Prosopis
prosopis area increasing
prosopis area reducing
prosopis actual spread rate
prosopis normal spread rate
prosopis removal fraction
prosopis removal multiplier
prosopis removal policy
total productive land area
prosopis area against total productive area
area under grassland
grassland biomass
grass productivity
Rainfall
fodder requirement
fodder surplus or deficit
fodder deficit
charcoal production
charcoal produced per day
impact of livestock on prosopis spread rate
total livestock
Buffalo Calves
Adult Buffalo
Kankrej Calf
Adult Kankrej
Buffalo Sold
Kankrej Stress Sales
net livestock income
total net income
profit per livestock
income from milk
income from livestock sale
net income from charcoal
charcoal price
total livestock expenses

Appendix 3.1 Household Level Questionnaire to assess dependence on forests in Uttarakhand

परिचय

यह अध्ययन टेरी द्वारा भारत सरकार पर्यावरण मंत्रालय के सौजन्य से किये गये विस्त्रित अध्ययन का एक अंग है। हम आपको विश्वास दिलाते है कि, इस सर्वेक्षण हेतु एकत्रित सभी जानकारी केवल अनुसंधान के उद्देश्य के लिए है और इस जानकारी का कोई हिस्सा किसी अन्य उद्देश्य के लिए इस्तेमाल नही किया जाएगा। कृपया हमें सर्वेक्षण में भाग लेने के लिए अपने समय

INTRODUCTION

This case study is part of larger study being conducted by TERI on 'The Economics of Desertification, Land Degradation and Drought (DLDD) in India supported by Ministry of Environment, Forest and Climate Change, Government of India. We assure you that, all the information collected for this survey is required for research purpose only and no part of this information will be used for any other purpose. Kindly give us 40 minutes of your time to participate in the survey.

साक्षात्कारकर्ता का नाम Name of the Interviewer		प्रश्नावली कोड Questionnaire Code	Village	Household
साक्षात्कार की तिथि Date of Interview		साक्षात्कार का समय Time of Interview		
Checked by				

I. Respondent Detail उत्तर देने बाले का विवरण

i.	**उत्तर देने बाले का** नाम Name of the Respondent		ii.	उम्र Age of the respondent	
iii.	घर के मुखिया से समबन्ध Relationship with head of the household		iv.	लिंग Gender of the respondent	
v.	ग्राम Village		vi.	ग्राम पंचायत Gram Panchayat	
vii.	ब्लाक Block		viii.	जाति Caste*	
ix.	धर्म Religion**		x.	समपर्क हेतु नम्बर Contact number	

Codes:

Qiii समबन्ध पिता= 1, माता = 2, पति = 3, पत्नी =4, पुत्र/ पुत्री = 5, भाई/ बहन = 6, भांजी/ भांजा = 7, पोता/ पोती = 8, चाचा = 9, चाची = 10, स्वय = 11, अन्य = 99 relationship – father = 1, mother = 2, husband = 3, wife =4, son/ daughter = 5, brother/ sister = 6, niece/ nephew = 7, grandson/ daughter = 8, uncle = 9, aunt = 10, self = 11, any other = 99

Qiv पुरुष=1, महिला=2 Male=1, Female=2

Qviii समान्य = 1, अनुसूचित जाति= 2, अनुसूचित जनजाति= ३, अन्य पिछड़ी जाति= 4General = 1, Schedule Caste = 2, Schedule Tribe = 3, Other Backward Class = 4

Qix हिंदू = 1, मुसलिम= 2, सिख = ईसाई= 4, अन्य = 99 Hindu = 1, Muslim = 2, Sikh = 3, Christian = 4, Others = 99

II. Household Demography

1. S.No क्रमांक	2. Name नाम	3. Age आयु	4. Gender लिंग Male=1, female =2	5. Relationship to head मुखिया से सम्बंध	6. Literate साक्षर Yes = 1, No = 2	7. Level of education (use code) Skip If '2' in 6	8. Occupation (Primary) मुख्य व्यवसाय (use code)	9. Occupation (Secondary) अनुपूर्वक व्यवसाय (use code)
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								

11.								

Education codes: Primary (1-5 std)= 1, middle (5-8 std) = 2 secondary (9-10)= 3, High school/intermediate (11-12 std) = 4, Graduate = 5, Post-graduation and above = 6, other =7

Occupation codes: own farm activities=1, agricultural labour=2, animal husbandry=3, domestic work=4, non-agricultural labour=5, petty trade/business=6 , collection of NTFP and sale=7, trade/business of forest based products=8, tourism, =9,mason=10, driver=11 carpenter=12, traditional family occupation=13 , salaried employment (govt)= 14, salaried employment (non-govt)=15 pension holder=16 , migrant worker (seasonal)=17, migrant worker (whole year)=18, not working (old age, illness, disabled)=19 studying=20, Any Others=21.

III. प्रवास Migration

S. No.	Question	Response	Codes
10.	a. क्या गांव में लोग आमतौर पर विस्थापित होते है? Do the individuals in the village commonly migrate?	कोई नहीं None migrate	1
		कुछ Few migrate	2
		ज्यादतर Mostly migrate	3
10 b.	How many members have migrated from your family?	☐☐ None.........98	
Skip to Q 15 id '1' in Q10a.			
11.	प्रवासी सदस्यो का प्रमुख व्यवसाय क्या है? What is the commonly performed occupation of the migrated member?	कृषि मजदूर Agricultural Labourer	1
		गैरकृषि मजदूर-, कुशल Non-Agricultural Labourer, Skilled	2
		अकुशल गैरकृषि - मजदूर,Unskilled Non-Agricultural Labourer,	3
		सेवा Services	4
		व्यापार Business	5
		अन्य , उल्लेखित करे Others, specify	99
12.	गांव में प्रवास के लिए आम कारण क्या हैं?एक) (से अधिक प्रतिक्रिया संभव What are the common reasons for migration in the village? (More than one response possible)	भूमि की उत्पादकता में कमी Decreased productivity of land	1
		भूमि के आकार में कमी decreased size of land	2
		मजदूरी आय के लिए अवसरों में कमी decrease in	3

		opportunities for wage income	
		अतिरिक्त आय Additional income	4
		वन का घ्नित्व कम होना Forest degradation	5
		अन्य , उल्लेखित करे Others, specify	99
13.	आमतौर पर कौन प्रवासी हो गया? Who commonly migrates?	बच्चे Children (0-10 years)	1
		किशोर Adolescent (11-18 years)	2
		युवा Young Adults (19-30 years)	3
		वयस्क Adults (31-50 years)	4
		बूढे Elderly (50years and above)	5
14.	आमतौर पर लोग कहाँ विस्थापित होते है Where do people commonly migrate?	जिले के भीतर Within district	1
		अन्य जिलों Other districts	2
		अन्य राज्यों Other States	3
		दूसरे देश Other Countries	4

IV. ग्रह ब्योरे HOUSE PARTICULARS

S. No.	Question	Response	Codes
15.	घर मे राशन कार्ड है Do you have a ration card?	हाँ Yes	**1**
		नहीं No	**2**

Skip to Q 17 if '2' in Q15			
16.	यदि हाँ, तो कौन सा राशन कार्ड है **If yes, which ration card does the household have**	**APL**	**1**
		BPL	**2**
		अंत्योदय **Antodaya**	**3**
		अन्नपूर्णा **Annapurna**	**4**
		अन्य **Others**	**99**
17.	आप या घर के सदस्य के पास मनरेगा जॉब कार्ड है? **Do you or household members have a MGNREGA job card?**	हाँ Yes	**1**
		नहीं No	**2**
Skip to Q 19 if '2' in Q17			
18.	काम के कितने कुल दिन मिले **How many days of total work have they received**	**________ no of days**	
19.	कितना वेतन आपने मनरेगा के तहत प्राप्त किया है? **How much wage have you received under MGNREGA?**	**Rs. ________/day**	
20.	आपके घर में कितने कमरे है? **How many rooms do you have in your house?**		
21.	आप इस घर के मालिक हैं? **Do you own this house?**	हाँ Yes	**1**
		नहीं No	**2**
22.	घर का प्रकार **Type of house**	कच्चा **Kuccha**	**1**
		पक्का **Pakka**	**2**
		मिश्रित **Mixed**	**3**
23.	क्या यह घर इंदिरा आवास योजना के तहत बनाया गया था? **Was this house built under Indira Awas Yojana?**	हाँ Yes	**1**
		नहीं No	**2**
24.	क्या आपके पास एक बैंक खाता है?	हाँ Yes	**1**

	Do you have a bank account?	नहीं No	**2**
Skip to Q 26 if '2' in Q24			
25.	इस खाते को जन धन योजना के तहत खोला गया था? **Was this account opened under Jan Dhan Yojana?**	हाँ Yes	**1**
		नहीं No	**2**
26.	आप निम्न के मालिक हैं? **Do you own the following?**	**Codes**	**Number Owned**
	1. पोली हाउज Poly house	**1**	
	2. हथकरघा **Handloom**	**2**	
	3. सिलाई मशीन **Sewing machine**	**3**	
	4. बिजली का पंखा **Electric Fan**	**4**	
	5. मोबाइल **Mobile**	**5**	
	6. वॉशिंग मशीन **Washing machine**	**6**	
	7. फ्रिज **Refrigerator**	**7**	
	8. माइसर **Mixer**	**8**	
	9. सौर उपकरण Solar equipment	**9**	
	10. साइकिल **Cycle**	**10**	
	11. स्कूटर मोटर साइकिल / **Scooter/motor cycle**	**11**	
	12. कार ट्रैक्टर / ट्रक / **Car/ truck/tractor**	**12**	

	13. कंप्यूटर टैबलेट / लैपटॉप / Computer/Laptop/tablet	13	
	14. घर के भीतर शौचालय 15. Toilet within house	14	
27.	घरेलू विद्युतीकरण किया गया है? **Is the household electrified?**	हाँ Yes	**1**
		नहीं No	**2**
28.	पीने के पानी का स्रोत क्या है ? **What is the source of drinking water**	खुद का नलकूप **Own tubewell**	**1**
		खुद का कुआ **Own well**	**2**
		सामुदायिक नलकूप **Community tubewell**	**3**
		सामुदायिक कुआ **Community well**	**4**
		खुद का नल **Own tap**	**5**
		सामुदायिक नल **Community tap**	**6**
		नहर **Canal**	**7**
		कोई दूसरा **Any other**	**99**
29.	आपका परिवार कितनी कृषि योग्य भूमि का मलिक है? How much agricultural land does your household own?	_________(in Hectare)	
		कृषि योग्य भूमि नही है Don't have agricultural land	77
30.	किसान का सही वर्ग चिन्हित करे Mark appropriate category of farmer	भूमिहीन Landless	1
		0.2 हेक्टेयर से कम Less than 0.2 Hectare	2
		0.2 से 0.4 हेक्टेयर	3

		0.2 to 0.4 Hectare	
		0.4 से 0.6 हेक्टेयर 0.4 to 0.6 hectare	4
		0.6 से 1 हेक्टेयर 0.6 to 1 hectare	5
		1 हेक्टेयर से अधिक More than 1 hectare	6

31. Please **provide details of livestock you own अपने पशुधन का विवरण दे**

Sl. No	a. Livestock पशुधन	Number of Livestock owned पशुधन संख्या		d. Use इस्तमाल/प्रयोग
		b. Total Number कुल	c. Milch Animals (number) दुधारू पशु संख्या	
1	Bullocks बैल			
2	Cow गाय			
3	Buffalo (He) भैंसा			
4	Buffalo (She) भैंस			
5	Calves बछड़े			
6	Goat बकरी			
7	Sheep भेड़			
8	Mule			

V. ACCESS TO FOREST

32.	Which forests are found near your village and its distance from your village? आपके गांव के पास कौन सा जंगल / वन है, गांव से	**a. Forest Type वन का प्रकार**	**Code**	**b. Distance दुरी**	**c. Rank in order of frequency in which they are accessed 1 being most accessed**
		Reserve Forest आरछित वन	1		
		Van Panchayat वन पंचायत	2		

		Civil-Soyam सिविल वन	3		
		Other अन्य	4		
		None कोई नहीं	5		
		Not sure पता नहीं	0		

33.	a. What services are derived from the forest ? वन से क्या सुविधाएं प्राप्त होती हैं?	Type of services सुविधाओं के प्रकार	code	b. Type of forest it is derived from जिस प्रकार के वन से यह सुविधाएं मिलती है (Reserve Forest आरछित वन =1, Van Panchayat वन पंचायत = 2, and Civil-Soyam सिविल वन =3)
		To collect fuelwood जलाऊ लकड़ी को एकल करना	1	
		To collect fodder चारा एकत्र करना	2	
		To collect small timber छोटी फर्नीचर की लकड़ी एकत्र करना	3	
		To collect NTFPs (medicinal herbs, etc.) लकड़ी के अतरिक्त वन उपज एकत्र करना	4	
		To graze animals जानवरों का चारा	5	
		For tourism पर्यटन के लिए	6	
		For recreation मनोरंजन के लिए	7	
		Hunting	8	
		Others-pls specify अन्य उलेख करे	9	
			10	

34. **Change in availability of forest products over time? वन उपज की उपलब्धता में बदलाव**

