UNDERSTANDING LIVELIHOOD IMPACTS OF CLIMATE CHANGE IN THE UPPER GANGA BASIN: A CASE STUDY APPROACH

Major Project Thesis

Submitted by

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The study was undertaken at The Energy and Resources Institute (TERI),
New Delhi.

DECLARATION

This is to certify that the work that forms the basis of this project "UNDERSTANDING LIVELIHOOD IMPACTS OF CLIMATE CHANGE IN THE UPPER GANGA BASIN: A CASE STUDY APPROACH" is an original work carried out by me and has not been submitted anywhere else for the award of any degree.

I certify that all sources of information and data are fully acknowledged in the project thesis.

YAMINI YOGYA

Date: 27th May 2015

CERTIFICATE

This is to certify that YAMINI YOGYA has carried out her major project in partial fulfillment of the requirement for the degree of Master of Science in ENVIRONMENTAL STUDIES AND RESOURCE MANAGEMENT on the topic "UNDERSTANDING LIVELIHOOD IMPACTS OF CLIMATE CHANGE IN THE UPPER GANGA BASIN: A CASE STUDY APPROACH" from December 2014 to May 2015. The project was carried out at THE ENERGY AND RESOURCES INSTITUTE (TERI).

The thesis embodies the original work of the candidate to the best of our knowledge.

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LIST OF ABBREVIATIONS

CID	Cognitive Interpretation Diagram
DFID	Department for International Development
FCM	Fuzzy Cognitive Map
FGD	Focus Group Discussion
GLOF	Glacial Lake Outburst Flood
HI-AWARE	Himalayan Adaptation, Water and Resilience
IFAD	International fund for Agricultural Development
INCCA	Indian Network on Climate Change Adaptation
IPCC	Intergovernmental Panel on Climate Change
NATCOM	National Communications
NGO	Non-Governmental Organisations
NTFP	Non Timber Forest Produce
PRA	Participatory Rural Appraisal
SAPCC	State Action Plan on Climate Change
SLA	Sustainable Livelihoods Approach
TERI	The Energy and Resources Institute
UGB	Upper Ganga Basin
UNFCCC	United Nations Framework Convention of Climate Change
UNSIDR	United Nations International Strategy for Disaster Reduction
WGII	Working Group II
WWF	World Wildlife Fund

ABSTRACT

Although impacts of climate change on livelihoods have been documented, there is insufficient knowledge on appropriate adaptation strategies. Given the changing climate, it is an urgent imperative for communities with vulnerable livelihood options to adapt. Hence, adaptation to climate change is no longer a secondary or long-term response measure, but seems to be the only resort. Studies have shown that effective adaptation can be attained through actions that focus on addressing the vulnerabilities of the poor, since climate change affects them disproportionately. Following thus, the current study aims to explicate the perceived climatic stressors and subsequent impacts on livelihoods of communities residing in the Upper Ganga Basin. Fuzzy cognitive maps have been used under the Sustainable Livelihood Approach framework to depict the various impacts and inter-linkages between the variables, while providing a comprehensive understanding of the impacts of different asset categories within each livelihood group. This process of mapping livelihood impacts has been carried out for livelihood groups in six villages across different elevations of the Basin. The perceived impacts on different asset classes and livelihood groups are then discussed under a scenario generation exercise to determine acute and critical areas of concern. In view of these impacts and the characteristics of the study sites, possible adaptation options have been discussed, drawing from expert opinions and existing body of literature.

Keywords*: Sustainable Livelihood Approach (SLA), Fuzzy Cognitive Maps (FCM), Adaptation, Livelihoods, Climate Change*

1.0 INTRODUCTION

Human-induced climate change has far reaching and complex impacts on water resources throughout the world. Such impacts through water are cross-sectoral, and are felt across inherently linked sectors of agriculture, energy, ecosystems, and human health. Future climate change or change in climate parameters, such as temperature, precipitation, humidity, evapotranspiration, etc., is said to result in an increase in vulnerability of society and the environment in its capacity to adapt to such a change. Observations by National Communications (NATCOM, 2004) state that a rise in temperature has already been observed in the Indian subcontinent. Projections show that the maximum temperatures are expected to rise by the 2050s by 2°C–4°C over South India, and that temperature is likely to increase by more than 4°C over Northern India. Similarly, the recent Indian Network for Climate Change Assessment (INCCA) report indicates accelerated warming trends for the period 1971-2007 which is mainly attributed to the increase in average air temperatures in winter and post–monsoon seasons. The mean temperature has increased by 0.2°C per decade for this period, resulting in a much steeper increase in minimum temperature than maximum temperature (GoI, 2010).

The current study, as part of the Himalayan Adaptation, Water and Resilience (HI-AWARE) research project, focuses on climate change in the Upper Ganga Basin. It seeks to explore the intersection between water resources, climate change, and adaptation in the Upper Ganga Basin, one that is vital to livelihood activities in different elevations of the Basin. Climate change is said to affect flows in rivers originating from Himalayan tributaries, and this is a serious threat to the sustainability of downstream water resources throughout the densely populated Gangetic plain. Runoff from mountain basins is particularly likely to be more susceptible to climatic warming since much of such flow is derived from melting of seasonal snow-pack and glacier ice. Snow and glacier melt contributions to major Himalayan rivers influenced by the monsoon are substantial, with on average from 35% of annual flow, estimated for the Beas at Pandoh dam (Kumar et al., 2007), to 60% for the Satluj at Bhakra dam (Singh and Jain, 2002). Snow- and ice-melt make significant contributions to total flow in both spring and fall and therefore, changes in the ice-melt component of runoff as glacier area decreases with declining glacier mass will consequently affect future water availability.

While there has been a reasonable amount of debate regarding the magnitude of recent climate change in the Himalayas (Bhutiyani et al., 2008; Krishnamurthy et al., 2009), extreme events appear to affect the Ganges basin more frequently and create flooding (Bookhagen, 2010; Thayyen and Gergan, 2010; Goswami et al., 2006; Singh et al., 2008). Indications of change in the frequency of droughts, however, are ambiguous (Moors et al., 2011). Changes in water demand and water availability, driven by projected population and economic growth, along with lifestyle changes, is exacerbated by climate change. In light of such cumulative impacts of climate change on society and the environment, it is of significance to enhance adaptive capacities and climate resilience of the poor and vulnerable women, men, and children, through the development of robust evidence to people-centered and gender-inclusive climate change adaptation policies for improving livelihoods. Such strategies for adaptation to climatic variation and other changing circumstances may decrease the adverse effects of climate change, while capitalizing on the opportunities presented by these changes (Smit et al. 2000; Carter et al. 1994). Adaptation can be divided into planned and autonomous adaptation. Governments or non-government organization usually undertake planned adaptations as a part of public policy initiative. "*These adaptations are conscious effort or response policies taken up by organization in concern to climate chang*e" (IPCC, 2007a). On the other hand autonomous adaptation refers to ''*those actions that are taken up by individual institutions, communities and individuals independently and not as a conscious response to climatic stimuli. It is triggered by ecological changes in natural systems and by market or welfare changes in human systems''*. It is also called spontaneous adaptation (IPCC 2007a). Autonomous actions are usually 'short-term modifications', and are often considered as a 'reactive or bottom-up approach' while planned are considered 'long term and having a top down approach' (The World bank, 2013). Reactive, proactive, private and planned are other ways to segregate adaptation options.

According to IPCC (2007a) adaptation involves changes in social and environmental processes, perceptions of climate risk, practices and functions to reduce potential damages or to realize new opportunities. In practice, adaptations measures to address climate change need to be dynamic, rather than discrete action, as climate change is considered as a 'wicked problem' where all the factors and elements are always in a state of flux (Bernstein et al., 2010). Useful tools for adaptive policy (re) design and implementation include: enabling self-organisation, decentralising decision making, promoting variation in policy responses, multi stakeholder deliberation, integrated and forward looking analysis, formal policy review, and continuous learning for improvements (Swanson and Bhadwal, 2009). However, the impacts of climate change on various livelihoods and its subsequent consequences have not been adequately addressed in the development of adaptation strategies (Bates et al. 2008). The majority of literature pertaining to the livelihood impacts of climate change focus almost entirely on agriculture. Whereas such an approach is justified while considering the country as a whole, given that India is a predominantly agrarian economy, the same becomes insufficient while dealing with livelihoods at a micro level. The current study does not overlook agriculture, but looks beyond it as well, in an attempt to map impacts of climate change on different livelihoods found in the Upper Ganga Basin and arrive at possible adaptation options.

The purpose of the study is to identify, consolidate and assess perceived climate change impacts on rural livelihoods in three different elevations of the Upper Ganga Basin, mapped through asset categories. The study further aims to identify crucial areas or impacts that require immediate adaptation action arrived at through scenario generation and determine subsequent possible adaptation options in light of the study sites against a set of indicators.

Section 2 of the study outlines the background of the HI-AWARE project and explains the rationale behind the study presented in this thesis. Section 3 covers the specific objectives of the study. Section 4 presents a literature review. Section 5 provides a brief overview of the study area. Section 6 explains the resources and methods used for data collection and for the analysis of results. Section 7 presents the results and discussions of the study and Section 8 concludes the study. Section 9 lists references.

2.0 Background and Rationale

2.1 Background

International Development Research Center and Department for International Development, Government of United Kingdom, have partnered to support a collaborative adaptation research in Africa and Asia until 2019. CARIAA, Collaborative Adaptation Research in Africa and Asia, aims to build the resilience of vulnerable populations and their livelihoods in these three hot spots by supporting collaborative research to inform adaptation policy and practice. The research aims to target climate change hotspots in Asia and Africa, which have been classified into Semi-arid Regions, River Basins, Deltas. Since such research on climate change adaptation demands collaboration across disciplines, each of the projects are carried out by a consortium which brings together five institutions with a range of regional, scientific and socio-economic development expertise.

HI-AWARE is one such consortia that is working on high calibre research on climate resilience and adaptation in the mountains and flood plains of the Indus, Ganges, and Brahmaputra river basins. Climate change induced change in precipitation, glacier retreat and melts, would have serious implications on this region. The Hindu Kush Himalayan region is often regarded as the Water Tower of Asia, giving rise to numerous rivers that help sustain more than 1.3 billion lives both in the mountains and plains in the region. Any changes in the above-mentioned parameters would have far reaching consequences affecting the livelihoods of millions of people and endangering critical biodiversity hotspots that would alter the human-environment interaction. Any change in precipitation would have serious implications on the farming community in the region and would pose a threat to food security of the region, such impacts are more magnified since most of the farmers in this region depend on rain fed irrigation systems for their agricultural produce. It has already been established that climate change would increase the occurrences of extreme events having serious implications on water availability, health and livelihood opportunities of the people living in these regions. This coupled with changes in demographic and socioeconomic changes will aggravate their vulnerabilities to changes in climate.

Communities residing in these regions have been autonomously adapting to the changes, however given the changing climate, action id required. In this light, planned adaptation strategies are the need of the hour, which can be achieved by better understanding the livelihood impacts of climate change and drivers of vulnerability, along with the interplay between them. Possible adaptation measures could be tried and tested for their efficacy and implementability. This would ensure in up-scaling and out-scaling these strategies. The HI-AWARE project aims to achieve this in its study areas of Indus, Ganges and Brahmaputra river basins.

The current study thus, focuses on assessing the climate change induced impacts of livelihoods within the Upper Ganga Basin which is a part of the Ganges Basin study area, for the project is being presented in this thesis.

2.2 Rationale

Identification of appropriate adaptation turning points and pathways, calls for a comprehensive understanding of the external environment that a project is set in. While there have been a fair number of projects focusing on adaptation action, lack of adequate ground expertise, standard methodologies to execute projects and lack of long-term funding hinder the implementation of such projects, leading to discontentment among stakeholders. It therefore becomes imperative to realize the interplay between the perceived impacts of climate change on the livelihood of communities in question and the factors contributing to the vulnerability the same. Such an understanding will serve to assist in developing appropriate and efficient policy measures.

Following thus, the current study aims to capture the perception of communities residing in the Upper Ganga Basin regarding climate change impacts on livelihood activities, through a bottom-up approach. An understanding of the various factors contributing to and compounding the impacts felt by different livelihood groups, aids in identifying core areas that require immediate adaptation action. The study also seeks to explore the reasons behind differences in perceptions of climate change impacts felt by various livelihood groups across elevations in the Basin.

The rationale of this study further includes identifying possible adaptation options for livelihood groups in question based on perception of impacts. This exercise stands to be helpful to a wider audience; it enables policy makers to identify critical areas of impact to focus on and it provides guidance to researchers by presenting a sense of the prevalent impacts as felt by communities. Finally, interactions with communities regarding the impacts of climate change on livelihood activities, raise a sense of awareness among stakeholders with respect to the factors contributing to such a change, and could potentially lead to informed decisions as regards environmental protection.