S. No.	a. Has the availability of the forest products changed in the last ten years? क्या पिछले १० सालो में वन से प्राप्त वस्तुओं में बदलाव आया है? (CODE: increase बड़ा है = 1, decreased कम हुआ है = 2, the same कोई बदलाव नहीं =3)		b. Provide reason for the same? Use codes below and give changes in distances walked and/or hours spent in collection इसका कारण दे \नीचे दिए गए कोड का इस्तेमाल करे Ask only if '1' or '2' in Q 34a.
	Forest products	Code	
1	Fuelwood जलाऊ लकड़ी		
2	Timber फर्नीचर/घर बनने की लिए लकड़ी		
3	Fodder चारा		
4	Medicinal Plants/NTFPs औषधि के पौधे		

Code: 1. Increased forest degradation वन में कमी 2 use prohibited by forest department वन विभाग द्वारा रोक 3 community-imposed bans समुदाय द्वारा रोक 4. Increase in distance walked to collect these products-specify distance वन उपज को एकत्र करने के लिए तय की गई दुरी,दुरी नोट करे 5. Increase in time spent (hours) to collect these products-specify वन उपज को एकत्र करने के लिए लगाया समय 6. Others-pls specify अन्य स्पष्ट करे

HOUSEHOLD DEPENDENCE ON FOREST

35. **खान पकाने के लिए किस इंधन का प्रयोग करते हैं?** **35 What are the cooking fuels used?** **MULTIPLE CODE**	ईंधन की लकड़ी Firewood	1
	टहनियाँ Other Twigs	2
	सूखी पत्तियाँ Dry Leaves	3
	उपले Dungcakes	4
	LPG	5
	कृषि अवशेष Agl. Residues	6
	अन्य, उल्लेख करें Others, Specify	99
36 खाना कहाँ पकता है? Where do you cook?	अधिकतर रसोई में Mostly in Kitchen	1
	अधिकतर बाहर	2

	Mostly Outside	
SKIP 38-44 IF ‘4’/’5’/’6’ IN Q36		
37 सप्ताह में कितनी बार ईंधन के लिए लकड़ी एकत्रित करते हैं? How many times in a week do you collect firewood?	प्रतिदिन Daily	1
	सप्ताह में एक बार Once a week	2
	सप्ताह में दो बार Twice a week	3
	सप्ताह में तीन बार Thrice a week	4
	सप्ताह में चार बार Four times a week	5
	सप्ताह में पांच बार Five times a week	6
	सप्ताह में छें बार Six times a week	7
38 सप्ताह में एकत्रित लकड़ी की मात्रा (किलो)Approximate quantity of firewood collected each time? (In Kgs)	☐☐☐ किलो Kgs	
39 A) इसे इकट्ठा करने में कितने घंटे लगते हैं?How many hours it takes to collect? (in hours)	☐☐☐ घंटे hours	
B) How many family members are involved in fire wood collection?	☐☐ members	
40 सालाना एकत्रित लकड़ी की मात्रा (किलो) How much firewood you collect per year? (approximate quantity in Kgs)	☐☐☐☐ किलो Kgs	
41 इसमें से कितने प्रतिशत लकड़ी हरी होती है?What percentage of the firewood is the greenwood?	☐☐%	

42 यदि आप सभी	स्त्रोत Source	Codes	43 भाग Share (%)

लकड़ी जंगल से नहीं लेते हैं तो कहाँ से लेते हैं?और कितनी What are the sources of firewood and their volume? **MULTIPLE CODE**	सुरक्षित वन Reserve Forest	1	
	Van Panchayat	2	
	Civil Soyam	3	
	अन्य वन Other Forest	4	
	गाँव में लगे पेड़ो से Village trees	5	
	निजी स्त्रोत Private Sources	6	
	अन्य, उल्लेख करें Any Other	99	

Collection of Fodder चारे का संग्रह

Skip Q 45 to Q51 if no response in Q32

44 How do you feed your livestock? आप अपने पशु धन को क्या खिलाते हैं?

REFER Q41. ASK FOR LIVESTOCK OWNED BY HOUSEHOLD

Livestock	Open grazing	Stall Feeding	Both
a) गाँयCows	1	2	3
b) बैल Bullocks	1	2	3
c) भैंस Buffaloes	1	2	3
d) बछड़ा Calves	1	2	3
e) भेड़Sheep	1	2	3
f) बकरी Goats	1	2	3
g) खच्चर Mule	1	2	3

45	सप्ताह में कितनी बार आपके मवेशी जंगल में चरते हैं ?How many days in a week do you graze your livestock in forest?	प्रतिदिन Daily	1
		सप्ताह में एक बार Once a week	2
		सप्ताह में दो बार Twice a week	3

			सप्ताह में तीन बार Thrice a week	4	
			सप्ताह में चार बार Four times a week	5	
			सप्ताह में पांच बार Five times a week	6	
			सप्ताह में छें बार Six times a week	7	
46	क्या आप stall-feeding के लिए जंगल से चारा इकट्ठा करते हैं?Do you collect fodder from forest for stall-feeding?			Yes हाँ	1
				No नहीं	2 → **Skip to Q50**
47	सप्ताह में एकत्रित चारे की मात्रा (लगभग) (किलो)Approximate quantity collected per day? In Kgs			Kg/day किलो / दिन	
48	माह में एकत्रित चारे की मात्रा (लगभग) (किलो)Approximate quantity collected per year? In Kgs			Kg/year किलो / वर्ष	
49	कोई अन्य चारा इसतेमाल होता है? What is the source of fodders that the household use? **MULTIPLE CODE**	Fodder चारा	Codes	50 Share (%) भाग	
		घास और पेड़ चारा (सुरक्षित वन से)Grass and Tree fodder (from Reserve Forest)	1		
		ाास और पेड़ चारा (सुरक्षित वन से)Grass and Tree fodder (from Van Panchayat)			
		ाास और पेड़ चारा (वन से)Grass and Tree fodder (from Civil Soyam)			
		घास और पेड़ चारा (वन के अतिरिक्त स्त्रोतों से)Grass and Tree fodder (Non-Forest)	2		
		कृषि अवशेष Agricultural residues	3		
		वाणिज्यिक चारा Commercial fodder	5		

Other Dependence on Forest वन निर्भरता

51	**a. For Agricultural Use** कृषि उपयोग के लिए	**Codes**	**b. Amount मात्रा**	
1.	लघु लकड़ी व खेती बाढ़ी के लिए खम्बे	1		
2.	सूखे पत्ते आदि	2		
3.	बाड़ के लिए सामान	3		
4.	गृह निर्माण के लिए For House Construction	4		
5.	लकड़ी	5		
6.	लघु लकड़ी व खम्बे	6		
7.	छप्पर के लिए घास	7		
52	**Foods and Fibres**	**Codes**	कितना	किस ऋतू में?
1.	जड़ें। Roots	1		
2.	सब्जियाँ Vegetables	2		
3.	फल आदि Fruits	3		
4.	Wild meat	4		
5.	Fish	5		
6.	औषधिक जड़ी बूटियाँ Medicinal Plants	6		Specify name of the plants

Is there a change in income sources since 10 years from now?

53 परिवार की आमदनी के स्त्रोत **Source of Income for the Household** **MULTIPLE CODE**	**a. Now**	**b. 10 years ago**	**54 आमदनी Approximate Annual Amount in Rs.**	
			a. Now	**b. 10 years ago**
a. खेती Agriculture	1	1		
b. पशुधन Livestock	2	2		
c. मजदूरी रोजगार Wage employment	3	3		
d. NTFP बिक्री / अन्य वन आधारित उद्यम NTFP Sale/Other Forest Based Enterprises	4	4		
e. वेतन Salary	5	5		
f. व्यापार Business	6	6		
g. दूसरे शहर पलायन किए गए सदस्य द्वारा भेजी गई रकम Remittances	7	7		
h. पेंशन Pension	8	8		
i. स्थानांतरण लाभ Transfer Benefits	9	9		
j. भूमि या कमरे से किराया Rent from leased out land/room	10	10		
k. Tourism	11	11		
l. अन्य, यदि है, तो उल्लेख करे Others, if any	99	99		
m. कुल Total				

Household Engagement in Ecotourism

55	a. Do you benefit from ecotourism in the area? क्या आपको पर्यटन से आपको कोई फायदा हुआ है	Yes हाँ	1	b. What ecotourism activity are you engaged in? आप कौन सी पर्यटन से जुड़े रोजगार के भाग है
		No नहीं	2	

56	a. Ask if '2' in Q56, Would you like to see ecotourism developing as an important activity in the area क्या आप अपने छेत्र में पर्यटन को महत्वपूर्ण बनना चाहते है	Yes हाँ	1	b. Reasons (use codes) कारण दे (कोड का इस्तेमाल करे)
		No नहीं	2	

If Yes. 1= current incomes from agriculture are low; कृषि से आमदनी काम होती है 2= to reduce outmigration प्रवास रोकने के लिए 3=as a means of protecting the forests वन को संरछित रखने के लिए 4=to reduce dependence on forests वन पर निर्भरता काम करने के लिए 5=others-pls specify अन्य स्पस्ट करे

If No. 1=Few tourists visit, unlikely source of revenue बहुत काम पर्यटक आते है \ अतः यह आय का अच्छा सोरोत्र नहीं है 2= too many tourists will lead to forest degradation बहुत पर्यटक वन के पतन का कारण बनेंगे 3=Only a few people of the village will cash in on the business गांव के कुछ ही लोग ऐसे आय अर्जन कर पाएंगे 4=lack of knowledge and training, जानकारी और प्रशिछण की कमी 5=inadequate capital to invest in ecotourism activities पर्यटन में निवेश करने के लिए पर्याप्त पूजी उपलब्ध नहीं है 6-Others, pls specify अन्य स्पस्ट करे

STATUS OF DEGREDATION

	QUESTION	OPTIONS	CODES
57	**Has there been a change in status of vegetation (forest) in dhanaulti in last 10 years क्या १० साल में उत्तराखं के वन में कोई बदलाव आया है?**	**Yes, increased हाँ बड़ा है**	**1**
		Yes Decreased हाँ घटा है	**2**
		No change नहीं कोई बदलाव नहीं है	**3**
58	**What is the reason for change? बदलाव का कारण क्या है ?**		

59	Has vegetation degradation impacted the following? क्या वन में बदलाव के कारण निम्न में से कोई प्रभाव पड़ा है? यदि हा तो कारण प्रदान करे Provide reasons for the same (codes: increased **बड़ा है** = 1, decreased **घटा है** = 2, no change **कोई बदलाव नहीं है** = 3)		
	Characteristics	**Status**	**Reasons**
1	Productivity of agricultural land कृषि भूमि की उत्पादकता		
2	Soil Errosion मिटी की परत धूल जाना		
3	Quantum of rainfall बारिश के मात्र		
4	Distribution of rainfall बारिश की विस्तारण		

5	Number of rainy days बारिश के दिन		
6	Outlier events अंपंछित घटना		
7	Arrival of monsoons वर्षा का आगमन		
8	Availability of drinking water कुएं /बोरबेल में पनि का स्तर		
9	Availability of water in irrigation tanks सिचाई टैंक में पनि की व्यवस्था		
10	Quality of water पनि की गुवत्ता		
11	Temperature(winter) तापमान (सर्दी में)		
12	Temperature(summer) तापमान (गर्मी में)		
13	Opportunities for farm work कृषि का अवसर		
14	Opportunities for non-farm work अन्य रोजगार के अवसर		
15	Wage rate per day मजदूरी का दर (प्रति दिन)		
16	Migration प्रवासा		
17	Instances of disease बीमारी		

Appendix 3.2 Perceptions Of Local Communities on Values of The Forest: Multi Criteria Analysis for Households

1 Please give relative weights to the options provided below निम्न में से किसे जायदा क्रम में डालिए

1	Biodiversity जैविविधता 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Grazing चराई
2	Biodiversity जैविविधता 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Ecotourism प्रकिति पर्यटन
3	Biodiversity जैविविधता 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Forest products वन उत्पाद
4	Grazing चराई 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Ecotourism प्रकिति पर्यटन
5	Grazing चराई 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Livelihoods रोजगार
6	Ecotourism प्रकिति पर्यटन 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Forest products वन उत्पाद
7	Livelihood रोजगार 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Ecotourism प्रकिति पर्यटन
8	Livelihood रोजगार 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Forest Products वन उत्पाद

2 Which of the forest produce is more important? Please assign relative weights to the options provided below निम्न में से कोन से वन उपत्पादन महत्वपूर्ण है? दिए गए दो विकल्प को वजन दे

1	Fuelwood इधन में उपयोगी लकड़ी 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Fodder चारा
2	Fuelwood इधन में उपयोगी लकड़ी 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Timber माकन बनाने में प्रयोग को गयी लकड़ी
3	Fuelwood इधन में उपयोगी लकड़ी 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Medicinal plants औषधि में प्रयोग लाये गए पोधे
4	Fuelwood इधन में उपयोगी लकड़ी 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Wild fruits
5	Fodder चारा 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Medicinal plants औषधि में प्रयोग लाये गए पोधे
6	Fodder चारा 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Timber माकन बनाने में प्रयोग को गयी लकड़ी
7	Fodder चारा 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Wild fruits
8	Timber माकन बनाने में प्रयोग को गयी लकड़ी 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Wild fruits
9	Timber माकन बनाने में प्रयोग को गयी लकड़ी 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Medicinal plants औषधि में प्रयोग लाये गए पोधे

10	Medicinal plants औषधि में प्रयोग लाये गए पोधे 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Wild fruits

3 Ranking the benefits to be accrued from forest conservation. Please assign relative weights to the options provided below वन संरक्षण से प्राप्त लाभ को क्रम में डाले दिए गए दो विकल्प को उपुक्त वजन दे