3.0 OBJECTIVES

The specific objectives of the study are:

1. To analyze perceived impacts of climate change on livelihoods of communities residing in different elevations (low, mid and high) of the Upper Ganga Basin.
2. To assess future impacts of climate change on livelihoods based on current perceptions (from Objective 1), through Scenario Generation.
3. To identify elevation-specific and elevation-generic adaptation options.

4.0 LITERATURE REVIEW

Mountains are early indicators of climate change (Singh *et al*. 2010). The Himalayas are known as the Water Tower of Asia, covering an area of about 7 million square kilometres. Climate-change impacts are being observed occurring in the Greater Himalayas over the past decade (Beniston 2003; Cruz et al. 2007). The projected changes include rise in temperatures (IPCC), erratic rainfall (both increasing and decreasing trends have been observed), glacial retreat (Dyurgerov and Meier, 2005), increase in run-off from mountains affecting low-lying regions (e.g., Barnett et al., 2005; Graham et al., 2007), increase in water-related hazards (UNISDR, 2007), cascading effects on river flows, groundwater recharge, biodiversity and natural hazards biodiversity; ecosystem composition, function and structure; and human livelihoods (Nijssen et al. 2001; Parmesan 2006; Bates et al. 2008; Ma et al. 2009). Rapid reduction of glaciers is the most widely reported effect, which in turn has implications for future downstream water supplies (Yao et al. 2004; Barnett et al. 2005; IPCC 2007*b*; Nogues-Bravo et al. 2007). Other impacts include decrease in endemic plant species (Mutke & Barthlott 2005; Salick et al. 2009), extinction of species species from mountains not high enough to offer escape routes in the case of upward shifts of taxa (Becker et al. 2007) and invasion of weedy and exotic species from lower elevations (McCarty 2001) (Xu et al., 2009)

In light of GLOF events, the safety of hydroelectric power plants and infrastructure is a major concern (Rupper et al. 2012), and since India is planning a number of hydroelectric projects in the Himalayas (Jain et al. 2012), this remains a concern. Riparian countries of the Ganga River Basin have faced increased surface air temperatures (Agrawala et al., 2003a, b; Cruz et al., 2007). Increased runoff from glacial retreat and snowmelt would increase annual discharge into the Ganga River in the short term, particularly in the Upper Ganga Basin (Barnett et al., 2005; World Bank, 2009). Additionally, higher air surface temperatures are expected to change form of precipitation from snow to rain, thereby increasing floods, further exacerbating the extent of climate change impacts. (Sud et al., 2015)

Water is a quintessential component of life, livelihoods and prosperity, but has also been seen to lead to death, devastation, and poverty (Grey & Sadoff

2007). The fairly recent 2013 floods are an example. Water-related risks and hazards are omnipresent in the Greater Himalayas, and the frequency of debris inflow, landslides and flash floods is only said to increase (Xu & Rana, 2005). Significant fluctuations in snowfall have been projected and will likely result in excessive or insufficient water supply flows (Xu et al, 2009). Shifting focus to the context of India, goods and services being offered by the rivers in India are being adversely affected by changes in quantity, quality and flow. The growing demand of water for agriculture, domestic, industrial and energy needs is leaving the river dry and polluted (WWF, 2010).

It has been observed that climate change disproportionately affects the poor and marginalised sections of society by adversely affecting their means of livelihood. In India, most of the rural population depends on agriculture for a sustained source of income. Some of the most crucial impacts of climate change felt in developing countries, affect ‘‘subsistence’’ or ‘‘smallholder’’ farmers to a greater extent (Morton, 2007). This vulnerability is subject to the location of the country and other socio-economic, demographic and policy trends hindering their adaptive capacities. Very few studies assess effectively the existing adaptive capacities and vulnerabilities of communities in these regions. In such cases, effective human adaptation to same includes the establishment of adaptive capacity—knowledge and governance—and adaptation itself (for example, changes in behaviors and livelihood practices to meet new conditions) (Smit & Pilifosova 2001; Mirza 2007).

Given that climate-change induced risks are only said to rise in the river basins of the Himalayas, a natural process of gradual adaptation alone cannot eliminate impacts. While mountain communities use traditional ecological knowledge and customs to cope with natural hazards, (Xu & Rana 2005; Byg & Salick 2009), government bodies are required to act now in order to reduce future negative consequences. For instance, floods are triggered by precipitation, but protection walls, biostabilization of slopes, and terracing of farmlands can prevent impacts of floods on livelihoods. Such measures can also reduce damage from landslides and rockfalls, another major hazard seen in the Upper Ganga Basin.

Despite the projected impacts for the Himalayan region and information on the potential impacts of climate change are increasingly available, research on climate change vis-à-vis its impact on ecosystems (e.g., forests, water, agricultural resources, etc.) is still in an infancy stage. To reduce vulnerability of mountain communities and to safeguard the means of livelihood, it is essential that the climate-induced impacts on livelihoods of these communities needs to be identified, preferably through a bottom-up approach in order to assimilate local perceptions, cultural concepts and aspirations for more socially-inclusive adaptation efforts.

This calls for planned adaptation measures, which is discussed as part of the study. The objective of providing recommendations for planned adaptations shares the opinion of Intergovernmental Panel on Climate Change (IPCC) that autonomous adaptations are far from adequate for coping with changes in the climate (IPCC WGII, 2007). Adaptation initiatives by communities are not a substitute for reducing greenhouse gas emissions, but are a necessary measure to manage impacts of climate change (Smit and Pilifosova, 2007). In the same vein, Burton, Diringer and Smith (2006) have also stated that the success of adaptation to climate and building of adaptive capacity is heavily dependent on development options and choices. In 2006, Dessai and Hulme stated that the elements of successful adaptation include effectiveness, equity, efficiency, and legitimacy. These statements support the fact planned adaptation measures are required for effective adaptation action.

The United Nations Framework Convention on Climate Change (UNFCCC, 2011) has listed three objectives that a planned adaptation should consider:

1. Minimise or avoid all or only part of the expected or observed impacts;
2. Return levels of human well-being to pre-climate change levels;
3. Maintain current levels of risk or as a minimum reduce them cost-effectively within agreed budgets or pre-defined acceptable levels.

The concept of planned adaptation require to adhere to the perceptions of multiple stakeholders involved, thus making planning of an adaptation measure an intricate and long-drawn process. Adding to this complexity, the degree of uncertainty with regard to climate change hinders implementation and funding for the measure (Smit and Pilifosova, 2007). The question for planned adaptation that then arises is concerning the appropriate measures that should be untaken to facilitate adaptation to climate change. This would involve identification and a comprehensive understanding of socio-economic and ecological conditions of the region and livelihood activities of communities, which would aid in evaluation of potential adaptation options (Smit et al., 1999).

As far as mountain ecosystems are concerned, Jodha (1992, 1994) developed the concept of 'Mountain Perspective', emphasizing the need for implicit and explicit of specific mountain conditions and characteristics and the subsequent implications, while designing and implementing development activities in mountain regions. The current study thus aims to understand the varied aspects of livelihood impacts of climate change in the Upper Ganga Basin through the perspective of communities, employing a bottom-up approach, and to present possible elevation specific adaptation options, that could guide further research before implementation.

5.0 STUDY AREA

The study sites under the HI-AWARE project have been chosen in three different elevations of the Upper Ganga Basin. A total of seven villages have been scoped during the course of this study, two each in the plains and the high hills, and three in the mid elevation. All of the scoped villages lie in the Garhwal region of the state of Uttarakhand. The villages along with the districts have been indicated in the map below.

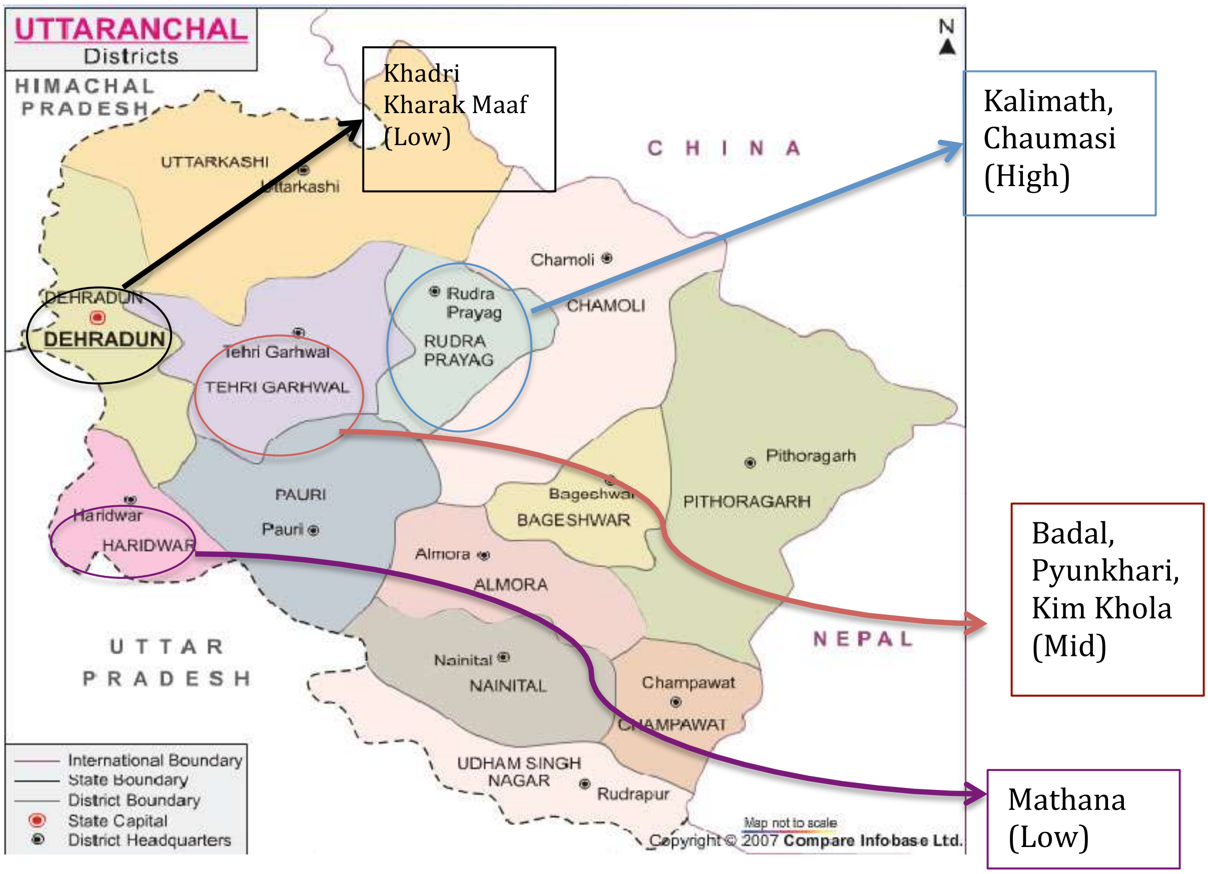

Figure 1: Map of Uttarakhand depicting Study Sites

The demarcation of the elevation for the study sites as decided upon by the project guidelines are as follows: low elevation: 0-500m, mid elevation: 500m-1500m and high elevation: >1500m. Following is the list of villages scoped and the respective elevations:

Village	Elevation Category	Average Elevation
Mathana	Low	250m
Khadri Kharak Maaf	Low	350m

Badal	Mid	620m
Pyunkhari, Kim Khola	Mid	1200m
Kalimath	High	1700m
Chaumasi	High	2200m

The study sites have been discussed in fair detail in Section 7 (Results). The criterion behind the selection of study sites is part of the wider scope of the HI-AWARE project and has not been explored as part of the current study.

6.0 Resources and Methodology

This section provides an insight into the various concepts and tools used to carry out the study. It helps provide a better understanding of the principles behind the methodology employed.

6.1 Approach: Sustainable Livelihood Approach

A sustainable livelihood has been defined as "A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living; a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long-term", by Chambers and Conway (1992). According to this, a sustainable livelihood is one that is able to cope with and recover from stress and shocks, while simultaneously maintain and enhance its capabilities and assets. The sustainable livelihood asset base consists of five principal capitals or assets (Scoones, 1998):

1. Natural capital: Includes natural resource stocks such as soil, water, air, genetic resources, among others) and environmental services (hydrological cycle, pollution sinks, etc.)
2. Human capital: Includes indigenous knowledge and skills, physical capabilities of labour and health.
3. Economic or financial capital: Includes the financial base in the form of cash, credit/debit, savings and other economic assets.
4. Physical capital: Consists of infrastructure such as buildings, roads, technology, production equipment, etc.
5. Social capital: Refers to the social resource base which consists of networks, social claims, social relations, affiliations, associations, etc.