1	Additional source of income and employment आय अर्जन के स्रोत अतिरिक्त 9 8 7 6 5 4 3 2	**1**	2 3 4 5 6 7 8 9 **Increased availability of wildlife समुदाय व् वन विभाग में बेहतर समन्वय**
2	Additional source of income and employment आय अर्जन के स्रोत अतिरिक्त 9 8 7 6 5 4 3 2	**1**	2 3 4 5 6 7 8 9 **Increased availability of forest produce वन्य उपज में वृद्धि**
3	Additional source of income and employment आय अर्जन के स्रोत अतिरिक्त 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Increased availability of water पानी की उपलब्धता
4	Additional source of income and employment आय अर्जन के स्रोत अतिरिक्त 9 8 7 6 5 4 3 2	**1**	2 3 4 5 6 7 8 9 Increased availability of clean air सवच्छ वायु
5	Increased availability of clean air सवच्छ वायु 2 3 4 5 6 7 8 9	**1**	2 3 4 5 6 7 8 9 Increased availability of water पानी की उपलब्धता
6	**Increased availability of forest produce वन्य उपज में वृद्धि** 2 3 4 5 6 7 8 9	**1**	2 3 4 5 6 7 8 9 **Increased availability of wildlife समुदाय व् वन विभाग में बेहतर समन्वय**
7	Increased availability of water पानी की उपलब्धता 2 3 4 5 6 7 8 9	**1**	2 3 4 5 6 7 8 9 **Increased availability of forest produce वन्य उपज में वृद्धि**
8	Increased availability of clean air सवच्छ वायु 2 3 4 5 6 7 8 9	**1**	2 3 4 5 6 7 8 9 **Increased availability of forest produce वन्य उपज में वृद्धि**

4 **Rank the disadvantages caused due to forest conservation.** Please assign relative weights to the options provided below वन संरक्षण से हानी को क्रम में डाले दिए गए दो विकल्प को उपुक्त वजन दे

1	Limited Income generation sources सिमित आय अर्जन के स्रोत 9 8 7 6 5 4 3 2	1	9 8 7 6 5 4 3 2 Increased difficulty in collection of fuel wood
2	Increased difficulty in collection of fuel wood इंधन एकत्र करने में कठिनाए (समय और दुरी)9 8 7 6 5 4 3 2	1	9 8 7 6 5 4 3 2 Limited involvement in decision making about forest conservation
3	Increased incidents of human animal conflicts वन पशुओं डोरा अक्रमण की घटनाओं का बजाना9 8 7 6 5 4 3 2	1	9 8 7 6 5 4 3 2 Increased difficulty in collection of fuel wood
4	Restriction to certain forest area	1	9 8 7 6 5 4 3 2 Limited involvement in decision making about forest conservation

	9 8 7 6 5 4 3 2		
5	Limited involvement in decision making about forest conservation 9 8 7 6 5 4 3 2	1	9 8 7 6 5 4 3 2 Limited Income generation sources
6	Increased incidents of human animal conflicts 9 8 7 6 5 4 3 2	1	9 8 7 6 5 4 3 2 Limited Income generation sources
7	Restriction to certain forest area 9 8 7 6 5 4 3 2	1	9 8 7 6 5 4 3 2 Increased incidents of human animal conflicts

5 How do **you** rank the importance of different forest management authorities in regard to forest management strategies? वन प्रबन्ध समती/संगठन डोरा अप्नायेगाये वन प्रबन्धन गतिविधिया को क्रम में डाले दिए गए विकल्पों को उपयुक्त वजन दे

1	Van Panchayats वन पंचयत 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Reserve forest अरछित वन
2	Van Panchayats वन पंचयत 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Civil Soyam सिविल सोयन
3	Reserve forest अरछित वन 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Civil Soyam सिविल सोयन

6 How do you rank the importance of different forest management authorities in regard to forest products collection? वन प्रबन्ध समती/संगठन को, वहा से मिलने वाले वन उपज की महत्वपूर्ण के अनुसार क्रम में डाले दिए गए विकल्पों को उपयुक्त वजन दे

1	Van Panchayats वन पंचयत 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Reserve forest अरछित वन
2	Van Panchayats वन पंचयत 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Civil Soyam सिविल सोयन
3	Reserve forest अरछित वन 9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 9 Civil Soyam सिविल सोयन

Appendix 4.1 Household Survey Questionnaire for Madhya Pradesh

Note: The survey is being undertaken for the case study of IWMP II in Mhow Block, Indore District in Madhya Pradesh. The case study is part of the larger TERI study on 'Economics of Desertification, Land Degradation and Drought (DLDD) in India' supported by Ministry of Environment, Forest and Climate Change, Government of India. All the information collected through this survey is required for research purposes only and no part of this information will be used for any other purpose.

Name of the Interviewer		Questionnaire Code		
Date of Interview		Interview Time		

A. HOUSEHOLD IDENTIFICATION

1.Name of the Respondent		4. Name of the Gram Panchayat	
2.Name of the Head of the Household		5. Caste Group (use code)	
3. Name of the Village		6. Religion (use code)	

***Code**: 5. Social Category: General=1, OBC=2, SC=3, ST=4;*

6. Religion: Hindu=1, Buddhist=2, Muslim=3, Christian=4, Others (specify) =5

***Note:** The primary respondent should be the current Head of the household. If the head of the household is not available for the interview, the information should be collected from the immediate responsible person in the family with knowledge of the agricultural practices and asset ownership details. Recall responses need to be recorded with caution.*

B. LAND HOLDINGS AND OPERATIONAL AREA (in Bighas)

Sl No	Particulars	Current Year				Before Watershed Project			
		Irrigable Land	Dry Land	Fallow Land	Total	Irrigable Land	Dry Land	Fallow Land	Total
1	Homestead Land								
2.1	Own Agrl. land								
2.2	Leased in								
2.3	Leased-out								
2.4	Plantations								
2.5	Total Operational Area								

C. CROPPING PATTERN AND CROP PRODUCTION

1. What crops do you grow?

Crop Name						
Specify the months						
Inter cropping						

2. How many different plots of agricultural land you have?

3. Do you pay any annual fee for irrigation? Yes [ ] No [ ]
4. If Yes, please specify, the total amount paid__________________

5. Crop Production and Other Details

Name of Crop	Area (in bigha)		Source of Irrigation Code*	Total Production (in quintal)		Quantity Sold (in quintal)		Average Price (Rs/ quintal)		Cost of Cultivation	
	Irrigated	Rainfed		Main	Byproduct	Main	Byproduct	Main	Byproduct	Labou	Other inputs
1. Soyabean											
2. Potatoes											
3. Onion											
4. Garlic											
5. Wheat											
6. Chana											
7.											
8.											
9											
10.											
11.											

Note: Other inputs include costs of hiring plough/ tractors for ploughing, levelling, lining (tisiya), weeding and harvesting; fuel cost of irrigation; cost of seeds, fertilizer, pesticides, weedicides and all other inputs for each of the crops.

Code: Source of Irrigation-River/Stream=1, Dam/Reservoir=2, Canal=3, Check dam=4, Dug-Well=5. Tube well=6, Farm Pond=7, Other (specify)=8

D. SOIL CONSERVATION PRACTICES AND BENEFITS

1. **How the household has benefitted from IWMP (Please tick the relevant boxes)**

Name of the Programme	Farm Bunds (Med bandhan)	Agro-Forestry/ Plantation	Water facility from check dam	Soil Testing Info	Critical Inputs/	Vermi Compost	Agri-Info (SMS & other info)	Livestock Support	SHG/ Micro-credit	Seeds
Whether Benefitted										

Name of the Programme	Farm Bunds (Med bandhan)	Agro-Forestry/ Plantation	Water facility from check dam	Soil Testing Info	Critical Inputs/	Vermi Compost	Agri-Info (SMS & other info)	Livestock Support	SHG/ Micro-credit	Seeds
How useful are they? (code)										

Code: extremely useful=1, very useful=2, somewhat useful=3, not all useful=4

2. Plot Characteristics and Soil Conservation Measures adopted by the Farmer in each of the Plot

Plot Name	Area (In bigha)	Land Tenure (use code)	Distance from home (in km)	Source of Irrigation (use code)	Distance from Irrigation Source (in kms)	Irrigation Technology (use code)	No. of Crops Grown in a Year	No of Crops grown before the project	Soil Type (use code)	Soil depth (in ft)	Soil Fertility	% of sloped land	Soil erosion status (use code)	Medbandhan (use code)	Other soil conservation measures *(use code)	Cost of Conservation Measures		No. of trees
																Initial Cost	**Annual Maintenanc**	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)

Codes:

(3) Land tenure: Owned=1, leased-out=2, shared –out=3, leased-in=4, shared-in=5

(5) Source of Irrigation: River/Stream=1, Canal=2, Check-dam=3, Dug Well=4, Tube Well=5, Farm Pond=6,

(7) Irrigation Technology: Flood irrigation=1, Drip Irrigation=2, Sprinklers=3,

(10) Soil type: Lal Miti=1, Bhuri Miti=2, Kali Miti=3, Other=4

(12) Soil fertility: Very Poor=1, Poor=2, Good=3, Very Good=4

(14) Soil erosion status: No erosion=1, Medium erosion=2, High erosion=3, Erosion only incase of heavy rainfall=4

(15) Medbandhan: Bund built under IWMP=1, Bund built under other project=2, Bund built from own sources=3, Bund not required=4, Bund urgently required=5

(16) Other Conservation Measures: Yes, adopted=1, Not adopted any other measure=2

* If Yes, Specify the measures: a)________________________ b) ________________________

c)____d)________________________

If No, specify why no other measures adopted: a) Not required ◯ , b) Required but don't know what to do ◯

c) Required but can't afford it ◯ Others, Specify____________________________________

3. What modern farming equipment/ machineries you use?

Sl No	Name	Tick if you hire	Hiring Charges (Rs per Hr)	Tick if you have purchased	Year of Purchase
1	Tractor				
2	Power Tiller				
3	Rotavator				
4	Sprayer				
5	Drip Irrigation Pipes				
6	Sprinkler				
7	Reaper				
8	Harvester				
9	Thresher				
10					
11					

4. In how many plots farm bunds were constructed under IWMP project?

1	Total no. of Plots	
2	No. of plots in which farm bund is required	
3	No. of plots where some or other form of bund exists	
4	No. of plots where farm bunds are built under IWMP	
5	No. of plots where farm bunds are built under other projects	

5. If no farm bunds were constructed under IWMP in your farm, what is the reason?

Sl. No	Reasons (Specify if it's not amongst the reasons listed)	Please Tick
1	My plots are not in the treatment area of the project	
2	There was no provision to build farm bunds on my farm	
3	I didn't agree as I didn't know the benefits	
4	I knew the benefits but didn't agree as I had standing crops	
5	I don't have adequate to land to spare for the bund	
6	Any other, specify	
7		

6. If farm bunds are constructed, how have you been benefitting? Please tick

1	Declining input cost			4	Recharge of Wells	
2	Reduced labour cost			5	No benefits at all	
3	Increased productivity			6		

7. Do you think the farm bunds under IWMP are more effective than the traditional bunds? Yes ◯ No ◯

8. Cost of Cultivation and Fam Output in a Plot with a Farm Bund (Crop 1)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	By-products	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/ day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/ Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/ Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/ Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/ Winnowing									
17	Packaging									
18	Transportation Charges									

9. Cost of Cultivation and Farm Output in a Plot with a Farm Bund (Crop 2)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/ day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/ Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/ Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/ Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/ Winnowing									
17	Packaging									
18	Transportation Charges									

10. Cultivation and Farm Output in a Plot with a Farm Bund (Crop 3)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/ day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/ Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/ Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/ Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/ Winnowing									
17	Packaging									
18	Transportation Charges									

11. Cost of Cultivation and Farm Output in a Plot without Farm Bund (Crop 1)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/ day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/ Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/ Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/ Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/ Winnowing									
17	Packaging									
18	Transportation Charges									

12. Cost of Cultivation and Farm Output in a Plot without a Farm Bund (Crop 2)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/ day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/ Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/ Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/ Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/ Winnowing									
17	Packaging									
18	Transportation Charges									

13. Cost of Cultivation and Farm Output in a Plot without a Farm Bund (Crop 3)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/ day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/ Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
						Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
		Hired	Owned	Hired	Owned					
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/ Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/ Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/ Winnowing									
17	Packaging									
18	Transportation Charges									

E. SOCIO-ECONOMIC INFORMATION

1. House Particulars

1	Is the household electrified? क्या घर में विद्युतीकरण है?	Y ☐ N ☐
2	What is the source of drinking water? पीने के पानी का स्त्रोत क्या है?	Own Tubewell ☐ Own Well ☐ Community Tubewell ☐ Community Well ☐
3	Does the household have BPL card? क्या परिवार के पास BPL कार्ड है?	Y ☐ N ☐
4	Does the household get ration from Public Distribution System? क्या घर को सार्वजनिक वितरण प्रणाली से राशन मिलता है?	Y ☐ N ☐ यदि हाँ, तो किस के अंतर्गत If Yes, which type (APL, BPL, Antyodaya, Annapurna yojana scheme or any others?)
5	Do any of members of the household have MNREAGA job card ? क्या नरेगा जॉब कार्ड है? If Yes, how many days in total worked and how much money received under MNREAGA Wages last year? यदि हाँ, क्या किसी सदस्य ने मनरेगा के अंतर्गत कार्य किया है?	Y ☐ N ☐ Number of Job Cards:___________ Total Number of Days worked:___________ Total Wage received:___________________
6	How many rooms in your house? घर में कितने कमरे हैं?	
7	Type of House? घर का प्रकार	Mostly Pucca ☐ Mostly Kutcha ☐ Mixed ☐ कच्चा पक्का मिश्रण
8	Whether benefitted from IAY or other scheme? यदि IAY या किसी अन्य योजना का लाभ उठाया है?	Y ☐ N ☐

2. Livestock Holding

Sl. No	Livestock	Number of Livestock Now		Number of Livestock 10 years back	
		Total Number	Milch Animals	Total Number	Milch Animals
1	Bullocks				
2	Cow				
3	Buffalo (He)				
4	Buffalo (She)				

Sl. No	Livestock	Number of Livestock Now		Number of Livestock 10 years back	
		Total Number	Milch Animals	Total Number	Milch Animals
5	Calves				
6	Goat				
7	Sheep				

3. Cooking Fuel and Collection of Firewood

1.What are the cooking fuels used? खान पकाने के लिए किस इंधन का प्रयोग करते हैं	Fuels	Tick if use	% of the total cooking fuel
	Firewood ईंधन की लकड़ी		
	Twigs टहनियाँ		
	Dungcakes उपले		
	LPG		
	Dry Leaves सूखी पत्तियाँ		
	Agl. Residues		
	Ele. Heater		
2. Where do you cook? खाना कहाँ पकता है ?	Mostly in Kitchen □ Mostly Outside □ अधिकतर रसोई में □अधिकतर बाहर□		

3. How many times in a week you collect firewood? 3. सप्ताह में कितनी बार ईंधन के लिए लकड़ी एकत्रित करते हैं?	
4. Approximate quantity of firewood collected each time? (In Kgs) 4. सप्ताह में एकत्रित लकड़ी की मात्रा (लगभग)	
5. How many hours it takes to collect? (in hours) 5. इसे इकट्ठा करने में कितने घंटे लगते हैं?	
6. How much firewood you collect per year? (approximate quantity in Kgs) 6. सालाना एकत्रित लकड़ी की मात्रा (किलो)	
7. What percentage of the firewood is the greenwood? 7. इसमें से कितने प्रतिशत लकड़ी हरी होती है?	

8. What are the sources of fuel wood and volumes?

Source स्त्रोत	Forest वन	Village Commons	Private Sources निजी स्त्रोत	Any Other अन्य
Share (%)				

4. Collection of Fodder चारे का संग्रह

1. How do you feed your livestock? Please tick

आप अपने पशु धन को क्या खिलाते हैं?

Livestock	Open grazing	Stall Feeding	Both
Cows			
Bullocks			
Buffaloes			
Calves			
Sheep			
Goats			

2. What are the sources of fodder for households?

	Forest	Village Commons	Private Land	*Other, Specify* ________
Open Grazing (No. of months)				
Fodder for Stall Feeding (% of the total)				

3. What are the shares of different fodders that the household use?

Fodder	Grass and Tree fodder		Agricultural residues	Bran/ husk	Commercial fodder
चारा	Forest	Non-Forest			
Share (%)					

5. Other Dependence on Forest वन निर्भरता

1.For Agriculture Use कृषि उपयोग के लिए	लघु लकड़ी व खेती बाढ़ी के लिए खम्बे। हाँ □नहीं □. यदि हाँ, तो मात्रा सूखे पत्ते आदि । हाँ □ नहीं□. यदि हाँ, तो मात्रा बाड़ के लिए सामान । हाँ □ नहीं □. यदि हाँ, तो मात्रा
2. For House Construction गृह निर्माण के लिए	लकड़ी हाँ □ नहीं □ .यदि हाँ, तो मात्रा लघु लकड़ी व खम्बे हाँ □नहीं□ .यदि हाँ, तो मात्रा छप्पर के लिए घास हाँ □नहीं □ .यदि हाँ, तो मात्रा

3. Foods and Fibres	जड़ें। हाँ □ नहीं □. यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में सब्जियाँ । हाँ □ नहीं□ . यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में फल आदि । हाँ □ नहीं□ . यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में Bushmeat । हाँ □ नहीं □ . यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में
4. Medicinal Plants औषधिक जड़ी बूटियाँ	

6. Household Demography

S.No क्रमांक	Name नाम	Age आयु	Gender लिंग	Relationship to head मुखिया से सम्बंध	Literate साक्षर	If Yes, number of years of education यदि हाँ, शिक्षा के वर्षों की संख्या	Occupation (Primary) मुख्य व्यवसाय	Occupation (Secondary) अनुपूर्वक व्यवसाय
1.			M □F □		Y □N □			
2.			M □F □		Y □N □			
3.			M □F □		Y □N □			
4.			M □F □		Y □N □			
5.			M □F □		Y □N □			
6.			M □F □		Y □N □			
7.			M □F □		Y □N □			
8.			M □F □		Y □N □			
9.			M □F □		Y □N □			
10.			M □F □		Y □N □			
11.			M □F □		Y □N □			

S.No क्रमांक	**Name** नाम	**Age** आयु	**Gender** लिंग	**Relationship to head** मुखिया से सम्बंध	**Literate** साक्षर	**If Yes, number of years of education** यदि हाँ, शिक्षा के वर्षों की संख्या	**Occupation (Primary)** मुख्य व्यवसाय	**Occupation (Secondary)** अनुपूर्वक व्यवसाय
12			M □F □		Y □N □			
13			M □F □		Y □N □			
14			M □F □		Y □N □			
15			M □F □		Y □N □			

7. **Sources of Income for the Household** परिवार की आमदनी के स्त्रोत

Sl No	Sources	Annual Income: Last Year i.e. 2015			Annual Income: Before Five Years i.e. 2010		
		Yes=1, No=2	Approximate Income (in Rs.)	% of Total Annual Income	Yes=1, No=2	Approximate Income (in Rs.)	% of Total Annual Income
1.	Agriculture खेती						
2.	Livestock पशुधन						
3	Wage employment मजदूरी रोजगार						
4	NTFP Sale/ Other Forest Based Enterprises NTFP बिक्री / अन्य वन आधारित उद्‌यम						
5	Salary वेतन						
6	Business व्यापार						
7	Remittances (Money Order)						
8	Pension पेंशन						
9	Transfer Benefits स्थानांतरण लाभ						
10	Rent from leased out land/ room भूमि या कमरे से किराया						

Sl No	Sources	Annual Income: Last Year i.e. 2015			Annual Income: Before Five Years i.e. 2010		
		Yes=1, No=2	Approximate Income (in Rs.)	% of Total Annual Income	Yes=1, No=2	Approximate Income (in Rs.)	% of Total Annual Income
11	Others, if any अन्य, यदि है						
12	Total कुल						

Thank You so much for your kind cooperation

Appendix 5.1 Household-Level Questionnaire for Uttar Pradesh

INTRODUCTION

The survey is being conducted for a study on 'Uttar Pradesh Sodic Land Reclamation Project', being implemented in Mainpuri district, Uttar Pradesh. This case study is part of larger study being conducted by TERI on 'The Economics of Desertification, Land Degradation and Drought (DLDD) in India supported by Ministry of Environment, Forest and Climate Change, Government of India. We assure you that, all the information collected for this survey is required for research purpose only and no part of this information will be used for any other purpose. Kindly give us 40 minutes of your time to participate in the survey.

Name of the Interviewer		Questionnaire Code	
Date of Interview		Time of Interview	
Checked by			

III. Respondent Detail

xi.	Name of the Respondent			xii.	Age of the respondent	
xiii.	Relationship with head of the household			xiv.	Gender of the respondent	
xv.	Village			xvi.	Gram Panchayat	
xvii.	Block			xviii.	Caste*	
xix.	Religion**			xx.	Contact number	
xxi.	Direct beneficiary in UPUSY	Yes	(1)	xxii.	If no, relationship with the beneficiary	
		No	(2)			

Codes:

Q3 relationship – father = 1, mother = 2, husband = 3, wife =4, son/ daughter = 5, brother/ sister = 6, niece/ nephew = 7, grandson/ daughter = 8, uncle = 9, aunt = 10, self = 11, any other = 99

Q4 Male=1, Female=2

Q8 General = 1, Schedule Caste = 2, Schedule Tribe = 3, Other Backward Class = 4

Q9 Hindu = 1, Muslim = 2, Sikh = 3, Christian = 4, Others = 99

Q10 (same as Q3)

Ownership of land

S. No.	Question	Response	Codes
36.	How much agricultural land does your household owns?	_________(in acres)	
		Don't have agricultural land	77
37.	Mark appropriate category of farmer	Landless	1
		Less than 0.2 Hectare	2
		0.2 to 0.4 Hectare	3
		0.4 to 0.6 hectare	4
		0.6 to 1 hectare	5
		More than 1 hectare	6

38.	According to you which of the following are causes of degradation in productivity of land in this area? **MULTIPLE RESPONSE QUESTION**	**Spontaneous**	**Recall**
	Sodic soil	1	1
	Non application of farm yard manure		
	Water with higher PH value than 8.5	2	2
	Non availability of water	3	3
	Non availability of farm inputs (Specify farm inputs ________________________________)	4	4
	Excessive use of fertilizer	5	5
	Migration (causing labour shortage)	6	6
	Workload of women	7	7
	Livestock and produce	8	8

	Invasion on agricultural land by exotic plant species	9	9
	Household income	10	10
	Standard of living	11	11
	Cultural festivals	12	12
	Tourism	13	13
	Any other, specify	99	99
39.	When did you first notice that the fertility of your agricultural land is dropping?	It was always degrade	1
		No of years ________	99
40.	Did you try to improve the productivity of the land?	Yes	1
		No	2
41.	What all did you do to improve the productivity of the land?	Removing top soil	1
		Soil Bunding	2
		Application of a layer of cow dung on the top soil	3
		Application of fertilizers	4
		Any other, specify	99

42.	Which of the following is caused by degradation of land?	**Spontaneous**	**Recall**
	Water with higher PH value than 8.5	1	1
	Shortage of water	2	2
	Shortage of farm inputs (Specify farm inputs ______________________________)	3	3
	Excessive use of fertilizer	4	4
	Migration (causing labour shortage)	5	5
	Increase in workload of women	6	6
	Livestock and produce	7	7
	Poverty (household income)	8	8
	Standard of living	9	9
	Cultural festivals	10	10
	Tourism	11	11
	Any other, specify	99	99

43.	Have you tried to improve the productivity of your land?	Yes	1
		No	2
44.	Were you allotted agricultural land under UPUSY?	Yes	1
		No	2
If no skip Q17 and Q18			
45.	If yes, what is the total area of the land that was allotted?		
46.	What was the category of land?	A	1
		B	2
		C	3

47. Kindly provide details of the agricultural land which was treated or is proposed to be treated under UP bhumi sudhar yojana?				
		1. Before project	**2. After project**	
A.	Total land			
B.	Area of irrigated land (of the total)			
C.	Source of irrigation for this land	Rain fed	1	1
		Only canal	2	2
		Only well/ Tube well	3	3
		Canal and Tube well	4	4
		Tank	5	5
		Others, Specify	99	99
D.	What is the quality of this land?	Absolutely degraded	1	1
		Average	2	2
		Fertile	3	3
E.	What is the category of land (as identified under UPUSY)?	A	1	1
		B	2	2
		C	3	3
48.	Have you experienced crop failure due to degraded soil fertility?		Yes	1
			No	2
Skip Q14 if NO in Q13				
49.	How were you able to keep up with the loss	Loan		1
		Selling expensive household item and/ or livestock		2
		Crop insurance		3
		Any other specify		99

50.	Cropping pattern					
	Before project			**After project**		
	Crop 1	**Crop 2**	**Crop3**	**Crop 1**	**Crop 2**	**Crop 3**
A. Kharif						
B. Rabi						
C. Zaid						

51. **Factors affecting agriculture**

S.no	Characteristics	Description	Main reasons
1	Quantum of rainfall	Increased/decreased/No change	
2	Distribution of rainfall	Increased/decreased/No change	
3	Number of rainy days	Increased/decreased/No change	
4	Outlier events	Increased/decreased/No change	
5	Arrival of monsoons	Increased/decreased/No change	
6	Availability of water in wells and bore wells	Increased/decreased/No change	
7	Availability of water in irrigation tanks	Increased/decreased/No change	
8	Temperature(winter)	Increased/decreased/No change	
9	Temperature(summer)	Increased/decreased/No change	

52.	Which of the activities were conducted/ organized under Bhumi Sudhar Yojana?	**Spontaneous**	**Recall**
	Exposure visits	1	1
	Rehabilitation of drains	2	2
	Farmer camps	3	3
	Demonstration for improved agriculture management practice	4	4
	Training and demonstration on livestock development	5	5
	Services on livestock management	6	6
	Provided boring for irrigation	7	7
	Technical support in leaching, bunding	8	8
	Provided gypsum	9	9
	Provided improved variety seeds at subsidised price	10	10
	Provided fertilizers at subsidised price	11	11
	Women SHGs were formed	12	12
	Animal husbandry training to women	13	13
	Access to market	13	13
	Others specify	99	99

53.	How has the status of labour market changed from the inception of the project?		
1	**Characteristics**	**Status**	**Reasons**
2	Opportunities for farm work	High /low /no change	
3	Opportunities for non-farm work	High /low /no change	
4	Availability of labour for work	Surplus /shortage /no change	
5	Involuntary unemployment days	Increased/decreased/no change	
6	Working hours for labour per day	Increased/decreased/no change	

7	Wage rate per day	Increased/decreased/no change	
8	Contract type of work	Increased/decreased/no change	
54.	How has the cost of the land under treatment changed?	Before Rs.____________/Ha	After Rs. ____________/Ha