The Sustainable Livelihoods Approach (SLA) serves as means to improve the understanding of the livelihoods of communities. It draws on the main factors that affect the livelihood of the marginalized sections of society and the typical inter-relations between these factors. As a framework, it proves to be beneficial in planning new developmental activities and in assessing the contribution that existing activities have made to sustain livelihoods. This approach is based around three components (Morse, McNamara and Acholo, 2009):

1. A set of principles guiding the development interventions.
2. Analytical framework to help understand what "is" and what "can" be done.
3. An overall development objective i.e., improving rural livelihoods.

6.1.1 Modified SLA Framework

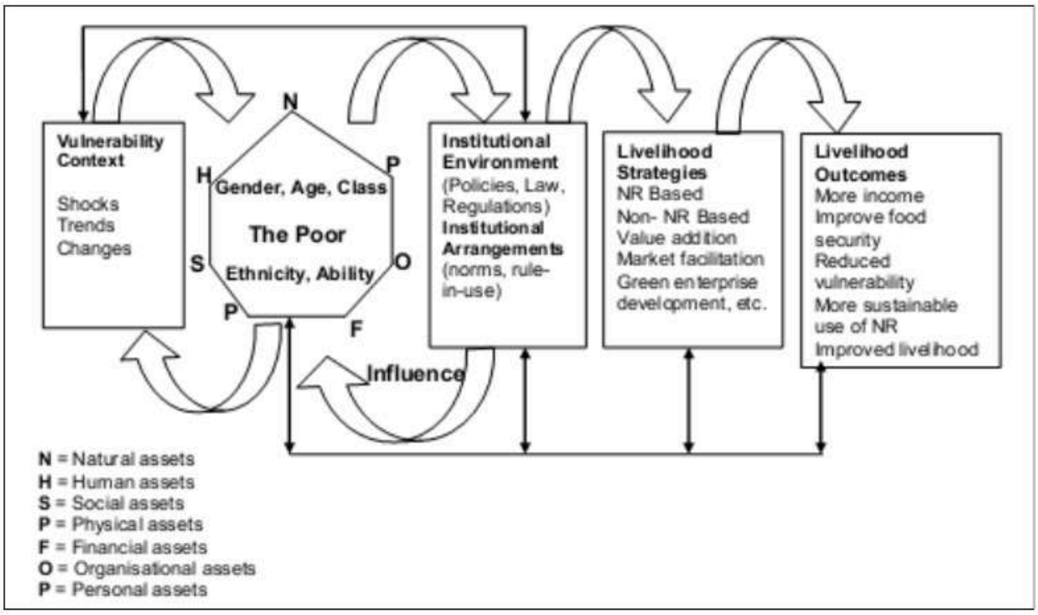

Figure 2: Modified SLA Framework

(Source: Nair, A. and Singh, P.K. 2012, Adapting Rural Livelihoods to Climate Change' Institute of Rural Management Anand (IRMA))

The framework of SLA has been taken from DFID (Department For International Development) and IFAD's (International Fund for Agricultural Development) Sustainable Livelihoods framework. This framework revolves around the "poor", and this is therefore placed at the centre. The assets of the communities in question form the basis for understanding their response to impacts of climate change and also to gauge their coping capacities. The assets (natural, human, social, etc.) are vulnerable to climate variability and extreme climate events, which in turn affect their livelihoods.

In this study, a modified SLA, derived from the DFID and IFAD frameworks has been employed. Here, two dimensions have been added to the existing five asset classes: Personal assets and Organizational capital. Personal asset accommodates the people's perception of themselves, motivation, self-esteem, self-confidence, emotional well-being, spiritual dimensions, etc. Organizational capital consists of civil society organizations, panchayati raj institutions, NGOs working in the region, etc. that work for the people for sustenance of their livelihoods. The impacts of climate change have been obtained using FCMs and presented based on the seven aforementioned asset classes by clustering the impacts accordingly. This methodology tries to provide a better understanding of how the various asset classes are being impacted by climate change and how they in turn influence other assets as a consequence.

6.2 Tools:

6.2.1 Participatory Rural Appraisal

Participatory rural appraisal (PRA) is an approach in development, which aims to incorporate the existing knowledge and opinions of rural people in the planning and management of development projects. Chambers (1994) stated that the more developed and tested methods of PRA include participator mapping and modeling, focus group discussions, transect walks, matrix scoring, well-being grouping and ranking, seasonal calendars, institutional diagramming, trend and change analysis, and analytical diagramming, all undertaken by local people. Among many applications, PRA has been used in natural resources management (soil and water conservation, forestry, fisheries, wildlife, village planning, etc.), agriculture, health, nutrition, food security and programs for the poor (RRA Notes, l988-; IDS, 1993). Using the principles of this tool, focus group discussions with semi-structured interviews were carried out in each of the scoped villages.

Focus Group Discussions:

A focus group discussion (FGD) is an effective way to gather together people from similar backgrounds or experiences to discuss specific topics of interest. The group of participants is usually guided by a moderator (or group facilitator) who introduces topics for discussion and helps the group to participate in a lively and natural discussion amongst themselves. The strength of FGD relies on allowing the participants to agree or disagree with each other so that it provides an insight into how a group thinks about an issue, about the range of opinion and ideas, the inconsistencies and variation that exist in a particular community in terms of beliefs, experiences and practices. FGDs can be used to explore the meanings of survey findings that cannot be quantified, the range of opinions or views on a topic of interest and to collect a wide variety of local terms and practices. In terms of bridging research and policy, FGD can be useful in providing an insight into different opinions among different parties involved in the change process, thus enabling the process to be managed more smoothly (Overseas Development Institute, 2012). Following thus, FGDs were used a tool for on-field analysis in the study, and were conducted across various livelihood groups, and for men and women, and the data collected was used for narratives and fed directly into the FCMs developed.

Hazard Identification

Hazard identification is carried out to highlight the type of hazards prevalent in different study sites. This exercise is typically carried out for natural hazards, such as earthquakes, volcanoes, landslides and flooding, among others. This helps in preventing serious damage and death. This exercise was carried out for the study sites in question to gauge the type of hazards in each elevation, in order to understand the varied parameters of climate change that stand to adversely impact livelihood activities of the communities in question.

Institutional Mapping

Institutional mapping concerns itself with understanding the existing distribution of power. The power to influence the success or failure of a particular management choice or innovation is in the hands of institutions. Institutional mapping can be considered a narrower subset of stakeholder mapping and engagement. It focuses on the key actors, their interactions and the seat of power, who has the ability to influence decisions, and who makes decisions. Such maps show who has the right, by virtue of their office in an organization or participation in an institution, to tell who to do what. Studies indicate that stakeholder mapping and institutional mapping should not be considered as two separate processes but faces of the same coin or two dimensions of the same analytical framework (Aligica, 2006). The term ‘mapping’ presents a good metaphor for the exercise of exploring institutional links (Green, 2007). This exercise has been carried out across elevations in an attempt to map the different institutions present and functional in the villages to better understand the seats of power in the Basin.

6.3 Fuzzy Cognitive Mapping

A cognitive map has been defined by Özesmi & Özesmi (2004) as a quantitative model that depicts how a system operates. It consists of defined variables and causal relationships or links between each of them. These variables can be either measurable physical entities (precipitation, vegetation cover, etc.) or abstract ideas (political forces, aesthetics, etc.). Hence, the cognitive mapping approach is ideal for modeling complex relationships. Such maps can be generated both by the decision makers and the local people, thus allowing for the comparison of differences and similarities in perceptions, perspectives and the effectiveness of different possible policy options. This ensures better acceptance of the chosen policy options by the communities in question due to inclusion of their inputs in the decision-making (Özesmi & Özesmi, 2004). In 1986, Kosko stated that consolidation of different Fuzzy cognitive maps (FCMs) and their visualization through Cognition Interpretive Diagrams (CIDs) allows expansion of existing knowledge bases. FCMs are based on a stakeholder perception and Özesmi (2004) claims that maps of such nature can be created for any kind of issue or problem. Axelrod (1976) explained how the connections (relationships) between the nodes (variables) are represented “A positive edge from node A to node B means A causally increases B. A negative edge from A to B means A causally decreases B”. He also devised a means for representing these maps in an adjacency matrix. Kosko (1986) modified Axelrod’s cognitive maps by replacing binary relations (+, -) with real numbers [-1, 1].

The primary data that is used in this study has been assimilated through fieldwork in the Upper Ganga Basin. The process of collection of data involved focus group discussions and participatory rural appraisal (PRA) activities with stakeholders, here, the major livelihood groups in each village. The tool used to map the climate change impacts on livelihoods was through FCMs. Details that could not be documented through FCMs were mentioned separately as a narrative in the present study. These FCMs were carried for each livelihood group in each village per elevation, i.e., low, mid and high elevation.

The data collection process was executed as follows:

1. Identification of the study areas through expert interviews as part of the HI-AWARE project.
2. Perception of climate related impacts on different livelihood groups through group discussions and Fuzzy Cognitive Mapping approach.
    a. Explanation of manifestations of climate change.
    b. Documentation of the direct and indirect impacts of climate change on livelihoods assets through FCMs.
    c. Documentation of additional information through FGDs in the form of field narratives.
    d. Assigning of weights for each individual relationship (links) between the variables on a scale of [-1, 1] by stakeholders.
3. Coding of the FCMs into Microsoft Excel sheets in the form of adjacency matrices.
    a. Coding of FCMs separately for each livelihood group per elevation.
    b. Augmentation of the matrices as per livelihood type in each elevation.
4. The augmented matrices are fed into FCMapper, a macro-enabled excel based fuzzy cognitive mapping tool.
    a. Obtaining of data for statistical network analysis for graph theory.
    b. Coding the matrices into .net file format (Pajek graph file) for visual representation using Visone 2.6.5 (Network data visualiser).
5. The perceived impacts of climate change on the various asset classes are visually represented in the form of cognitive interpretation diagrams (CIDs) for each livelihood groups in each elevation.
    a. Identification of major climate change impacts by each livelihood group.
6. Scenario generation has been developed using FCMapper on the basis of current perceptions of different livelihood groups in each elevation.

6.4 Systematic Literature Review

A Systematic literature review was carried out for identifying possible adaptation strategies for the study area in question. This involved scoping Peer Reviewed Journal Articles, Government Reports, Project Reports and grey literature. This information aided in determining a wide range of possible adaptations. These options were then discussed in light of the most acute climate change induced impacts, across elevations as well as specific to elevations.

6.5 Sampling

In the current study, purposeful sampling with saturation has been applied. Purposeful sampling is a kind of 'non-probabilistic' sampling method in which elements are selected for a purpose or a reason, usually because of the unique position of the sample elements. Purposive sampling may involve studying the entire population or a subset of a population (in this study, different livelihood groups).

Herbert Rubin and Irene Rubin (1995) suggest three guidelines for selecting informants when designing any purposive sampling strategy. The informants should be:

- "Knowledgeable about the cultural arena or situation or experience being studied,"
- "Willing to talk," and
- "Represent[ative of] the range of points of view."

In addition, Rubin and Rubin (1995) suggest continuing to select interviewees until you can pass two tests:

- *Completeness:* "What you hear provides an overall sense of the meaning of a concept, theme, or process."
- *Saturation:* "You gain confidence that you are learning little that is new from subsequent interview[s]."

Saturation has said to be attained at a state when no new themes or data are formed from discussions with stakeholders.

7.0 RESULTS:

7.1 Perceived Climatic Changes:

Since the aim of the study was to understand and map livelihood impacts of climate change felt by communities, it became imperative to first understand their observations regarding the changing climate. This understanding would help in determining the contextual meaning of the central variable, which was used in fuzzy cognitive maps used to understand livelihood impacts. Hence, such an exercise was carried through focus group discussions for every elevation of the study area, i.e., the low, mid and high elevation.

a) Low Elevation

An overview of the perceived climatic changes in the villages of Mathana and Khadri Kharak Maaf are depicted in the table below:

Table 1: Overview of perceived climate changes in the low elevation villages

S. No.	Village	Summer Temperature	Winter Temperature	Average Precipitation
1.	Mathana	Increase	Increase	Increase, with increase in intensity
2.	Khadri Kharak Maaf	Increase	Increase	Increase, with increase in intensity
	Overall for Low Elevation	**Increase**	**Increase**	**Increase, with increase in intensity**

During the course of the focus-group discussions, the locals were asked to describe the changes observed in the climate over a time-span of three decades. From the discussions, as can be seen from the table above, the communities in both the villages of Mathana and Khadri Kharak Maaf experienced an increase in summer temperature and winter temperature. This implies that the summer season in these areas has grown to be hotter, and the winter season is not as cold as it used to be earlier. Precipitation has also seen an increase over the past years, with an increase in both average rainfall and the intensity of rainfall. The incidence of extreme events such as floods has increased in the past three to four years in both villages. The village setting in Mathana is such that all the houses are clustered together in the centre and are surrounded by farmlands. The protective wall or the 'bund' breaks every year due to floods, affecting majority of the croplands, however the houses remain unaffected by the event. Khadri Kharak Maaf has a sloping topography, which implies that farmlands located closer to the river are more likely to get affected by floods as opposed to those at a slightly higher elevation. Extreme events such as hail and untimely high intensity rainfall has been observed in both villages, and adversely impacts the wheat crop. Blackening of wheat has been a phenomenon every winter for the past four years.

b) Mid-Elevation

An overview of the perceived climatic changes in the villages of Badal, Pyunkhari and Kim Khola are depicted in the table below:

Table 2: Overview of perceived climate changes in the mid elevation villages

S. No.	Village	Summer Temperature	Winter Temperature	Average Precipitation
1.	Badal	Increase	Increase	Decrease, with increase in intensity
2.	Pyunkhari	Increase	Increase	Decrease, with increase in intensity
3.	Kim Khola	Increase	Increase	Decrease, with increase in intensity
	Overall for Mid Elevation	**Increase**	**Increase**	**Decrease, with increase in intensity**

When asked to describe changes observed in climate over the past three decades, the general observation for the mid-elevation villages indicated an increase in summer and winter temperature, implying that the summer season grew hotter with the years, and the winter season grew less cold. Discussions with women in Badal pointed towards health issues arising out of the increase in summer temperature, with instances of weakness and fainting among women working in farms. In a contrast from what was observed in the plains, the precipitation saw a decline, with a decrease in the average rainfall received, but an increase in intensity of rainfall. This change in rainfall pattern has proven to be detrimental to cultivation of ginger and rajma, the only crops that would be sold in the market, and were subsequently a source of income for farmers. In Pyunkhari, there has been an increase in the damage to terraced farms caused due to high intensity, untimely rainfall. Locals from Kim Khola stated that this change has resulted in an increase in disasters such as landslides in the village. The incidence of extreme events such as floods has increased in the past few years as well, especially in Badal. This has affected agricultural productivity and rafting activities.

c) High Elevation

An overview of the perceived climatic changes in the villages of Kalimath and Chaumasi are depicted in the table below:

Table 3: Overview of perceived climate changes in the High elevation villages

S. No.	Village	Summer Temperature	Winter Temperature	Average Precipitation
1.	Kalimath	Increase	Increase	Increase, with increase in intensity
2.	Chaumasi	Increase	-	Increase, with increase in intensity
	Overall for High Elevation	**Increase**	**Increase**	**Increase, with increase in intensity**

When locals from Kalimath and Chaumasi were asked during focus-group discussions to describe changes observed in climate over the past three decades in their respective villages, the general observation for the high-elevation villages indicated an increase in summer and winter temperature. The trends for winter temperature however, could not be gauged with certainty in Chaumasi. Observations indicated an overall increase in amount and intensity of rainfall received in both the villages. The locals in Chaumasi stated that an increase in the intensity of rainfall over the past decade has resulted in an increase in landslides, which washes away the productive topsoil. Similarly, in Kalimath, huge tracts of land have been washed away due to the 2013 flood, subsequently making the land weak and unproductive. With an increase in extreme events such as floods and landslides, the soil productivity in these villages has become progressively poor, and been increasingly replaced by boulders and rocks brought along with floods and left behind by landslides.

7.2 Hazard Identification

The common types of hazards in the villages scoped in the Upper Ganga Basin are floods, high intensity rainfall, landslides, forest fires and human-wildlife conflict. The table below details the hazard and the elevation it is prominently observed at.

Table 4: Types of Hazards in the UGB

S. No.	Incidences/ Hazards	Elevation	Consequences
1.	Floods	Low, Mid, High	Washing away land, affecting agricultural productivity, Health implications
2.	Hail	**Low**, Mid, High	Impact on wheat crop
3.	Land Inundation	Low, High	Washing away of productive soil, farmlands
4.	Landslides	High	Washing away of productive soil, weakening land, leading to increased landslides.
5.	Drying of Water Source	**Mid**, High	Extreme situation of water scarcity, impact on

			agricultural productivity
6.	Forest Fires	Mid, High	Impact on forest cover and soil quality
7.	Human-Wildlife Conflict	Mid, High	Major impact on agricultural productivity

Incidences of floods were observed to increase in the plains and the mid hills, and the high hills saw an increase in high intensity rainfall. However, majority of the damage to life, property and farmlands in the high hills has been due to the 2013 floods, an event from which the region has still not fully recovered. Landslides are a frequent phenomenon in the mid- and high-hills with high intensity rainfall only making matters worst. An increase in pine cover, and decrease in existing forest cover leads to weakening of the mountain soil, in turn contributing to landslides. Natural sources of water are drying up in most parts of the UGB, majorly due to increase in summer temperature. Additionally, in the high hills, interactions with the local communities suggested that the decrease in oak forests is also a contributing factor, since the roots of the tree run deep and are extensive, thereby aiding in perpetuating the natural water source. Pine trees are rapidly invading the niche of oak, with the shallow roots of the tree no longer binding the soil together or helping in preserving the natural water source. With a decrease in forest cover, there have been increased instances of human-wildlife conflict across majority of the river basin, however the impact is felt to a great extent in the mid- and high- hills. This is because farmlands of a particular farmer in these regions are scattered, making it difficult for a farmer to keep a check on the extent of damage to each stretch of land owned.

7.3 Perceived Livelihood Impacts of Climate Change based on Asset Categories:

The Sustainable Livelihood Approach includes the presence of seven fundamental asset categories. These assets are the capital or endowments that people possess which aids in reducing their vulnerability. The assets are Natural Asset, Human Asset, Social Asset, Physical Asset, Financial Asset, Organizational Asset and Personal Asset.

The process of categorization of livelihood impacts under such assets forms the basis for understanding how communities respond to climate-induced vulnerabilities along with the extent to which people can adapt to changing climatic conditions. In light of this, livelihood impacts based on asset classes have been identified through the *cognitive interpretation diagrams (CIDs)*. These diagrams have been generated for main livelihoods in each elevation of the Upper Ganga Basin. In view of better visualization of the extent of impacts and existing inter-linkages, chord diagrams have also been developed for the same.

Analysis of Augmented FCMs though Graph theory

Cognitive maps are complex systems because they are made up of a large number of variables that have many interconnections and feedback loops. The analysis is based on graph theory. For the analysis of cognitive maps through FCMapper, the number of variables (N) and the links between them i.e. the connections (C) from the FCMs are noted. Additionally, graph theory also provides the density (D) of a map. The density serves as an index of connectivity, which indicates how densely or sparsely connected the maps are. Hence, the density is a calculated indicator of the maximum number of possible connections (C) between *N* numbers of variables. Higher the value of density, larger are the number of causal links between the variables. For a better understanding of the dynamics of the map, it is important to be aware of how each variable influences each other. Three types of variables identified are: transmitter (forcing functions, givens, tails), receiver variables (utility variables, ends, heads), and ordinary variables (means) (Özesmi and Özesmi, 2004).

Out-degree indicates the row sum of absolute values of a variable in the adjacency matrix. It denotes cumulative strength of connections exiting the variable. In-degree on the other hand, is the column sum of absolute values of a variable. It denotes the cumulative strength of variables entering the variable. Following thus, transmitter variables have a positive out-degree, and zero in-degree. Receiver variables have a positive in-degree, and zero out-degree and ordinary variables have both a non-zero in-degree and out-degree (Özesmi and Özesmi, 2004).

Another factor to be considered is centrality. The centrality of a variable is the sum of the number of in-degrees (in-arrows) and out-degrees (out-arrows). This denotes the cumulative strength of connectivity between variables. Additionally, more the number of receiver variables, more complex are the maps. These receiver variables represent various impacts and consequences within a system. A large number of transmitter variables indicate a top-down influence showing "flatness" of a cognitive map. Hence, cognitive maps can be compared for their complexity from the receiver to transmitter ratio (R/T). Complex maps will have a smaller ratio. A higher density indicates more links between concepts in a given map (Özesmi and Özesmi, 2004).

This exercise is carried out for each cognitive interpretation diagram (for livelihood groups in different elevations) to better understand the maps and subsequently the perception of livelihood groups.

7.3.1 Low Elevation

The villages visited in the plains were Mathana and Khadri Kharak Maaf.
Brief Overview of villages visited:
Village: Mathana
District: Haridwar
Tehsil: Laksar
Number of households: 250-300
Coordinates: 29.734621 N, 77.963158 E

The village is approximately 1.5 kilometres from the Solani river, which is a tributary of the Ganga river.
The main sources of livelihood in the village are agriculture and labour, with a small percentage of people involved in livestock rearing and government jobs. The youth of the village are involved in both farming, as well as labour or seek jobs in nearby villages. Due to lack of adequate road connectivity, people in the village are unable to look for means of livelihood outside the village. The main cause of concern is flooding, the frequency of which has increased over the past five years. The increase in this hazard has an adverse impact on agriculture and has also led to health issues in the village. Floods affect majority of the

farmlands in the village. This leads to crop failure, which keeps farmers in debt for long periods of time. The land holding per farmer is less. It was observed that very few women from farmer households work, but women from labourer households worked in farmlands. In terms of village setting, the farmlands in Mathana are protected by a 'bund. However, with frequent flooding, the 'bund' is said to break every year, flooding most of the farmlands in the village. The major crops grown include sugarcane, wheat and rice. Vegetables are grown for household consumption. There has been an increase in pests and weeds after the occurrence of floods in this region. New varieties of the same have been observed. Higher amounts of fertilizers and pesticides are being used for the past three-four years owing to this reason. There is not enough monetary compensation to farmers from the government in cases of crop failure. There is a lack of a proper system for evaluation of crop losses, and hence the estimation of crop loss and subsequent compensation rendered is inadequate at most times.

Apart from farming, labour is the other major source of livelihood. They are usually from a lower caste and may in some cases; own small plots of farmlands. Groundwater is usually extracted for the purpose of irrigation. There are three government operated bore wells in the village; two of which function (not very efficiently) and one is not operational. Bore-wells run 60-70 feet, and run on diesel, which is bought from Laksar, 10 kms from the village. The lack of proper road connectivity and transportation during and after the occurrence of floods adds to their woes. Drinking water is not an issue in the village, and almost each household has its own handpump.

Village: Khadri Kharak Maaf

Tehsil: Rishikesh

District: Dehradun

Coordinates: 30.050894 N, 78.248546 E

The village is close to both the Song River, which is a tributary of Sooswa River, which is inturn a tributary of Ganges itself. It falls in the apparent water shadow region between Pashulok Barrage and Bheemgoda Barrage. The village has a sloping topography, with a clearly distinguishable lower part and upper part. The upper part consists of small shops and schools; while the lower part, that is closer to the river consists mainly of agricultural lands.

The main source of livelihood is agriculture and labour, however with rapid urbanization, it has been observed that in the past 8-10 years majority of agricultural land has been sold and there has been establishment of small businesses in the village. The '*Boksa*' tribe resides in the lower part of the villages and is essentially the labour force that works in farmlands. The main crops grown are rice, wheat, sugarcane and vegetables. Irrigation is mainly through tube wells in the upper regions and through a 'neher' or a canal in the lower region. While people in the upper region can sell their land, people with land near the banks of the rivers are unable to do so due to the proximity to water and hence flooding would remain a cause of concern.

Drinking water is not a problem in the village. Tube-wells in the village are privately owned and the government has provided hand-pumps. Interactions with the *Boksa* community brought to light the work pressure faced by women to collect firewood and fodder. Majority of the community members do not own the land but work in the farms as labour, and the produce is shared between them and the farmers. Since the tribe resides in the low-lying area of the villages, the frequent floods are a major cause of concern. Due to the lack of livelihood avenues to diversify into, they feel that in an event of floods and subsequent crop failure, their livelihood is most impacted.

Understanding Perceived Impacts through Cognitive Interpretation Diagrams:

A Collective Fuzzy Cognitive Map or a CID was generated for livelihoods in the two villages situated in the plains, Mathana and Khadri Kharak Maaf, with 'Climate Change' as the central variable. Here, 'climate change' implies extreme events such as floods and changes in temperature and precipitation. The impacts are categorized under the different assets categories.

The two main sources of livelihood in the plains are: a) Agriculture and, b) Labour. The CID generated for each, and subsequent inferences and observations are as follows:

7.3.1.1 Agriculture

In both villages, focus-group discussions were held with both large farmers (farmlands > 6 'bigah') and small/marginal farmers (farmlands < = 6 'bigah') in order to gauge a comprehensive picture of the various climate change impacts on agriculture. The number of large farmers in both villages was a small number, with most farmers being small or marginal. It was observed that impacts felt by both groups were similar, however marginal farmers felt the extent or the repercussions of the impacts to a larger extent.