House Particulars

S. No.	Question	Response	Codes
55.	Is the household electrified?	Yes	1
		No	2
56.	What is the source of drinking water	Own tubewell	1
		Own well	2
		Community tubewell	3
		Community well	4
		Own tap	5
		Community tap	6
		Canal	7
		Any other	99
57.	Does the household have ration card	Yes	1
		No	2
58.	If yes, which ration card does the household have	APL	1
		BPL	2
		Antodaya	3
		Annapurna	4
		Others	99
59.	Do you or household member have a MGNREGA job card?	Yes	1
		No	2

60.	How many days of total work have they received	________ no of days	
61.	How much wage have you received under MGNREGA?	Rs. ________/ day	
62.	How many rooms do you have in your house?	Yes	1
63.	Do you own this house?	No	2
64.	Type of house	Kuccha	1
		Pakka	2
		Mixed	3
65.	Was this house built under indira awas yojana?	Yes	1
		No	2
66.	Do you have a bank account?	Yes	1
		No	2
67.	Was this account opened under Jan dhan yojana?	Yes	1
		No	2
68.	Do you own the following?	Codes	Number Owned
	Improved agricultural tool	1	
	Handloom	2	
	Sewing machine	3	
	Electric Fan	4	
	Mobile	5	
	Washing machine	6	
	Refrigerator	7	
	Miser	8	
	Solar equipment	9	
	Cycle	10	

	Scooter/ motor cycle	11	
	Car/ truck/ tractor	12	
	Computer/ Laptop/ tablet	13	
	Toilet within house	14	

III. Migration

S. No.	Question	Response	Codes
69.	Do the individuals in the village commonly migrate?	None migrate	1
		Few migrate	2
		Mostly migrate	3
70.	What is the commonly performed occupation of the migrated member?	Agricultural Labourer	1
		Non-Agricultural Labourer, Skilled	2
		Unskilled Non-Agricultural Labourer,	3
		Services	4
		Business	5
		Others, specify	99
71.	What are the common reasons for migration in the village? (More than one response possible)	Decreased productivity of land	1
		decreased size of land	2
		decrease in opportunities for wage income	3
		Additional income	4
		Others, specify	99
72.	Who commonly migrated?	Children (0-10 years)	1
		Adolescent (11-18	2

		years)	
		Young Adults (19-30 years)	3
		Adults (31-50 years)	4
		Elderly (50years and above)	5
73.	Where do people commonly migrate?	Within district	1
		Other districts	2
		Other States	3
		Other Countries	4

Women Participation

S. No.	Questions	Response	Code
74.	Did HH adult women participate in UPBSY?	No, only male members were involved	1
		Helped male counterpart as labour	2
		Are / Were part of UPBSY SHG	3
		Were equal recipient of all the benefits received under UPBSY	5
		Others, secify	99
75.	How you or other HH adult women were benefited under UPBSY?	Land was allotted in name of women along with male counter part	1
		Received farm inputs	2
		Training for improved farming	3
		Training for livestock	4
		Saving and credit under SHG	5
		Participated in Income Generating Activity	6

		Other, specify		99
76.	What there a change in woman's daily routine? (in no. of hours spent/ day)	Activity	Before project	After project
		1. Cleaning and cooking		
		2. Looking after children		
		3. Arranging and feeding animals		
		4. Farm work		
		5. Income generating activity		
		6. Attending meetings (community groups, in a month)		
		7. Drawing and storing water		
		8. Rest		
		9. Any other, specify		
		10.		
77.	Do women participate in community groups?	Yes		1
		No		2
78.	Is there a change in how you perceive women after joint allotment was done under the project	Yes		1
		No		2

Change in Production due to intervention

79. **Details of top two major crop grown by season**

S. no.	BP / AP	Crop name	Variety sown	Area in which it was cultivated (of the (to be) reclaimed plot)		Irrigate d = 1 Non-irrigated = 2, partially irrigate = 3	Total produce obtained (in quintal)	Amount Self consumed (in quintal)	Amount sold (in quintal)	Average rate @ which it is sold (Rs/ Kg)	Total Cost of production (in Rs)
				Local	Hybrid						
1	2	3	4	5	6	7	8	9	10	11	12
Kharif crop											
A	BP										
B											
C	AP										
D											
Rabi Crop											
E	BP										
F											
G	AP										
H											

Zaid Crop												
I	BP											
J												
K	AP											
L												

Codes Q2 - local = 1, hybrid = 2, mixed = 3

80. **Cost of Cultivation of Major Crop 1 _________________________(name of the crop)**

S.No.	Operation	BP / AP	Bullock Power		Machine Power		Human Labour		Input		Amount of subsidy received (in Rs.)
			Hired	Owned	Hired	Owned	Family	Hired	Quantity	Cost borne by farmer (in Rs.)	
1	2	3	4	5	6	7	8	9	10	11	12
A	Land Preparation (including bunding and levelling)	BP									
		AP									
B	Seed/Nursery	BP									
		AP									
C	Transplantation	BP									
		AP									
D	Inter cropping	BP									
		AP									
E	Irrigation	BP									
		AP									
F	Farm Yard Manure and	BP									

S.No.	Operation	BP / AP	Bullock Power		Machine Power		Human Labour		Input		Amount of subsidy received (in Rs.)
			Hired	Owned	Hired	Owned	Family	Hired	Quantity	Cost borne by farmer (in Rs.)	
1	2	3	4	5	6	7	8	9	10	11	12
	Organic Fertilizer	AP									
G	Gypsum	BP									
		AP									
H	Urea (N)	BP									
		AP									
I	Phosphorus (P)	BP									
		AP									
J	Potash (K)	BP									
		AP									
K	Zinc	BP									
		AP									
L	Plan protection (i) weedicide	BP									
		AP									
M	(ii) insecticide	BP									
		AP									
N	(iii) pesticide	BP									
		AP									
O	Harvesting and Threshing	BP									
		AP									
P	Transporting	BP									
		AP									
Q	Marketing	BP									
		AP									
R	Other 1.______________	BP									
		AP									
S	2	BP									

S.No.	Operation	BP / AP	Bullock Power		Machine Power		Human Labour		Input		Amount of subsidy received (in Rs.)
			Hired	Owned	Hired	Owned	Family	Hired	Quantity	Cost borne by farmer (in Rs.)	
1	2	3	4	5	6	7	8	9	10	11	12
		AP									

81. Cost of Cultivation of Major Crop 2 ________________________(name of the crop)

S.No.	Operation	BP / AP	Bullock Power		Machine Power		Human Labour		Input		Amount of subsidy received (in Rs.)
			Hired	Owned	Hired	Owned	Family	Hired	Quantity	Cost borne by farmer (in Rs.)	
1	2	3	4	5	6	7	8	9	10	11	12
A	Land Preparation (including bunding and levelling)	BP									
		AP									
B	Seed/Nursery	BP									
		AP									
C	Transplantation	BP									
		AP									
D	Inter cropping	BP									
		AP									
E	Irrigation	BP									
		AP									
F	Farm Yard Manure and Organic Fertilizer	BP									
		AP									
G	Gypsum	BP									
		AP									
H	Urea (N)	BP									
		AP									
I	Phosphorus (P)	BP									
		AP									

S.No.	Operation	BP / AP	Bullock Power		Machine Power		Human Labour		Input		Amount of subsidy received (in Rs.)
			Hired	Owned	Hired	Owned	Family	Hired	Quantity	Cost borne by farmer (in Rs.)	
1	2	3	4	5	6	7	8	9	10	11	12
J	Potash (K)	BP									
		AP									
K	Zinc	BP									
		AP									
L	Plan protection	BP									
	(i) weedicide	AP									
M	(ii) insecticide	BP									
		AP									
N	(iii) pesticide	BP									
		AP									
O	Harvesting and	BP									
	Threshing	AP									
P	Transporting	BP									
		AP									
Q	Marketing	BP									
		AP									
R	Other 1.________________	BP									
		AP									
S	2.______________________	BP									
		AP									

V. Impact of intervention on Livestock

82. **Please provide details of the domesticated livestock**

S.No.	Domesticated Animals **(A)**	Total Number		Number for each type of breed				Number of Milching Cattle				Number reproduced since project inception **(L)**	Number Sold since project inception **(M)**	Number used as meat **(N)**	Animal Produce obtained each year **(O)** *
		BP **(B)**	AP **(C)**	Local		Improved		Local		Improved					
				BP **(D)**	AP **(E)**	BP **(F)**	AP **(G)**	BP **(H)**	AP **(I)**	BP **(J)**	AP **(K)**				
1.	Cow														
2.	Goat														
3.	Buffalo														
4.	Ox														
5.	Calf														
6.	Cock/ hen														
7.	Chicken														
8.	Horse/ Donkey														
9.	Fish														
10.	Rabbit														

*Codes Animal Produced - 1=Milk, 2=Ghee (fat), 3=Curd, 4=Butter, 5=Manure

83. **Please provide details of Animal produce**

S.No.	Type of Produce **(A)**	Quantity Produced (in Kg/ l) **(B)**		Amount used for Self Consumption (in Kg/ l) **(C)**		Amount Sold (in Kg/ l) **(D)**		Rate (Rs./ Kg or l) **(E)**		What is the quality of animal produce (now/ since project) **(F)**		
		BP	FP	BP	AP	BP	AP	BP	AP	It has deteriorated	It's the same	Has improved
1.	Milk									1	2	3
2.	Ghee									1	2	3
3.	Curd									1	2	3
4.	Butter									1	2	3
5.	Manure									1	2	3

84. **Inputs for** Livestock Management

S.No.	Domesticated Animals **(A)**	Rate at which the animal was procured (in Rs.)		Cost of transportation		Cost of vaccination and disease (if applicable)		Animal feed required for one unit of animal/ day		% of animal feed Procured from market (yes/ no) **(J)**	Rate at which fodder is procured (Rs/ Kg) **(K)**	Time spent by HH members on domesticated animals	
		Local **(B)**	Improved **(C)**	Local **(D)**	Improved **(E)**	Local **(F)**	Improved **(G)**	Local **(H)**	Improved **(I)**			**Male**	**Female**
1.	Cow											1	2
2.	Goat											1	2
3.	Buffalo											1	2
4.	Ox											1	2
5.	Calf											1	2
6.	Cock/ hen											1	2
7.	Chicken											1	2
8.	Horse/ Donkey											1	2
9.	Fish											1	2
10.	Rabbit											1	2

85.

86. **Fodder from other sources (Forest, agricultural residue, backyard plantations)**

S.No.	Domesticated Animals (A)	How are the following cattle fed?* (B)	Number of days of open grazing in a month (C)	Source of fodder for stall feeding				Who in Household is involved in collection of fodder?** (H)	Total time spent on collection of fodder/ day (I)
				% Forest (D)	% Agricultural Residue (E)	% Backyard Plantation (F)	% Market (G)		
1.	Cow								
2.	Goat								
3.	Buffalo								
4.	Ox								
5.	Calf								

*1=stall-feeding, 2=Open grazing, 3= Open grazing

**1=Adult Male, 2=Young male, 3=Adult female, 4 = Young Female

87. **How has the household income changed after the project?**

S.No.	Sources	Annual Income before project			Annual income after project		
		Source of income Yes = 1, no = 2	Approximate Income (in Rs.)	% of Total Annual Income	Source of income Yes = 1, no = 2	Approximate Income (in Rs.)	% of Total Annual Income
1	Agriculture						
2	Livestock						
3	Wage Employment						
4	Salary						
5	Business						
6	Remittance						

S.No.	Sources	Annual Income before project			Annual income after project		
		Source of income Yes = 1, no = 2	Approximate Income (in Rs.)	% of Total Annual Income	Source of income Yes = 1, no = 2	Approximate Income (in Rs.)	% of Total Annual Income
7	Pension						
8	Transfer Benefits						
9	Rent from leased out land/room						
10	Others						
11	Total						

Saving and Expenditure

	Who decides, how will HH income be spent?	Head of the household		1
		Male members of the household		2
		Women of the household		3
	Is there a change in household expenditure pattern due to the project	Average amount spent before project (in Rs.)	Average amount spent after project (in Rs.)	Reason for change
	Food			
	Clothing			
	Education of male child			
	Education of female child			
	Child health			
	Leisure and entertainment			
	Medicine and hospitalisation			

	Saving			

88. **Details of the family members**

S.No.	Name of Members	[1]Relation to head of household	Gender[2]	Age (in completed years)	Level of Education[3]	Primary Occupation[4]	Secondary Occupation[4]	Migrated (yes -1 no – 2)	Duration of migration (in years, permanent migrant – 77)	Reason for migration
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

11										
12										
13										
14										
15										

Note- please provide details for members who reside in the same house as the respondent, or members who migrated but were living in the same house as respondent.

[1] relationship – father = 1, mother = 2, husband = 3, wife =4, son/ daughter = 5, brother/ sister = 6, niece/ nephew = 7, grandson/ daughter = 8, uncle = 9, aunt = 10 any other = 99

[2] Gender – Male =1, Female=2

[3] Education – Illiterate = 1, Primary=2, Secondary=3, Senior Secondary=4, Graduate=5, Post Graduate=6, Vocational training=7, less than 5 years=8

[4] Occupation – Farming =1, Agricultural labour=2, labour (Other)=3, Housewife=4, Business=5, Government service=6, Private service=7, others, specify=99

Appendix 6.1 Household Survey Questionnaire for Andhra Pradesh

Note: The survey is being undertaken for the case study of Kalipatnam (E) village of Mugaltaru taluka of West Godavari District in Andhra Pradesh. The case study is part of the larger TERI study on 'Economics of Desertification, Land Degradation and Drought (DLDD) in India' supported by Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. All the information collected through this survey is required for research purposes only and any part of this information will not be used for any other purpose.