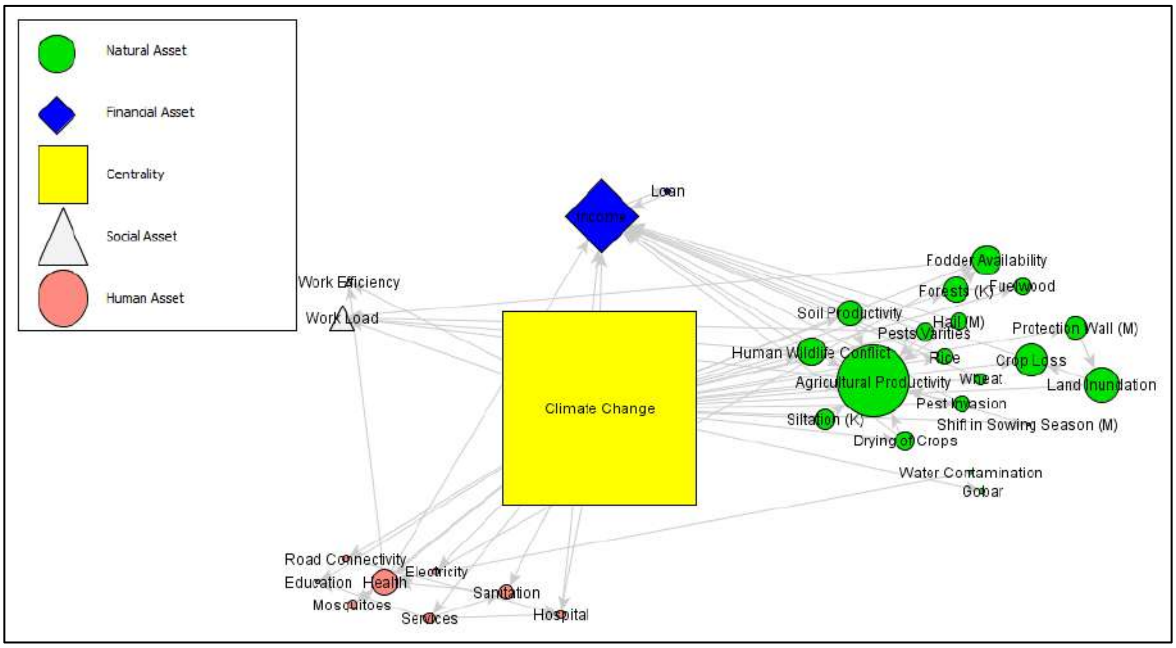

Figure 3: CID for Farmers in Plains of the UGB

As can be seen from the CID for mapping impacts of climate change on agriculture in the plains with climate change as the central variable, the maximum impacts are faced by natural assets and human assets based on the clusters formed. The CID is compiled from FCMs or large farmers and small/marginal farmers.

<u>Natural assets</u>: Under this category, among the various impacts, agricultural productivity has been most impacted due to climate change. Mathana and Khadri Kharak Maaf are both located close to the river, and are frequently affected by floods, the incidence of which has greatly increased over the past couple of years. The main crops grown in this region are rice, wheat and sugarcane. Floods affect the rice crop to a larger extent when compared to sugarcane owing to the smaller size of the crop. Land inundation is a major concern in Mathana, with the

'bund' or the protection wall breaking almost every year during the occurrence of the flood. This results in crop loss, which in turn has an impact on the financial assets such as income levels of farmers. Khadri Kharak Maaf has a gently sloping topography, making farmlands located in the lower elevation (and therefore, closer to the river) more vulnerable to the onset of floods. This has led to increased siltation in the croplands located near the river, rendering the land unfit for cultivation and thereby forcing farmers to leave such tracts of lands barren for about three to four years before resuming cultivation. This affects the soil productivity and has an indirect impact on income. Floods have also been observed to wash away portions of the forest located along the banks of the river, a phenomenon observed in Khadri Kharak Maaf in particular. This decrease in forest cover has increased instances of human-wildlife conflict, thereby affecting agricultural productivity and fuel wood or firewood availability. With the forest cover decreasing, women are forced to travel to farther distance within the forest to obtain firewood, thus increasing their work burden and placing them in a vulnerable situation. In both villages, fodder for livestock is cultivated within the farmlands, and the increase in incidence of floods tends to wash away fodder, which has been stated as a major issue by locals. Apart from floods, increased summer temperatures have been observed to dry up crops. Untimely, high intensity winter rainfall and hail severely damage the wheat crop.

Financial Assets: The impact on income in the plains has a major in-degree from impacts on natural assets. For example, income is affected predominantly due to a decrease in agricultural productivity, crop loss due to land inundation, new pest varieties being observed, drying of crops, increased human-wildlife conflict among others. There is also an in-degree from human assets such as health and services.

Social Assets: Farmers in the villages have listed work efficiency and workload as the two social assets. A decrease in forest cover increased work burden or workload, especially for women in Khadri Kharak Maaf. Work efficiency has been observed to decrease due to increased summer temperatures. The increase in pests and newer pest varieties also affect productivity of labour. Human assets such as health are also seen to have an impact on work efficiency.

Human Assets: Assets such as sanitation, education, health and other services are also affected by climate change. Road connectivity is a major issue in

Mathana, with it taking a few months post the floods for roads to be motorable again. However, the same is not a cause of major concern in Khadri, owing to rapid urbanization and better access to markets and services. Hence, it is easier for farmers in Khadri to send their produce to the nearest market, and return to a situation of normalcy faster than is possible for farmers in Mathana. Farmers in both villages highlighted sanitation and other health issues arising out of climate change.

Network Statistics:

Number of maps: 6

Number of factors: 32

Number of connections (C): 68

Density: 0.066406

Transmitter: 2, Receiver: 5, Ordinary 25

R/T: 2.5

As can be seen from the network statistics, the number of factors or impacts perceived by the farmers in the plains are high are 32, and so are the number of connections. This indicates a certain knowledge base among the farmers in the plains about climate change impacts and the interconnectedness. The map is at a medium density of 0.067, indicating low density of the map. The R/T ratio is 5 to 2 or 2.5, which is low, thereby indicating a complex network. The number of ordinary variables is 25. A higher number of ordinary variables in indicative of the map being interconnected with most concepts, or in this case, impacts, having an influence on many other impacts.

7.3.1.2 Labour

The labour force in both villages work predominantly in farmlands within the village, and are at times involved in projects implemented under MNREGA. As observed in both villages, the labour force is generally the lower caste/ class and is landless. In Khadri Kharak Maaf, the 'Boksa' tribe comprises of the labour force. This tribe resides in the lower portion of the village, and ancestrally owned land, however over time the land was sold off to people from neighbouring villages who began to settle in Khadri. This has led to the entire tribe now being close to landless and forced to work as labour in lands that were once in their name. The mode of payment is in terms of half of the agricultural produce of the land they work in. However, with the increase in events such as floods, fall in soil productivity, and a lack of an avenue to diversify into, labourers in both villages were of the opinion that they are most vulnerable and adversely affected.

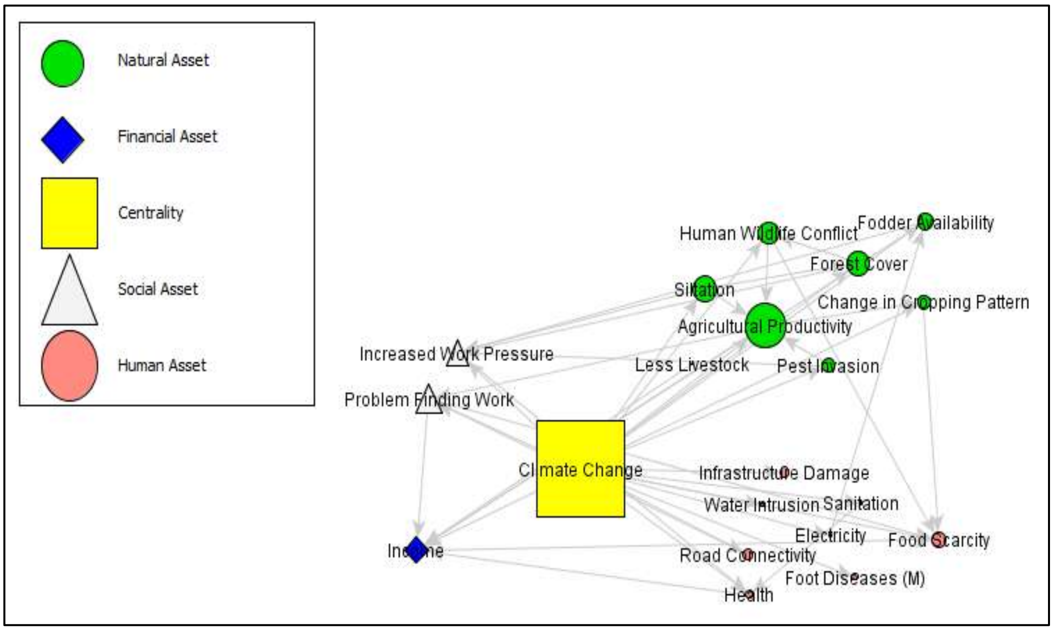

Figure 4: CID for Labour in the Plains of the UGB

From the CID for mapping impacts of climate change on labour in the plains with climate change as the central variable, it is clear that the maximum impacts are faced by natural assets and human assets based on the clusters formed. However, the extent of climate change impacts on Increased Work Pressure and Problem Finding Work is higher for labour, as opposed to the same for farmers in the region.

<u>Natural Assets</u>: When asked which aspects of natural assets were impacted due to climate change, the labour force mentioned agricultural productivity as the major issue, which impacts financial assets such as income. Siltation in Khadri was pointed out as a phenomenon that affected croplands situated near the river, which in turn impacts social assets such as increased work pressure. The decrease in forest cover due to frequent floods has led to increased human-wildlife conflict and firewood and fodder availability issues. Increased pest invasion was linked to increasing temperatures and variable rainfall in both villages.

Financial Assets: Loss in agricultural productivity adversely affects food security and income levels for labourers. Income is also impacted by issues such as problem finding work during heavy monsoons or after the floods. Due to the extremely limited options of income generation, the labour force in both villages is majorly dependent on work in farms.

Social Assets: Increased work pressure and Problem finding work have been listed as the major causes of concern for labour due to changes in climate. In both villages, people dependent on labour for their livelihood stated that due to an increase in events such as floods and untimely, high intensity rainfall, it becomes difficult for them to find work elsewhere, since there is close to no work possible at that time in the farmlands. Labour in Mathana face this difficulty to a greater extent due to poor road connectivity even weeks after the occurrence of a flood or an event of heavy rainfall. Increased pest invasion in both villages, and siltation, particularly in Khadri has increased their work pressure.

Human Assets: Aspects such as road connectivity and food scarcity were listed as the most affected by the labourers in this asset category. The repercussions of poor road connectivity due to floods or heavy rainfall, as discussed earlier, is realized to a greater extent in Mathana, since it affects their ability to find work elsewhere in other to make ends meet. Impacts on agricultural productivity affects their food needs directly leading in most cases to a situation of scarcity. Health issues were not emphasized greatly by them, however, the labourers in Mathana stated that over the past few years, the water brought along by the floods contained some sort of chemical that affect their feet and hands while they work in the farms, as opposed to ten years ago, when floods brought along productive, fertile soil. In Khadri Kharak Maaf, there is an issue of water entering houses, since labourers reside in the lower part of the village, making them closer to the river, and therefore more vulnerable.

Network Statistics:

Number of maps: 6
Number of factors: 20
Number of connections: 42

Density:0.105
Transmitter: 2, Receiver: 4, Ordinary: 14
R/T ratio: 2

Unlike the farmers in the low elevation villages, the labour force here has lesser number of factors or impacts perceived and lesser connections. This however, should not be confused with the lesser impact of climate change being felt by this community, and is infact on the contrary. This lesser number could be attributed to the lack of knowledge among the labour force of certain issues. The density is medium at 0.105, and the R/T ratio is 2, which is lesser than that for farmers (2.5), indicating a more complex network. The ordinary variables however, is lesser at 14, hinting at lesser impacts being interconnected or dependent on others when compared with the same for farmers.

Comparison between Farmers and Labourers:

Despite being affected by similar changes in climate, there are differences in the impacts listed by the two livelihood groups that reside and work in the same region. For instance, the impacts on natural assets due to climate change listed by farmers are far greater than those listed by labourers. The issue of finding work and increase in work pressure is felt more by labourers, thereby making them more vulnerable to the same change. In an interesting take on differential priorities, it was observed that under constant conditions of weather changes, vector- and water-borne disease occurrences; health issues were given a lot more thought and discussion space by farmers and opposed to labourers. As is clear from the CIDs for the two livelihood groups, health has almost been neglected as an issue by the labourers, and a higher weightage has been given to the issue of finding work in the wake of the changing climate. Since diseases do not differentially affect or impact people of different livelihood or social groups, it is fascinating to see how certain impacts of climate change, though imperative, are not a part of the mind space of the labour force, to the point that it is almost neglected. This therefore becomes an example of the social or cultural cognition aspect of climate change, where issues perceived by people are subject to and shaped by social conditioning.

7.3.2 Mid Elevation

The villages visited in the mid elevation were Badal, Pyunkhari and Kim Khola.

Brief Overview of the villages scoped:

Village: Badal

Tehsil: Narendranagar

District: Tehri Garhwal

Coordinates: 30.138197 N, 78.386198 E

The village is located roughly at a distance of 20 km from Rishikesh. The village lies along the Shivpuri stretch, which is famous for rafting and beach camping and hence relies heavily on tourism as a means of livelihood. Most young people from the village are involved in tourism activities after completion of high school and do not pursue further education. Not many locals own rafting companies, but find employment as labour in such establishments during 'season time'. There has been a considerable fall in rafting activities since the disastrous floods of 2013.

The agriculture practiced in the village is mainly subsistence, since hill agriculture is not very productive owing to lower soil quality and lack of adequate irrigation facilities. The village is located close to the banks of the river, and is a hub for adventure tourism activities. The locals have felt a change in the summer and winter temperature along with the duration and intensity of rainfall. There have been increased instances of the nala or canal flooding during the monsoon season, wrecking havoc in the farmlands around it. The soil productivity and land holdings have also decreased over time. The main crops grown in the region are ginger, rajma, wheat, rice, pulses and certain vegetables. Firewood and fodder is collected from the forest opposite the village, on the other side of the river. With an increase in the frequency of floods and a subsequent decrease in forest cover, there is an increased burden on women to provide for the same. Both men and women work in farmlands in this village.

The village has witnessed a high degree of outmigration with the younger generation moving to peri-urban and urban centres in search of better services and livelihood opportunities. Thus, this has resulted in a substantial number of older people left behind in the village to fend for themselves.

There is no such issue of drinking water in the village, however there is a common perception that the drinking water being supplied to the village is of bad quality and possibly contaminated by animal feces, since animals are allowed to graze close to the source of this water.

Village: Pyunkhari and Kim Khola

Tehsil: Devprayag

District: Tehri Garhwal

Both the villages are located in a naturally water scarce region. Hill agriculture is not very productive. Men and women are engaged in agriculture or labour activities such as road construction, due to the lack of an alternate source of livelihood. The major crops grown are rice, maize, madua and soyabean. Soyabean from the villages is sent to the market if there is a surplus. Farming is largely rainfed. Many people are now reluctant to practice agriculture due to damage of crops caused by monkeys and wild pigs resulting in lesser yield and productivity. Women are largely responsible for collecting fodder and firewood from the forest, and water from the nearest handpump, which is usually about 10 kilometers away. Women indicated that the forest cover has decreased to an extent. There is a major crisis of drinking water in these villages. Currently, the water supply is through pipes to a common tank in the village from where women carry water to their respective households. However, there are times when there is no water in the tank, and women have to travel for about 8-10 km to collect water. There is a major water shortage especially in summers (where roughly about 200 litres is required in summer, they get only 50litres). Natural water sources have all dried up due to increased summer temperatures. The main source of drinking water is springs, which become active only during monsoons. Though this water is muddy, but it is consumed due to water shortage issues. Not many people have outmigrated from the village, due to the lack of skill sets for other means of livelihood. The villages face no major hazard in terms of floods, however unpredictable, high intensity rainfall is said to cause havoc to agriculture. Locals from Pyunkhari believe that there are hardly any government schemes that have benefitted the community and they believe that the government has largely neglected them, however people residing in Kim Khola did not have the same opinion. Intrestingly, there is a stronger institutional presence in Kim Khola as opposed to Pyunkhari, the reasons for which were not evident and could not be explored in detail.

Understanding perceived impacts through Cognitive Interpretation Diagrams:

A Collective Fuzzy Cognitive Map or a CID is generated for livelihoods in the three villages situated in the mid elevation of the Upper Ganga Basin: Badal, Pyunkhari and Kim Khola, and organized according to different asset categories.

Table 5: Main sources of Livelihoods in the Mid Elevation Villages

Village	**Livelihood**
Badal	Adventure Tourism (Rafting activities) and Agriculture.
Pyunkhari	Combined livelihood of Subsistence Agriculture and Labour
Kim Khola	Agriculture

Following thus, two CIDs have been generated, one detailing impacts on agriculture as seen in Badal and Kim Khola, and the other depicting impacts on the combined livelihood of subsistence agriculture and labour, as observed in Pyunkhari.

7.3.2.1 Agriculture

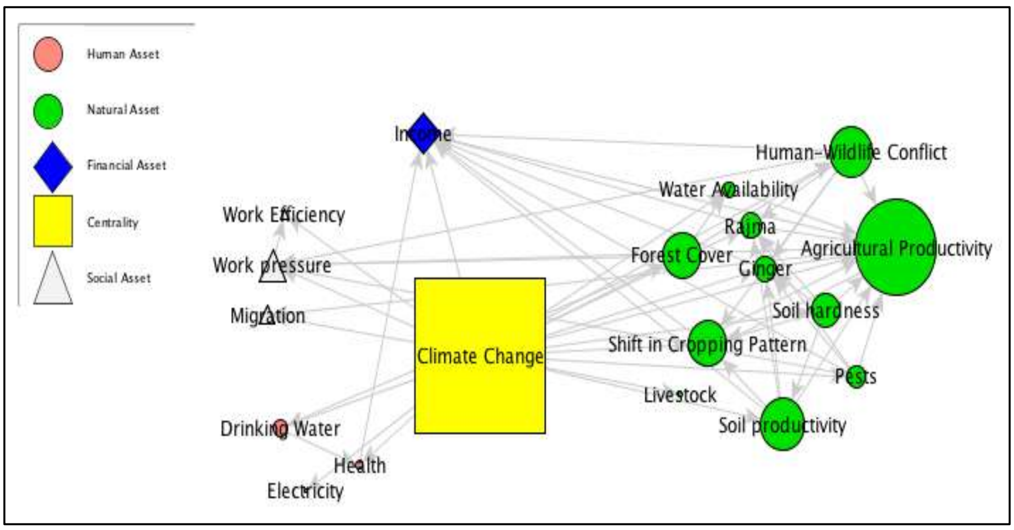

Figure 5: CID for Farmers in the Mid Elevation villages of the UGB

From the CID for mapping impacts of climate change on farmers in the mid elevation with climate change as the centrality, it is evident that natural assets face the maximum impacts, followed by human and social assets based on the clusters formed. For farmers, the impact on agricultural productivity is a cause of major concern, since yields from hill agriculture are not tremendous, and the common perception, similar to scientific evidence, is that climate change exacerbates such an impact.

Natural Assets: Climate change parameters such as heavy rainfall and floods (in Badal) impact a large number of natural assets, and agricultural productivity has taken the highest toll. The yield from agriculture has been reduced to one-thirds of what it used to be ten years ago, owing to increased incidences of floods, and high intensity rainfall. Badal and Kim Khola are surrounded by forests, and locals state that the forest cover has decreased over time, leading to increased human-wildlife conflict, which in turn affects agricultural produce. Tracts of forests are lost due to floods in Badal and high intensity rain in Kim Khola. Another aspect of natural assets that impacts agricultural productivity is soil. Soil quality has decreased over the years in both villages, reasons attributed to the overuse of fertilizers. In Badal it was observed that the soil is subjected to increased instances of high intensity rainfall, which has made the soil 'hard', thereby adversely affecting crop yield. Although agriculture practiced in the hills has historically been subsistence agriculture, kidney beans (rajma) and ginger from Badal, and mustard from Kim Khola would find its way to the market, thereby becoming a source of income (financial asset) for farmers. However, over time the produce of rajma, ginger and mustard has reduced owing to fall in soil productivity. An increase in the variety of pests has also been observed. Water availability is an issue for hill agriculture due to the lack of irrigation facilities. Natural sources of water have been observed to dry up owing to increased summer temperatures, in turn affecting domestic and agricultural water needs.

Financial Assets: Natural and human assets predominantly impacted income. Fall in agricultural productivity was cited as the main cause of concern, followed by health implications. Since hill agriculture has not been an income-generating activity as such, rafting or adventure tourism is a major source of livelihood in Badal, but there is a lack of an alternate source of livelihood in Kim Khola.

Social Assets: Climate change was seen to adversely impact social assets such as work efficiency and work pressure. Fall in agricultural productivity, new varieties of pests, human-wildlife conflict and soil hardness led to increase work pressure, and decreased work efficiency. This in turn takes a toll on financial assets such as income. Owing to the lack of education facilities and livelihood options to diversify into, a large number of people in Badal and Kim Khola have migrated to nearby urban centres such as Rishikesh, leaving old people behind in the village to fend for themselves.

Human Assets: Farmers stated impact on services such as electricity, health and drinking water as causes of concern under human assets. Lack of adequate and safe drinking water is a problem in Kim Khola, and high intensity rainfall has been observed to hinder the efforts of the locals to collect drinking water from nearby villages (usually 10 kilometers away). There is no major impact of increased rainfall or floods on electricity in the mid hills.

Network Statistics:

Number of maps: 5
Number of factors: 19
Number of connections: 57
Density: 0.157895
Transmitter: 1, Received: 5, Ordinary: 13

For the farmers in the mid elevation villages, the factors are at 19, but the connections are high at 57. Density is at 0.16 and the R/T ratio is 5, which is high, indicating a map that is not very complex. The ordinary variables are lesser as well at 13, reinstating the conclusions from the density and R/T ratio.

7.3.2.2 Combined Livelihood (Agriculture+ Labour)

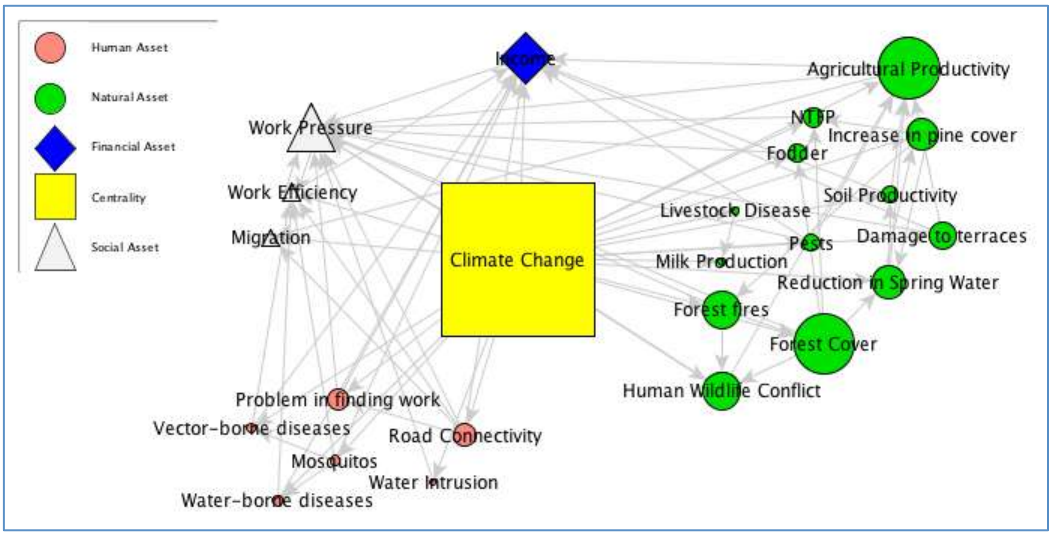

Figure 6: CID for Combined livelihood (Agriculture+Labour) in the mid elevation of the UGB

Pyunkhari has no single major means of livelihood, and the combined livelihood of agriculture and labour was observed here. However, neither of the two livelihood options proved to be a stable means of income generation, making this village the poorest of the villages scoped in the Upper Ganga Basin. From the CID for mapping impacts of climate change on people in this village with climate change as the centrality, it is evident that natural assets face the maximum impacts, closely followed by human and social assets based on the clusters formed. For people in the village, this source of livelihood is extremely unstable, and climate change exacerbates the already existent vulnerability.

Natural Assets: Similar to other villages scoped in the mid elevation; natural assets such as agricultural productivity and forest cover are adversely impacted by high intensity rainfall. Decrease in forest cover leads to human-wildlife conflict. There has been an observed increase in the pine cover, and a decrease in the oak cover. This increase in pine cover has led to an increase in forest fires, contributing to the declining forest cover. This has in turn impacted the NTFP availability for the locals. There has been an increase in pest invasion and variety in this village as well, and a lack of agency to deal with such a change. High intensity rainfall causes damage to terraces and affects soil quality. The increase in summer temperature has resulted in drying up of natural sources of water (streams and springs) in the village.