Name of the Interviewer		Questionnaire Code		
Date of Interview		Interview Time		

A. HOUSEHOLD IDENTIFICATION

1.Name of the Respondent		4. Name of the Gram Panchayat	
2.Name of the Head of the Household		5. Caste Group (use code)	
3. Name of the Village		6. Religion (use code)	

*Code: **5. Social Category: General=1, OBC=2, SC=3, ST=4;***

6. Religion: Hindu=1, Buddhist=2, Muslim=3, Christian=4, Others (specify) =5

Note: *The primary respondent should be the current Head of the household. If the head of the household is not available for the interview, the information should be collected from the immediate responsible person in the family with knowledge of the agricultural practices and asset ownership details. Recall responses need to be recorded with caution.*

B. LAND HOLDINGS AND OPERATIONAL AREA (in Acre)

Sl No	Particulars	Current Year				Before Project			
		Irrigable Land	Dry Land	Fallow Land	Total	Irrigable Land	Dry Land	Fallow Land	Total
1	Homestead Land								
2.1	Own Agrl. land								
2.2	Leased in								
2.3	Leased-out								
2.4	Plantations								
2.5	Total Operational Area								

C. CROPPING PATTERN AND CROP PRODUCTION

6. What crops do you grow?

	Jan-Feb	Mar-Apr	May-June	July-Aug	Sep-Oct	Nov-Dec
Crop Name						
Inter cropping						

7. How many different plots of agricultural land you have?

8. Do you pay any annual fee for irrigation? Yes [ ] No [ ]
9. If Yes, please specify, the total amount paid____________________

10. Crop Production and Other Details

Name of Crop	Area (in Acre)		Source of Irrigation Code*	Total Production (in quintal)		Quantity Sold (in quintal)		Average Price (Rs/quintal)	
	Irrigated	Rainfed		Main (Grain)	Bi-product	Main	Bi-product	Main	Bi-product

Note: Other inputs include costs of hiring plough/tractors for ploughing, levelling, lining (tisiya), weeding and harvesting; fuel cost of irrigation; cost of seeds, fertilizer, pesticides, weedicides and all other inputs for each of the crops.

Code: Source of Irrigation-River/Stream=1, Dam/Reservoir=2, Canal=3, Check dam=4, Dug-Well=5. Tube well=6, Farm Pond=7, Other (specify)=8

11. Cost of Cultivation (Rs/acre)

Name of Crop	Labour	Water	Electricity	Diesel	Seed	Fertilizer			Fungicide	Harbicide	Pesticide	Other
						N	P	K				

D. SOIL CONSERVATION PRACTICES AND BENEFITS

14. How the household has benefitted from the SSD project (Please tick the relevant boxes)

Name of the Programme	SSD	Agro-Forestry/ Plantation	Water facility from check dam	Soil Testing Info	Critical Inputs/	Compost	Agri-Info (SMS & other info)	Livestock Support	SHG/ Micro-credit	Seeds
Whether Benefitted										
How useful are they? (code)										

Code: extremely useful=1, very useful=2, somewhat useful=3, not all useful=4

15. Plot Characteristics and Soil Conservation Measures adopted by the Farmer in each of the Plot

Plot Nam e	Area (In	Land Tenur e (use	Distan ce from	Source of Irrigat	Distanc e from Irrigati	Irrigat ion Techn	No. of Crops Grown	No of Crops grown	Soil Type	Soil depth	Soil Fertilit y	% of slope d land	Soil organic carbon	Soil Salinit y	Other soil conserv	Cost of Conservatio n Measures	No. of tree

	acre)	code)	home (in km)	ion (use code)	on Source (in kms)	ology (use code)	in a Year	before the project	(use code)	(in ft)			(use code)	(use code)	ation measures* (use code)	Initial Cost	Annual Maintenance	s
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)

Codes:

(3) Land tenure: Owned=1, leased-out=2, shared –out=3, leased-in=4, shared-in=5

(5) Source of Irrigation: River/Stream=1, Canal=2, Check-dam=3, Dug Well=4, Tube Well=5, Farm Pond=6,

(7) Irrigation Technology: Flood irrigation=1, Drip Irrigation=2, Sprinklers=3,

(10) Soil type: Lal Miti=1, Bhuri Miti=2, Kali Miti=3, Other=4

(12) Soil fertility: Very Poor=1, Poor=2, Good=3, Very Good=4

(14) Soil organic carbon level: low=1, Medium =2, High =3,

(15) Soil salinity level: No salinity = 1; moderately saline = 2; Saline = 3; Highly saline = 4; Extremely saline = 5

(16) Other Conservation Measures: Yes, adopted=1, Not adopted any other measure=2

* If Yes, Specify the measures: a)________________________________ b) ______________________________

c)____d)______________________________

If No, specify why no other measures adopted: a) Not required ◯ , b) Required but don't know what to do ◯

c) Required but can't afford it ◯ , d) Others, Specify____

16. What modern farming equipment/machineries you use?

Sl No	Name	Tick if you hire	Hiring Charges (Rs per Hr)	Tick if you have purchased	Year of Purchase
1	Tractor				
2	Power Tiller				
3	Rotavator				
4	Sprayer				
5	Drip Irrigation Pipes				
6	Sprinkler				
7	Reaper				
8	Harvester				
9	Thresher				

17. **Whether you have plots under the SSD project?** Yes [ ] No [ ]
If 'Yes', then answer 4(a) otherwise move to 4(b);

4(a)

1	Total no. of Plots	
2	No. of plots in which SSD is required	
3	No. of plots where SSD are built under the SSD project	
4	No. of plots where some or other form of mitigation exists	
5	No. of plots where no mitigation measure adopted	

4(b)

Sl. No	Reasons (Specify if it's not amongst the reasons listed)	Please Tick
1	My plots are not in the treatment area of the project	

2	There was no provision to build SSD on my farm	
3	I didn't agree as I didn't know the benefits	
4	I knew the benefits but didn't agree as I had standing crops	
5	I don't have adequate time to spare for the building of the SSD	
6	Any other, specify	
7		

18. If Yes to 4, how have you been benefitting? Please tick

1	Declining input cost			4	Recharge of Wells	
2	Reduced labour cost			5	No benefits at all	
3	Increased productivity			6		

19. **Do you think the SSD is more effective than the traditional methods of soil salinity control?** Yes◯ No◯

20. Cost of Cultivation and Farm Output in a Plot with SSD (Crop 1)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/Winnowing									
17	Packaging									
18	Transportation Charges									

21. Cost of Cultivation and Farm Output in a Plot with SSD (Crop 2)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/Winnowing									
17	Packaging									
18	Transportation Charges									

22. Cultivation and Farm Output in a Plot with SSD (Crop 3)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/Winnowing									
17	Packaging									
18	Transportation Charges									

23. Cost of Cultivation and Farm Output in a Plot without SSD (Crop 1)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/Sowing									
5	Lining									
6	Irrigation									
7	Weeding									

8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/Winnowing									
17	Packaging									
18	Transportation Charges									

24. Cost of Cultivation and Farm Output in a Plot without SSD (Crop 2)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									

10	Chemical Fertilizer									
11	Pesticide/Insecticide									
12	Weedicide									
13	Reaping									
14	Guarding from wildlife									
15	Harvesting									
16	Threshing/Winnowing									
17	Packaging									
18	Transportation Charges									

25. Cost of Cultivation and Farm Output in a Plot without SSD (Crop 3)

Name of the Plot:	Seed Variety:	Crop Output	Quantity Produced (qtl.)=	Byproducts	Production in last 2 yrs
Name of the Crop:	Wage Rate (Rs/day):		Quantity Sold (qtl.) =	Quantity:	2:
Crop Duration:	Prices at which sold (Rs/Qtl):		Quantity Retained (qtl) =	Value:	3:

Sl. No.	Operations	Bullock power (Rs)		Machine power (Rs)		Human labour (days)		Inputs		Remarks
		Hired	Owned	Hired	Owned	Family labour	Hired labour	Qty (kgs).	Value (Rs.)	
1	Land Preparation									
2	Seed									
3	Nursery									
4	Transplantation/Sowing									
5	Lining									
6	Irrigation									
7	Weeding									
8	Farm Yard Manure									
9	Vermi Compost									
10	Chemical Fertilizer									
11	Pesticide/Insecticide									
12	Weedicide									
13	Reaping									

14	Guarding from wildlife									
15	Harvesting									
16	Threshing/Winnowing									
17	Packaging									
18	Transportation Charges									

E. SOCIO-ECONOMIC INFORMATION

8. House Particulars

1	Is the household electrified? क्या घर में विद्युतीकरण है?	Y ☐ N ☐
2	What is the source of drinking water? पीने के पानी का स्त्रोत क्या है?	Own Tubewell ☐ Own Well ☐ Community Tubewell ☐ Community Well ☐
3	Does the household have BPL card? क्या परिवार के पास BPL कार्ड है?	Y ☐ N ☐
4	Does the household get ration from Public Distribution System? क्या घर को सार्वजनिक वितरण प्रणाली से राशन मिलता है?	Y ☐ N ☐ यदि हाँ, तो किस के अंतर्गत If Yes, which type (APL, BPL, Antyodaya, Annapurna yojana scheme or any others?)
5	Do any of members of the household have MNREAGA job card ? क्या नरेगा जॉब कार्ड है? If Yes, how many days in total worked and how much money received under MNREAGA Wages last year? यदि हाँ, क्या किसी सदस्य ने मनरेगा के अंतर्गत कार्य किया है?	Y ☐ N ☐ Number of Job Cards:___________ Total Number of Days worked:___________ Total Wage received:___________________
6	How many rooms in your house? घर में कितने कमरे हैं?	
7	Type of House? घर का प्रकार	Mostly Pucca☐ Mostly Kutcha☐ Mixed ☐ कच्चा पक्का मिश्रण
8	Whether benefitted from IAY or other scheme? यदि IAY या किसी अन्य योजना का लाभ उठाया है?	Y ☐ N ☐

9. Livestock Holding

Sl. No	Livestock	Number of Livestock Now		Number of Livestock 10 years back	
		Total Number	Milch Animals	Total Number	Milch Animals
1	Bull				

2	Cow				
3	Buffalo (Male)				
4	Buffalo (Female)				
5	Calves				
6	Goat				
7	Sheep				

10. Cooking Fuel and Collection of Firewood

1.What are the cooking fuels used? खाना पकाने के लिए किस इंधन का प्रयोग करते हैं	Fuels	Tick if use	% of the total cooking fuel
	Firewood लकड़ी		
	Twigs टहनियाँ		
	Dungcakes उपले		
	LPG		
	Dry Leaves सूखी पत्तियाँ		
	Agl. Residues		
	Ele. Heater		
2. Where do you cook? खाना कहाँ पकता है ?	Mostly in Kitchen ☐ Mostly Outside ☐ अधिकतर रसोई में ☐अधिकतर बाहर☐		

3. How many times in a week you collect firewood? 3. सप्ताह में कितनी बार ईंधन के लिए लकड़ी एकत्रित करते हैं?	
4. Approximate quantity of firewood collected each time? (In Kgs) 4. सप्ताह में एकत्रित लकड़ी की मात्रा (लगभग)	
5. How many hours it takes to collect? (in hours) 5. इसे इकट्ठा करने में कितने घंटे लगते हैं?	
6. How much firewood you collect per year? (approximate quantity in Kgs) 6. सालाना एकत्रित लकड़ी की मात्रा (किलो)	

7. What percentage of the firewood is the greenwood? 7. इसमें से कितने प्रतिशत लकड़ी हरी होती है?	

8. What are the sources of fuel wood and volumes?

Source स्त्रोत	Forest वन	Village Commons	Private Sources निजी स्त्रोत	Any Other अन्य
Share (%)				

11. Collection of Fodder चारे का संग्रह

1. How do you feed your livestock? Please tick

आप अपने पशु धन को क्या खिलाते हैं?

Livestock	Open grazing	Stall Feeding	Both
Bull			
Cow			
Buffaloes			
Calves			
Sheep			
Goats			

2. What are the sources of fodder for livestock?

	Forest	Village Commons	Private Land	*Other, Specify* ________
Open Grazing (No. of months)				
Fodder for Stall Feeding (No. of months)				

3. What are the shares of different fodders that the household use?

Fodder चारा	Grass and Tree fodder		Agricultural residues	Bran/husk	Commercial fodder
	Forest	Non-Forest			

Share (%)					

12. Other Dependence on Forest वन निर्भरता

1.For Agriculture Use कृषि उपयोग के लिए	लघु लकड़ी व खेती बाढ़ी के लिए खम्बे। हाँ □नहीं □. यदि हाँ, तो मात्रा सूखे पत्ते आदि । हाँ □ नहीं□. यदि हाँ, तो मात्रा बाड़ के लिए सामान । हाँ □ नहीं □. यदि हाँ, तो मात्रा
2. For House Construction गृह निर्माण के लिए	लकड़ी हाँ □ नहीं □ .यदि हाँ, तो मात्रा लघु लकड़ी व खम्बे हाँ □नहीं□ .यदि हाँ, तो मात्रा छप्पर के लिए घास हाँ □नहीं □ .यदि हाँ, तो मात्रा
3. Foods and Fibres	जड़ें। हाँ □ नहीं □. यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में सब्जियाँ । हाँ □ नहीं□ . यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में फल आदि । हाँ □ नहीं□ . यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में Bushmeat । हाँ □ नहीं □ . यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में
4. Medicinal Plants औषधिक जड़ी बूटियाँ	

13. Household Demography

S.No क्रमांक	Name नाम	Age आयु	Gender लिंग	Relationship to head मुखिया से सम्बंध	Literate साक्षर	If Yes, number of years of education यदि हाँ, शिक्षा के वर्षों की संख्या	Occupation (Primary) मुख्य व्यवसाय	Occupation (Secondary) अनुपूर्वक व्यवसाय
1.			M □F □		Y □N □			
2.			M □F □		Y □N □			
3.			M □F □		Y □N □			
4.			M □F □		Y □N □			
5.			M □F □		Y □N □			
6.			M □F □		Y □N □			
7.			M □F □		Y □N □			
8.			M □F □		Y □N □			
9.			M □F □		Y □N □			
10.			M □F □		Y □N □			

11.			M □F □		Y □N □			
12			M □F □		Y □N □			
13			M □F □		Y □N □			
14			M □F □		Y □N □			
15			M □F □		Y □N □			

14. **Sources of Income for the Household** परिवार की आमदनी के स्त्रोत

Sl No	Sources	Annual Income: Last Year i.e. 2015			Annual Income: Before Five Years i.e. 2010		
		Yes=1, No=2	Approximate Income (in Rs.)	% of Total Annual Income	Yes=1, No=2	Approximate Income (in Rs.)	% of Total Annual Income
1.	Agriculture खेती						
2.	Livestock पशुधन						
3	Wage employment मजदूरी रोजगार						
4	NTFP Sale/Other Forest Based Enterprises NTFP बिक्री / अन्य वन आधारित उद्यम						
5	Salary वेतन						
6	Business व्यापार						
7	Remittances (Money Order)						
8	Pension पेंशन						
9	Transfer Benefits स्थानांतरण लाभ						
10	Rent from leased out land/room भूमि या						

	कमरे से किराया						
11	Others, if any अन्य, यदि है						
12	Total कुल						

Thank You so much for your kind cooperation

Appendix 7.1 Household Survey Questionnaire for Rajasthan

Note: The survey is being undertaken for the case study of the shelterbelt programme of the Rajasthan state forest department in Jaisalmer Block, Jaisalmer District in Rajasthan. The case study is part of the larger TERI study on 'Economics of Desertification, Land Degradation and Drought (DLDD) in India' supported by Ministry of Environment, Forest and Climate Change, Government of India. All the information collected through this survey is required for research purposes only and no part of this information will be used for any other purpose.

यह सर्वेक्षण जैसलमेर जिले में राजस्थान राज्य के वन विभाग के shelterbelt कार्यक्रमों के अध्ययन के लिए किया जा रहा है। यह अध्ययन 'भारत में बंजर, भूमि क्षरण और सूखा (DLDD) के अर्थशास्त्र' पर एक टेरी अध्ययन का हिस्सा है। यह पर्यावरण मंत्रालय, वन एवं जलवायु परिवर्तन, भारत सरकार द्वारा समर्थित है। इस सर्वेक्षण के माध्यम से एकत्र सभी जानकारी केवल अनुसंधान प्रयोजनों के लिए आवश्यक है और इस जानकारी का कोई हिस्सा किसी अन्य उद्देश्य के लिए इस्तेमाल नहीं किया जाएगा।

Name of the Interviewer साक्षात्कर्ता का नाम		Questionnaire Code प्रश्नावली कोड		
Date of Interview दिनांक		Interview Time समय		

F. HOUSEHOLD IDENTIFICATION

1.Name of the Respondent प्रतिवादी का नाम		4. Name of the Gram Panchayat ग्राम पंचायत	
2.Name of the Head of the Household घर के मुखिया का नाम		5. Caste Group (use code) सामाजिक वर्ग	
3. Name of the Village गांव का नाम		6. Religion (use code) धर्म	

Code: 5. Social Category सामाजिक वर्ग : General सामान्य=1, OBC पिछड़े वर्गों =2, SC अनुसूचित जाति =3, ST अनुसूचित जनजाति =4;

Code 6. Religion धर्म: Hindu हिंदू =1, जैन =2, Muslim मुसलमान =3, Christian ईसाई =4, Others अन्य (specify उल्लिखित करना) =5

Note: *The primary respondent should be the current Head of the household. If the head of the household is not available for the interview, the information should be collected from the immediate responsible person in the family with knowledge of the agricultural practices and asset ownership details. Recall responses need to be recorded with caution.*

प्राथमिक प्रतिवादी घर के वर्तमान मुखिया होना चाहिए। परिवार के मुखिया साक्षात्कार के लिए उपलब्ध नहीं है, तो जानकारी परिवार में तत्काल जिम्मेदार व्यक्ति जिसे कृषि पद्धतियों और संपति के विवरण के ज्ञान हो उनसे एकत्र किया जाना चाहिए। याद करने की प्रतिक्रियाओं को सावधानी के साथ दर्ज करने की जरूरत है।

G. LAND HOLDINGS AND OPERATIONAL AREA (in Bighas) भूमि जोत और परिचालन क्षेत्र (बीघा में)

Sl No	Particulars	Current Year वर्तमान साल				Before IGNP Project IGNP परियोजना से पहले			
		Irrigable Land सिंचाई भूमि	Dry Land सूखा भूमि	Fallow Land परती भूमि	Total	Irrigable Land सिंचाई भूमि	Dry Land सूखा भूमि	Fallow Land परती भूमि	Total
1	Homestead Land रियासत भूमि								
2.1	Own Agricultural land कृषि भूमि								
2.2	Leased in पट्टे पर पाया								
2.3	Leased-out पट्टे पर दिया								
2.4	Plantations बाग़ान								
2.5	Total Operational Area कुल परिचालन क्षेत्र								

H. CROPPING PATTERN AND CROP PRODUCTION फसल पद्धति और फसल उत्पादन

12. What crops do you grow? आप क्या फसलें पैदा करते हो?

Crop Name फसल का नाम						
Specify the months कौन से महीने						
Inter cropping (crops grown along with main crop) साथ में लगाए फ़सल						

13. How many different plots of agricultural land you have? कृषि भूमि के कितने अलग भूखंडों है तुम्हारे पास?

14. Do you pay any annual fee for irrigation? If Yes, please specify, the total amount paid or amount paid per bigha per year. आप किसी भी सिंचाई के लिए वार्षिक शुल्क का भुगतान करते हैं? यदि हाँ, तो कृपया स्पष्ट करें, कुल राशि का भुगतान या प्रति वर्ष प्रति बीघा राशि का भुगतान?

15. A. Crop Production and Other Details in today's date फसल उत्पादन और अन्य विवरण - आज की तारीख में

Name of Crop फसल का नाम	Area (in bigha) क्षेत्र (बीघा में)		Source of Irrigation Code* सिंचाई के स्रोत	Total Production (in quintal) कुल उत्पादन (क्विंटल में)		Quantity Sold (in quintal) बेचा गया सामान (क्विंटल में)		Average Price (Rs/quintal) औसत कीमत (रुपये / क्विंटल)		Cost of Cultivation खेती की लागत	
	Irrigated सिंचित	Rainfed बारानी		Main मुख्य फसल	By product गौण पैदावार	Main मुख्य फसल	By product गौण पैदावार	Main मुख्य फसल	By product गौण पैदावार	Labour श्रम की लागत	Other inputs अन्य उत्पादक सामग्री
1.											
2.											
3.											
4.											
5.											
6.											
7.											
8.											
9											
10.											

Note: Other inputs include costs of hiring plough/tractors for ploughing, levelling, lining (tisiya), weeding and harvesting; fuel cost of irrigation; cost of seeds, fertilizer, pesticides, weedicides and all other inputs for each of the crops. अन्य आदानों में शामिल हैं - जुताई के लिए हल / ट्रैक्टर की धरती को समतल करने के लिए, अस्तर, निराई और कटाई की लागत; सिंचाई के ईंधन की लागत; बीज, उर्वरक, कीटनाशक, weedicides और अन्य सभी आदानों प्रत्येक फसलों की लागत के लिए।

Code: Source of Irrigation-River/Stream नदी / धारा=1, Dam/Reservoir बांध / जलाशय=2, Canal नहर=3, Check dam रोक बाँध=4, Dug-Well कुआं =5. Tube well नलकूप=6, Farm Pond खेत तालाब=7, Other अन्य (specify)=8

B. Crop production and other details before shelterbelts were planted 1988-1998 फसल उत्पादन और अन्य विवरण – shelterbelt से पहले

Name of Crop फसल का नाम	Area (in bigha) क्षेत्र (बीघा में)		Source of Irrigation Code* सिंचाई के स्रोत	Total Production (in quintal) कुल उत्पादन (क्विंटल में)		Quantity Sold (in quintal) बेचा गया सामान (क्विंटल में)		Average Price (Rs/quintal) औसत कीमत (रुपये / क्विंटल)		Cost of Cultivation खेती की लागत	
	Irrigated सिंचित	Rainfed बारानी		Main मुख्य फसल	By product गौण पैदावार	Main मुख्य फसल	By product गौण पैदावार	Main मुख्य फसल	By product गौण पैदावार	Labour श्रम की लागत	Other inputs अन्य उत्पादक सामग्री
1.											
2.											
3.											
4.											
5.											
6.											
7.											
8.											
9											
10.											

Note: Other inputs include costs of hiring plough/tractors for ploughing, levelling, lining (tisiya), weeding and harvesting; fuel cost of irrigation; cost of seeds, fertilizer, pesticides, weedicides and all other inputs for each of the crops. अन्य आदानों में शामिल हैं - जुताई के लिए हल / ट्रैक्टर की धरती को समतल करने के लिए, अस्तर, निराई और कटाई की लागत; सिंचाई के ईंधन की लागत; बीज, उर्वरक, कीटनाशक, weedicides और अन्य सभी आदानों प्रत्येक फसलों की लागत के लिए।

Code: Source of Irrigation-River/Stream नदी / धारा=1, Dam/Reservoir बांध / जलाशय=2, Canal नहर=3, Check dam रोक बाँध=4, Dug-Well कुआं =5. Tube well नलकूप=6, Farm Pond खेत तालाब=7, Other अन्य (specify)=8

I. SOIL CONSERVATION PRACTICES AND BENEFITS मृदा संरक्षण प्रथाओं और उनके लाभ

26. How has the household benefitted from IGNP shelterbelts (Please tick the relevant boxes) shelterbelts से परिवार को कैसे लाभ हुआ है? (कृपया प्रासंगिक बक्से टिक कीजिए)

Benefits लाभ	Agro-Forestry/ Plantation कृषि वानिकी / पेड़ लगाना	Anchoring sand dunes रेत के टीलों की एंकरिंग	Soil improvement - leaf litter मृदा सुधार - घासफूस	Better groundwater availability बेहतर भूजल उपलब्धता	Reducing wind speeds हवा की गति का कम करना	Fuel wood & timber ईंधन की लकड़ी और इमारती लकड़ी	Livestock Support – fodder पशुधन समर्थन - चारा	Livestock Support – shelter पशुधन समर्थन - आश्रय	Any Other अन्य कोई
Whether Benefitted यदि लाभ मिला									
How useful are they? (code) कैसे उपयोगी? (कोड)									

Code: extremely useful अत्यंत उपयोगी =1, very useful बहुत उपयोगी =2, somewhat useful कुछ हद तक उपयोगी =3, not at all useful बिल्कुल उपयोगी नहीं =4

27. Plot Characteristics and Soil Conservation Measures adopted by the Farmer in each of the Plot प्लॉट के विवरण और मृदा संरक्षण के उपाय

Plot Name प्लाट नाम	Area (In bigha) क्षेत्र (बीघा में)	Land Tenure (use code) पट्टेदारी (कोड)	Distance from home (in km) घर से दूरी (किमी में)	Source of Irrigation (use code) सिंचाई के स्रोत (कोड)	Distance from Irrigation Source (in kms) सिंचाई स्रोत से दूरी (किलोमीटर में)	Irrigation Technology (use code) सिंचाई प्रौद्योगिकी (कोड)	No. of Crops Grown in a Year इस साल में फसलों की संख्या	No of Crops grown before the shelterbelts shelterbelts से पहले उगाई फसलों की संख्या	Soil Type (use code) मिट्टी के प्रकार (कोड)	Soil depth (in ft) मिट्टी गहराई (फुट में)	Soil Fertility मिट्टी की उर्वरता	% of sloped land % भूमि की ढलान	Soil erosion status (use code) मिट्टी का कटाव का दर्जा (कोड)	Shelter belt (use code)	Other soil conservation measures* (use code) अन्य मृदा संरक्षण के उपाय (कोड)	Cost of Conservation Measures संरक्षण के उपायों के लागत		No. of trees पेड़ों की संख्या
																Initial Cost	Annual Maintenance	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)

Codes:

(3) Land tenure पट्टेदारी: Owned खुद का =1, leased-out पट्टे पर दिया =2, shared –out साझा-बाहर =3, leased-in पट्टे पर पाया =4, shared-in साझा-में =5

(5) Source of Irrigation सिंचाई के स्रोत: River/Stream नदी / धारा =1, Canal नहर =2, Check-dam रोक बाँध =3, Dug Well कुआं =4, Tube Well नलकूप =5, Farm Pond खेत तालाब =6