Financial Assets: Income has a number of in-degrees from natural, human and social assets. Fall in agricultural productivity; poor road connectivity (leading to difficulty in finding work), work inefficiency and health implications have an adverse impact on income. In the light of lack of opportunities to earn money, a few people have migrated out of the village, however majority of the locals are forced to rely on this unstable combined livelihood, thereby not relying heavily on remittance.

Social Assets: Out of the three social assets listed, namely work pressure, work efficiency and migration; work pressure was impacted to a larger extent. This impact is subject to human assets, such as road connectivity and problem in finding work; and a number of natural assets such as pest invasion, human-wildlife conflict, damage to terraces, loss in agricultural productivity, issue of fodder and firewood availability (arising from decrease in forest cover), among other inter-linkages.

Human Assets: Poor road connectivity is a major issue in this village, leading to problems in finding work and increasing work pressure. Other human assets such as water- and vector-borne diseases and increase in mosquitos directly impacts income. Locals also reported of water entering their houses during the monsoon season, with the region experiencing higher intensity of rainfall.

Network Statistics:

Number of maps: 6
Number of factors: 24
Number of connections: 73
Density: 0.126736
Transmitter: 1, Receiver: 2, Ordinary 21

For the combined livelihood of farming and labour in Pyunkhari, the number of factors and connections are both high. The R/T ratio is low and the number of ordinary variables are high, indicating a complex map, with variables being highly interconnected and impacting other variables.

7.3.2.3 Adventure Tourism (Rafting)

The major source of livelihood in a major part of the mid elevation villages is adventure tourism, especially rafting. Rafting as an adventure tourist activity started in 1984. The rafting season extends from September through June, every year, with the business remaining non-operational during the monsoon and winter months. Interactions with locals who ran adventure tourism businesses indicated that rafting as a business was slow from 1993-2000, but picked up 2000 onwards. However, in spite of being the major source of livelihood in the region, various impacts of climate change could not be mapped, as is done for other livelihoods, due to the 2013 floods. Post the flood; tourism in the region has taken a major dip. The Rishikesh-Shivpuri-Kaudiyala region, where Badal falls, has seen only one-fourth of the tourists it used to receive every year. Income from rafting is at an all-time low, due to increased competition and lower pricing. Since the flood originated in the higher reaches, information about the event was passed on in time to people in this business, and hence the loss and damage to property was lesser here. However, a total of 95% locals are involved in rafting related activities (guides and instructors for rafting and kayaking, and as labour working in beach camps) and 5% are from outside (Nepal, Bihar). Clearly, the people who depend on tourism as a sole means of livelihood have been affected adversely, but remain in the same business due to lack of avenues to diversify into, and due to the amount of investment in their current business. Hence, they continue hoping for an increase in tourist influx and help from the government in reassuring people of the safety of the region. Tariff for adventure tourism has decreased post the floods (where they would charge 1800/- per day, the price has decreased to around 1400-1200/- for the same). Hence, the income from tourism has reduced by about 30-35%. Since there is a slump in the business currently, people are finding it very difficult to pay for a tourism tax, along with paying for their staff and instructors.

7.3.3 High Hills

The villages visited in the high hills were Kalimath and Chaumasi.

Brief overview of the villages scoped:

Village: Kalimath

Tehsil: Ukhimath

District: Rudraprayag

Number of households: 90

Located around 47 kilometres from Kedarnath, Kalimath is a serene hill village, with scattered settlements. Religious tourism used to be the major source of livelihood, with 80% of the men from this village going to Kedarnath for six months. However, the 2013 floods have taken a major toll on this means of income. Apart from this, the flood has changed majority of the village's landscape, washing away huge tracts of land, and bringing with it rocks and debris. According to the locals, the level of the river has risen by about 10-15m from its normal height. Since the floods have washed the 'good', productive soil away, there has been a major fall in productivity. Frequency and intensity of extreme events (such as floods and landslides) has increased. Due to an increase in habitats, people are forced to migrate closer to the river, thereby increasing their vulnerability.

Agriculture practiced now is mostly subsistence and rain-fed, and at times even that does not fulfill domestic requirements. The major crops are madua, wheat, pulses, rice, jau, corn and mustard. There has been a shift from cultivation of rice, wheat, pulses and vegetables to only rice and wheat, post the 2013 floods. Fruits cultivated include malta, oranges, bananas, guava and lemons. A small percentage of fruits are sold in the market. During summers there is a water availability issue. Land holdings are in the village are scattered, adding to woes of the farmers. Repeated division of land over generations leaves some farmers close to landless. Girls/women do not inherit farmlands. Workload on women in hill villages is very high. Vegetation cover has decreased over time due to an increase in population and unplanned construction. Pine trees are invasive and are occupying the niche of the oak forests. The main sources of income now are either labour or government jobs. The lack of livelihood opportunities has led to an increase in out-migration, in search of better jobs and education opportunities.

Village name: Chaumasi

Tehsil: Ukhimath

District: Rudraprayag

Number of households: 60

Coordinates: 30.36676 N, 79.4306 E

Chaumasi lies at an elevation of 2100 m above sea level. It is the last inhabited village before the mighty Kedarnath range.
The main source of livelihood here, similar to Kalimath used to be religious tourism. However, after the 2013 floods, many families have lost their loved ones, and the survivors refuse to head back just yet. Due to the floods, a large number of families consist only of old people, who have lost close to their entire families during the hazard. Livelihood activities presently include agriculture and livestock rearing (pasturalists, locally known as the 'Chaaniwalas').

Agriculture here is rain-fed and subsistence. Firewood and fodder is obtained from the forest around. Locals believe that an increase in the intensity of rainfall has resulted in increased landslides that wash away farmlands thereby adversely affecting their livelihood. Extreme winters, experienced over the last couple of years are increasing destroying winter crops. The oak trees are drying up in the village, with pine rapidly invading its niche.

Understanding Perceived Impacts through Cognitive Interpretation Diagrams:

A Collective Fuzzy Cognitive Map or a CID is generated for livelihoods in the two villages situated in the high elevation of the Upper Ganga Basin; Kalimath and Chaumasi, and organized according to different asset categories.

7.3.3.1 Agriculture

Agriculture in the high hills, similar to that in the mid elevation is mainly subsistence. Large tracts of agricultural land have been washed away in Kalimath due to the 2013 floods, and due to increased instances of landslides in Chaumasi. Since the villages are in a geographically difficult terrain, access to markets is challenging. Climate change impacts have been observed to adversely impact various aspects of community life in the high hills, with no alternate livelihood options to diversify into.

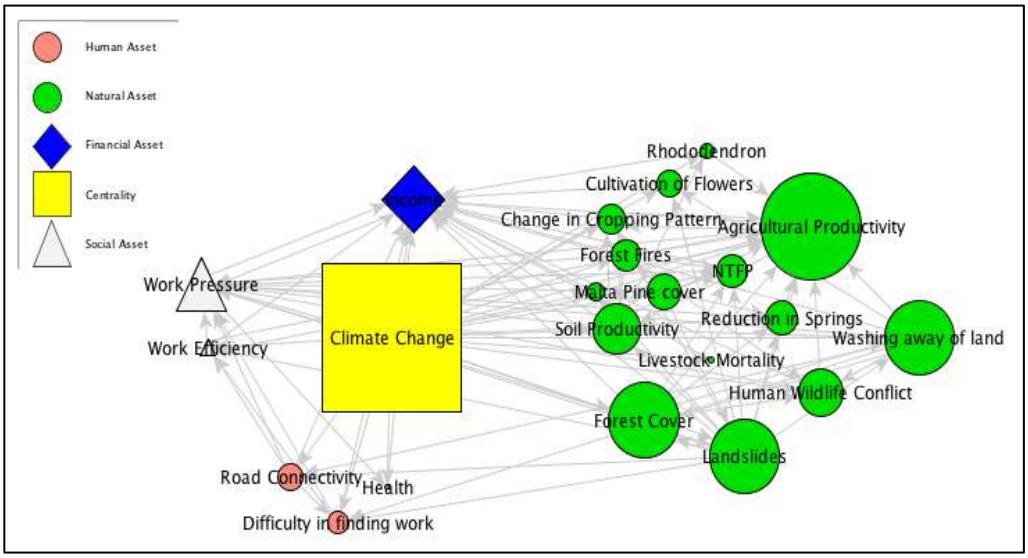

Figure 7: CID for Farmers in High Hills of the UGB

From the CID for mapping impacts of climate change on farmers in the high hills with climate change as the centrality, it is evident that natural assets face the maximum impacts, followed by human and social assets based on the clusters formed.

Natural Assets: Majority of the damage to agricultural land in Kalimath has been due to the 2013 floods. In Chaumasi however, cultivable land is washed away due to high intensity rainfall, which has increased in the past five to ten years. Landslides have also been affecting the yield of fruit trees such as 'malta', which served as a source of income until very recently. The locals in Kalimath stated that the size of the fruit has now decreased, along with a number of the trees drying up due to the increase in summer temperature. Floods in Kalimath and landslides in Chaumasi have also resulted in a decline in forest cover, which has led to increased human- wildlife conflict, leading in turn to a drop in crop yield. The cover of the rhododendron plant, which is used in making juices and has health benefits, has also reduced. An increase in pine cover is resulting in increased instances of forest fires. Discussions in Kalimath indicated that pine has been invading the niche of oak trees, and this is one of the reasons for the depletion of natural sources of water such as streams or springs. Locals stated that oak has deep and extensive roots, which helps perpetuate the natural water source. Hence, a dense oak cover implied that there is a natural spring in the proximity. Pine trees, on the other hand, have shallow roots, and do not tend to bind the soil well. This not only leads to drying up of springs and forest fires, but also triggers landslides. With increased temperatures, pine trees are invading the niche of oak forests.

Financial Assets: Income is impacted by a number of natural, human and social assets, and their inter-linkages with each other. Loss in agricultural productivity, exacerbated by floods and landslides, coupled with poor road connectivity or accessibility (leading to difficulty in finding work); collectively impact income. Since hill agriculture is not productive to the extent of becoming an income-generating means of livelihood, religious tourism is the major source of livelihood in the high hills.

Social Assets: As can be gauged from the CID, the impact on Work Pressure is immense. With a high number of in-degrees from natural and human assets, the geographical setting of the villages is also a contributing factor to the increased work pressure and lack of work efficiency. Decrease in forest cover adds to their woes since there is an increased pressure to meet firewood and fodder needs.

Human Assets: Lack of proper road connectivity leads to difficulty in finding work for people in this elevation. Repeated landslides and high intensity rainfall destroy mountain roads and the restoration of the same takes up to months at times, making it difficult to find work. Health issues, though prevalent are not a major cause of concern in the villages here. Kalimath has a primary health centre, which also caters to Chaumasi. However, interactions with the doctors there indicated the absence of pertinent health implications of climate change in this elevation.

Network Statistics:

Number of maps: 6
Number of factors: 22
Number of connections: 104
Density: 0.214876
Transmitter: 1, Receiver: 0, Ordinary 21

For farmers in villages in the high elevation, the factors and connections are high, as is the density. The R/T ratio is very low; indicating a complex map and the high number of ordinary variables at 21, hint at high interconnectedness and linkages between the different perceived impacts.

7.3.3.2 Religious Tourism

The high elevation villages are bestowed with panoramic view from the magnificent and mighty Himalaya to the alpine meadows, lush green temperate forests of the highlands, terraced agricultural fields and sparsely located settlements of the mid-altitudes, waterfall, gorges and cascades of the river valleys and above them the pilgrimages, the symbol of the Hindu sanctity. The shrines have shown an increase in the number of pilgrims visiting the region, and this has led to the development of new urban centres.

Urbanisation in Uttarakhand has been unplanned and rapid, leading to the conversion of rural settlements to small towns, initially owing to the fact that these regions were stopping points and centres for pilgrims visiting the major pilgrimage centres during the 'yatra season'. Slowly, these small hubs of commercial activity developed into small towns, then medium towns and subsequently into larger cities. This poses an immense pressure on resources and is a cause of concern. Additionally, the state is impacted by a huge influx of transient population every year (pilgrims and tourists) (Government of Uttarakhand, 2014). The table below shows the decadal growth rate for districts in Uttarakhand. Both the villages scoped in the high hills lie in the Rudraprayag district, and as can be seen from the table, the district shows the maximum decadal growth rate at 263.03%.