(7) Irrigation Technology सिंचाई प्रौद्योगिकी: Flood irrigation बाढ़ सिंचाई =1, Drip Irrigation टपकन सिंचाई =2, Sprinklers छिड़कनेवाला साधन =3, Other अन्य = 4

(10) Soil type मिट्टी के प्रकार: Yellowish Brown पीले भूरे रंग =1, Reddish Brown लाल भूरे रंग =2, Dark Brown गहरा भूरा =3, Loamy sand चिकनी बलुई मिट्टी =4, Mixed मिश्रित =5

(12) Soil fertility मिट्टी की उर्वरता: Very Poor बहुत कम उपजाऊ =1, Poor कम उपजाऊ =2, Good अच्छा उपजाऊ =3, Very Good बहुत अच्छा उपजाऊ =4

(14) Soil erosion status मिट्टी का कटाव**: No erosion कोई कटाव नहीं =1, Medium erosion मध्यम कटाव =2, High erosion बहुत कटाव =3, Erosion only incase of heavy rainfall/wind storm कटाव केवल भारी वर्षा में / आंधी तूफान में =4**

(15) Shelter belt: Plantation done under IGNP IGNP के तहत किया =1, Plantation done under other project किसी भी अन्य परियोजना के तहत =2, Plantation done from own sources स्वयं के स्रोतों से किया =3, Plantation not required shelterbelt की आवश्यकता नहीं =4, Plantation urgently required or more plantation required आश्रय बेल्ट की आवश्यकता =5

(16) Other Conservation Measures अन्य मृदा संरक्षण के उपाय**: Yes, adopted अन्य उपाय अपनाया =1, Not adopted any other measure किसी भी अन्य उपाय को नहीं अपनाया =2**

* If Yes, Specify the measures विवरण दें: a)________________________________ b) ______________________________

c)____d)_______________________________

If No, specify why no other measures adopted यदि नहीं, तो क्यों कोई अन्य उपायों को नहीं अपनाया:

a) Not required आवश्यकता नहीं ◯

b) Required but don't know what to do आवश्यकता है लेकिन क्या करना है पता नहीं है ◯

c) Required but can't afford it आवश्यकता है लेकिन अपनाने के लिए महंगा , ◯

d) Others अन्य, Specify____

28. What modern farming equipment/machineries you use? आप क्या आधुनिक खेती के उपकरण / मशीनरी का उपयोग करते हैं?

Sl No	Name नाम	Tick if you hire किराये पर (✓)	Hiring Charges (Rs per Hr) किराया (प्रति घंटे रुपए)	Tick if you have purchased खरीदा (✓)	Year of Purchase खरीद के वर्ष
1	Tractor ट्रैक्टर				
2	Power Tiller पावर टिलर				
3	Rotavator रोटावेटर				
4	Pitter or Ridger हलकी या रिजर				
5	Sprayer छिड़कनेवाला यंत्र				
6	Drip Irrigation Pipes ड्रिप सिंचाई पाइप				
7	Sprinkler फव्वारा				
8	Reaper कटनी करने वाला				
9	Harvester फ़सल काटने की मशीन				
10	Winnower फटकना की मशीन				
11					

29. Shelterbelts planted under IGNP and Forest Department project
IGNP और वन विभाग परियोजना के तहत लगाए shelterbelts

1	Total no. of Plots in village गांव में भूखंड की कुल संख्या	
2	No. of plots in which shelter belt is required भूखंडों की संख्या जिनमे आश्रय बेल्ट की आवश्यकता है	
3	No. of plots where some or other form of shelter belt existed भूखंडों की संख्या जहां shelterbelt अस्तित्व में था	
4	No. of plots where shelter belts have been planted under IGNP भूखंडों की संख्या जहां shelterbelts IGNP के तहत लगाए गए हैं	
5	No. of plots where shelter belts planted under other projects भूखंडों की संख्या जहां shelterbelts अन्य परियोजनाओं के तहत लगाए	

30. If no shelter belt was planted under IGNP in your farm, what is the reason? यदि आश्रय बेल्ट अपने खेत में IGNP के तहत नहीं लगाया गया था, तो क्या कारण है?

Sl. No	Reasons (Specify if it's not amongst the reasons listed) कारण	Please Tick
1	My plots are not in the treatment area of the project मेरे भूखंड परियोजना के उपचार के क्षेत्र में नहीं हैं	
2	There was no provision to plant shelter belt on my farm मेरे खेत पर shelterbelt संयंत्र के लिए कोई प्रावधान नहीं था	
3	I didn't agree as I didn't know the benefits मैं सहमत नहीं था क्योंकि लाभ नहीं पता था	
4	I knew the benefits but didn't agree as I had standing crops लाभ पता थी लेकिन उस समय खेत में फसल खड़ी थी	
5		
6		
7		

31. Do you think the shelter belts under IGNP are effective?
32. क्या आपको लगता है IGNP के अंतर्गत शरण बेल्ट प्रभावी रहे हैं? Yes ◯ No ◯

J. SOCIO-ECONOMIC INFORMATION

15. House Particulars घर का ब्यौरा

1	Is the household electrified? क्या घर में विद्युतीकरण है?	Y ☐ N ☐
2	What is the source of drinking water? पीने के पानी का स्त्रोत क्या है?	Own Tubewell घर का नलकूप ☐ Own Well घर का कुंआ ☐ Community Tubewell समुदाय नलकूप ☐ Community Well समुदाय कुंआ ☐ Piped water supply नल-जल ☐
3	Does the household have BPL card? क्या परिवार के पास BPL कार्ड है?	Y ☐ N ☐
4	Does the household get ration from Public Distribution System? क्या घर को सार्वजनिक वितरण प्रणाली से राशन मिलता है?	Y ☐ N ☐ यदि हाँ, तो किस के अंतर्गत If Yes, which type (APL, BPL, Antyodaya, Annapurna yojana scheme or any others?)
5	Do any of members of the household have MNREGA job card ? क्या नरेगा जॉब कार्ड है? If Yes, how many days in total worked and how much money received under MNREAGA Wages last year? यदि हाँ, क्या किसी सदस्य ने मनरेगा के अंतर्गत कार्य किया है?	Y ☐ N ☐ Number of Job Cards जॉब कार्ड की संख्या :___________ Total Number of Days worked कुल दिनों की संख्या में काम किया :___________ Total Wage received कुल वेतन प्राप्त:__________________
6	How many rooms in your house? घर में कितने कमरे हैं?	
7	Type of House? घर का प्रकार	Mostly Pucca पक्का ☐ Mostly Kutcha कच्चा ☐ Mixed मिश्रण ☐
8	Whether benefitted from Indira Aawaas Yojana (IAY) or other scheme? यदि IAY या किसी अन्य योजना का लाभ उठाया है?	Y ☐ N ☐

16. Livestock Holding

Sl. No	Livestock पशु	Number of Livestock Now पशुधन की संख्या		Number of Livestock 20-25 years back पशुधन की संख्या 20-25 साल पहले	
		Total Number कुल संख्या	Milch Animals दुधारू पशु	Total Number	Milch Animals

				कुल संख्या	दुधारू पशु
1	Bullocks बैल				
2	Cow गाय				
3	Buffalo भैंसा				
4	Buffalo भैंस				
5	Calves बछड़ा				
6	Goat बकरी				
7	Sheep भेड़				

17. Cooking Fuel and Collection of Firewood

1.What are the cooking fuels used? खान पकाने के लिए किस इंधन का प्रयोग करते हैं	Fuels	Tick if use	
	Firewood ईंधन की लकड़ी		
	Twigs टहनियाँ		
	Dungcakes उपले		
	LPG		
	Dry Leaves सूखी पत्तियाँ		
	Agl. Residues कृषि अवशेष		
	Ele. Heater इलेक्ट्रिक हीटर		
2. Where do you cook? खाना कहाँ पकता है ?	Mostly in Kitchen ☐ Mostly Outside ☐ अधिकतर रसोई में ☐अधिकतर बाहर☐		

3. How many times in a week you collect firewood? 3. सप्ताह में कितनी बार ईंधन के लिए लकड़ी एकत्रित करते हैं?	
4. Approximate quantity of firewood collected each time? (In Kgs) 4. सप्ताह में एकत्रित लकड़ी की मात्रा (लगभग)	
5. How many hours it takes to collect? (in hours) 5. इसे इकट्ठा करने में कितने घंटे लगते हैं?	
6. How much firewood you collect per year? (approximate quantity in Kgs) 6. सालाना एकत्रित लकड़ी की मात्रा (किलो)	
7. What percentage of the firewood is the greenwood?	

7. इसमें से कितने प्रतिशत लकड़ी हरी होती है?				
8. What are the sources of fuel wood? ईंधन की लकड़ी का स्रोत क्या हैं?				
Source स्त्रोत	Forest वन	Village Commons गांव के मैदान	Private Sources निजी स्त्रोत	Any Other अन्य
Tick if use				

18. Collection of Fodder चारे का संग्रह

1. How do you feed your livestock? Please tick आप अपने पशु को क्या खिलाते हैं? Grass and Tree fodder घास और पेड़ चारा ☐ Agricultural residues कृषि अवशेष ☐ Commercial fodder वाणिज्यिक चारा ☐
2. What are the sources of fodder for households? चारे की स्रोत? Forest वन ☐ village commons गांव के मैदान ☐ private lands निजी भूमि ☐ Stall Feeding स्टाल चराई ☐ others अन्य ☐

19. Other Dependence on Forest वन निर्भरता

1.For Agriculture Use कृषि उपयोग के लिए	लघु लकड़ी व खेती बाढ़ी के लिए खम्बे। हाँ ☐नहीं ☐. यदि हाँ, तो मात्रा सूखे पत्ते आदि। हाँ ☐ नहीं☐. यदि हाँ, तो मात्रा बाड़ के लिए सामान। हाँ ☐ नहीं ☐. यदि हाँ, तो मात्रा
2. For House Construction गृह निर्माण के लिए	लकड़ी हाँ ☐ नहीं ☐ .यदि हाँ, तो मात्रा लघु लकड़ी व खम्बे हाँ ☐नहीं☐ .यदि हाँ, तो मात्रा छप्पर के लिए घास हाँ ☐नहीं ☐ .यदि हाँ, तो मात्रा

3. Foods and Fibres खाने का पदार्थ और रेशे	जड़ें। हाँ नहीं . यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में सब्जियाँ। हाँ नहीं . यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में फल आदि। हाँ नहीं . यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में गोश्त। हाँ नहीं . यदि हाँ, तो कितनी जल्दी बार ? किस ऋतू में
4. Medicinal Plants औषधिक जड़ी बूटियाँ	

20. Household Demography

S.No क्रमांक	Name नाम	Age आयु	Gender लिंग	Relationship to head मुखिया से सम्बंध	Literate साक्षर	If Yes, number of years of education यदि हाँ, शिक्षा के वर्षों की संख्या	Occupation (Primary) मुख्य व्यवसाय (use code)	Occupation (Secondary) अनुपूर्वक व्यवसाय (use code)
1.			M □F □		Y □N □			
2.			M □F □		Y □N □			
3.			M □F □		Y □N □			
4.			M □F □		Y □N □			
5.			M □F □		Y □N □			
6.			M □F □		Y □N □			
7.			M □F □		Y □N □			
8.			M □F □		Y □N □			
9.			M □F □		Y □N □			
10.			M □F □		Y □N □			
11.			M □F □		Y □N □			

Occupation codes: *own farm activities स्वयं के खेत =1, agricultural labourer कृषि श्रम =2, animal husbandry पशुपालन =3, domestic work घरेलू कार्य =4, non-agricultural labourer गैर कृषि श्रम =5, petty trade/business व्यापार / व्यवसाय =6 , collection of NTFP and sale NTFP संग्रह और बिक्री =7, trade/business of forest based products वन आधारित उत्पादों के व्यापार / व्यवसाय =8, mason मिस्त्री =9, driver ड्राइवर =10, carpenter सुतार / खाती =11, traditional family occupation पारंपरिक परिवार उपजीविका =12 , salaried employment (govt) सरकारी नौकरी = 13, salaried employment (non-govt) प्राइवेट नौकरी =14, pension holder पेंशन धारक =15, , migrant worker (seasonal) मौसमी प्रवासी मजदूर =16, migrant worker (whole year) प्रवासी कर्मचारी (पूरा साल)=17, not working (old age, illness, disabled) काम नहीं कर रहा (बुढ़ापा, बीमारी, विकलांग)=18 studying छात्र=19, Any Others अन्य =20.*

21. **Sources of Income for the Household** परिवार की आमदनी के स्त्रोत

Sl No	Sources	Last Year i.e. 2015 पिछले साल			Before Twenty Years i.e. 1995 20 साल पहले		
		Yes=1, No=2	Approximate Income (in Rs.) अनुमानित आमदनी		Yes=1, No=2	Approximate Income (in Rs.) अनुमानित आमदनी	
1.	Agriculture खेती						
2.	Livestock पशुधन						
3	Wage employment मजदूरी रोजगार						
4	NTFP Sale/Other Forest Based Enterprises NTFP बिक्री / अन्य वन आधारित उद्यम						
5	Salary वेतन						
6	Business व्यापार						
7	Remittances प्रेषित धन						
8	Pension पेंशन						
9	Transfer Benefits स्थानांतरण लाभ						
10	Rent from leased out land/room भूमि या कमरे से किराया						
11	Others, if any अन्य, यदि है						
12	Total कुल						

<u>**Thank You so much for your kind cooperation**</u>