Table 6: Percentage Growth of Urban Population and Decadal Growth Rate in the districts of Uttarakhand

Districts	2001 (in thousand)	2011 (in thousand)	Decadal growth rate (%)
Uttarkashi	7.77	7.35	-5.67
Chamoli	13.69	15.11	16.54
Rudraprayag	1.20	4.19	263.03
Tehri	9.90	11.37	17.06
Dehradun	52.94	55.90	39.90
Pauri	12.89	16.41	25.37
Pithoragarh	12.94	14.31	16.26
Bageshwar	3.16	3.50	16.51
Almora	8.61	10.02	14.36
Champawat	15.04	14.79	13.52
Nainital	35.27	38.94	38.22
Udham Singh Nagar	32.62	35.58	45.33
Haridwar	30.84	37.77	63.11
Uttarakhand	25.67	30.55	45.27
India	27.81	31.16	31.80

Source: Uttarakhand Rural–Urban Distribution, COI, 2001–2011.

Religious tourism is the main source of livelihood in the high elevation, with at least one man involved in the livelihood from every household per village. Their mode of engagement with this livelihood included guides, labour involved in carrying the 'doli', shopkeepers, providing for horses, getting fodder for horses, running restaurants and hotels, among other allied activities. The livelihood extended from around 40-50 kilometres before Kedarnath, thereby proving a means of income for most villages in the high hills. Discussions indicated that since the 'yatra' season extended for a period of about six months, people from these villages would earn good money in these six months, which would be more than sufficient to live off of for the rest of the year; since agriculture is mainly subsistence and not a means of generating income.

However, due to the devastating 2013 flood, religious tourism as a means of livelihood has taken a major hit. Apart from washing away of shops, hotels and horses, the number of people that have lost their families and houses in the flood are beyond imagination. Among those who survived, there is an overwhelming sense of fear as far as returning to this means of livelihood is concerned. This coupled with the lack of sufficient restoration of roads and property near Kedarnath, has forced thousands of people out of work. Although, after two years of the incident, the roads have been freshly laid and the infrastructure is being restored, the majority of locals stated that they would refrain from going back to Kedarnath due to the string sense of fear. Due to a lack of livelihood to diversify into, people who once earned more than enough money to sustain in the hills are not finding it extremely difficult to make ends meet.

7.3.3.3 Pastoralists

In addition to means of livelihood such as agriculture and religious tourism, livestock rearing is a significant income generating activity for villages in the high hills. Locally known as 'Chaaniwalas', the pastoralists migrate with livestock from within the village to higher elevations in search of meadows, typically from the months of April to November. They take goats to high altitude meadows or 'Bugyals', which is a grass with thorns that goat feed on. They typically charge around 140 rupees per goat, and take around 500 goats at a time, armed with hunter dogs, in an event of wildlife conflict. During the course of the six months that the Chaaniwalas rear livestock, it is possible that some goats may die, or be eaten by the wildlife encountered at high elevations. They shared that this is common, and that on their return, the rightful owners are informed of the same. The owners of the goat are told to not take offence to this, or blame the Chaaniwala. This brings to light the level of trust and mutual understanding within the community residing in this village. Interactions with a few members of the Chaaniwala group brought to light the fact that 'bugyal' or fodder is of a higher grade or better quality in the upper reaches as compared to lower elevations, as observed in the past couple of years.

7.4 Scenario generation

Making use of the impacts identified by communities mapped through CIDs in Section 7.3, scenarios are generated for each livelihood group in every elevation. FCMapper using iterative calculations generates present state scenarios. Using the current state scenarios as baselines, future impacts of climate change are projected by scaling up the generated value to 25%, 50%, 75% and 100%. Thus the percentage impacts on various sub- assets at these particular levels of change in central climate variable can be estimated. This exercise therefore helps understand different perceived impacts in light of the changing climate, thereby helping in identifying which areas to focus on for planning and implementing adaptation strategies.

For each livelihood group, the present scenario has a value of 0.50 and its impacts on various sub-assets are shown in the graph below. The present scenario value has been scaled up to see the impacts on various sub-assets due to an increase climate change parameters (extreme events, rainfall, temperature). At 25%, value of increased summer temperature becomes 0.62, at 50% the value becomes 0.75, at 75% the value becomes 0.87 and at 100% the value becomes 1. Scenario generation is carried out at these values and impacts on various sub-assets are observed.

7.4.1 Low elevation

7.4.1.1 Agriculture

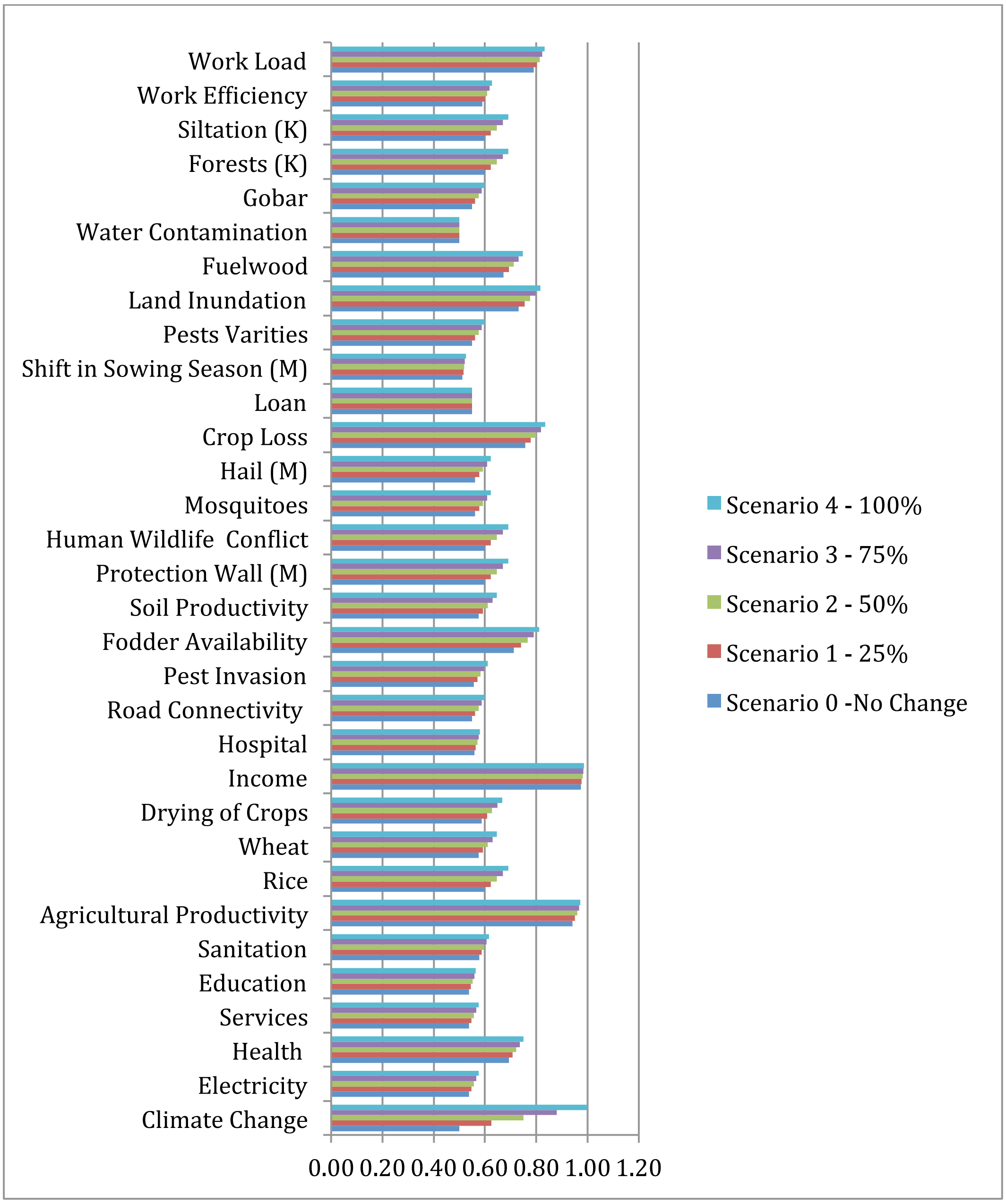

Figure 8: Scenario Generation for Farmers (Plains)

Looking at the extent of change from a scenario of no change (Scenario 0) to a scenario of 100% change (Scenario 4) for each of the variables (impacts) as perceived by farmers in the plains, the following will be affected to a great extent in accordance with the scenarios:

1. Natural Assets: Rice and wheat production, drying of crops, fodder and firewood availability, soil productivity, land inundation, forest cover, human-wildlife conflict, siltation, crop loss.

2. Human Assets: Health, road connectivity.
3. Physical Assets: Protection Wall.

Hence, in order to arrive at appropriate adaptation strategies, such a scenario generation helps identify key areas to address, in order to reduce the impacts of climate change on the livelihood of farmers in the plains of the UGB. For instance, if the protection wall were strengthened as a means of adaptation, it would reduce crop loss and siltation and would thereby reduce the impact on the income of farmers.

7.4.1.2 Labour

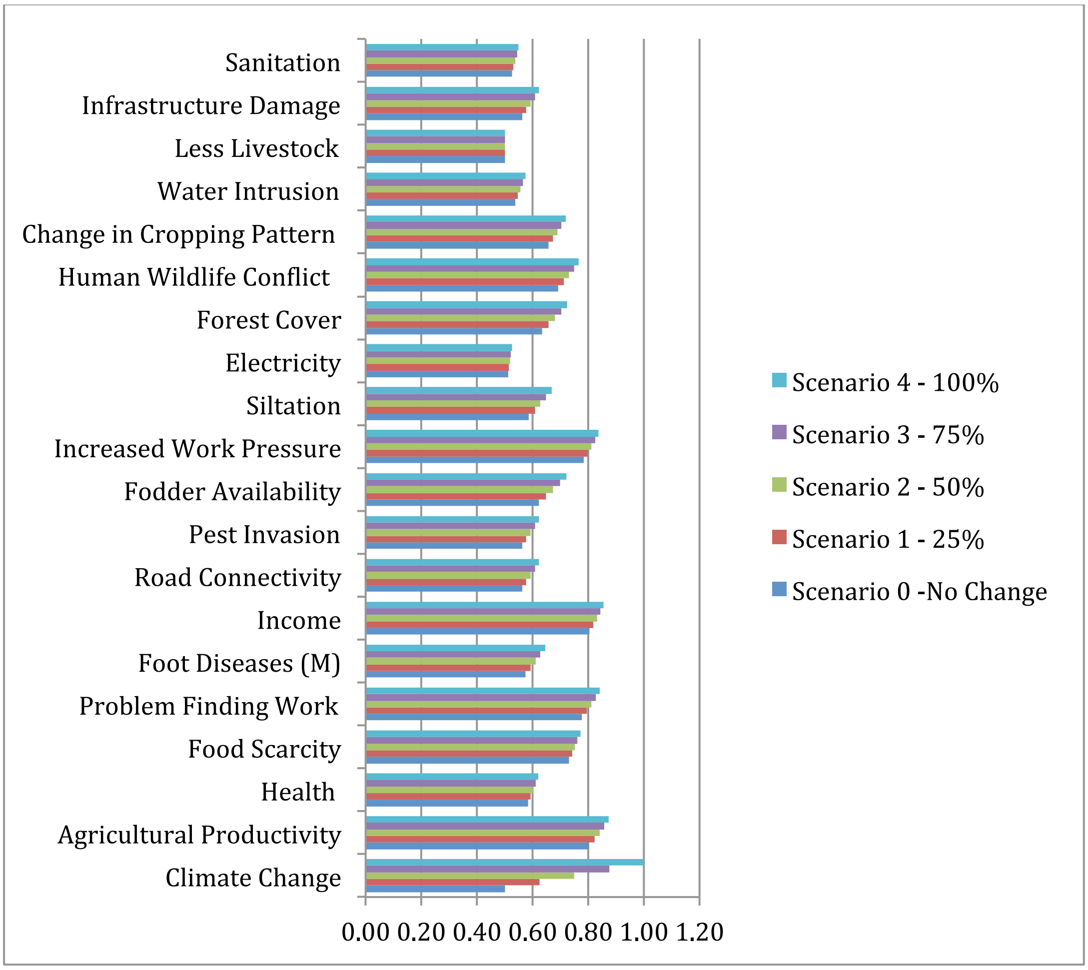

Figure 9: Scenario Generation for Labour (Plains)

Looking at the extent of change from a scenario of no change (Scenario 0) to a scenario of 100% change (Scenario 4) for each of the variables (impacts) as perceived by labourers in the plains, the following will be affected to a great extent in accordance with the scenarios:

1. Natural Assets: Forest cover, crop loss, human-wildlife conflict, siltation, fodder availability, pest invasion.
2. Social Assets: Problem finding work, work pressure.
3. Human Assets: Road connectivity, foot diseases.

7.4.2 Mid Elevation

7.4.2.1 Agriculture

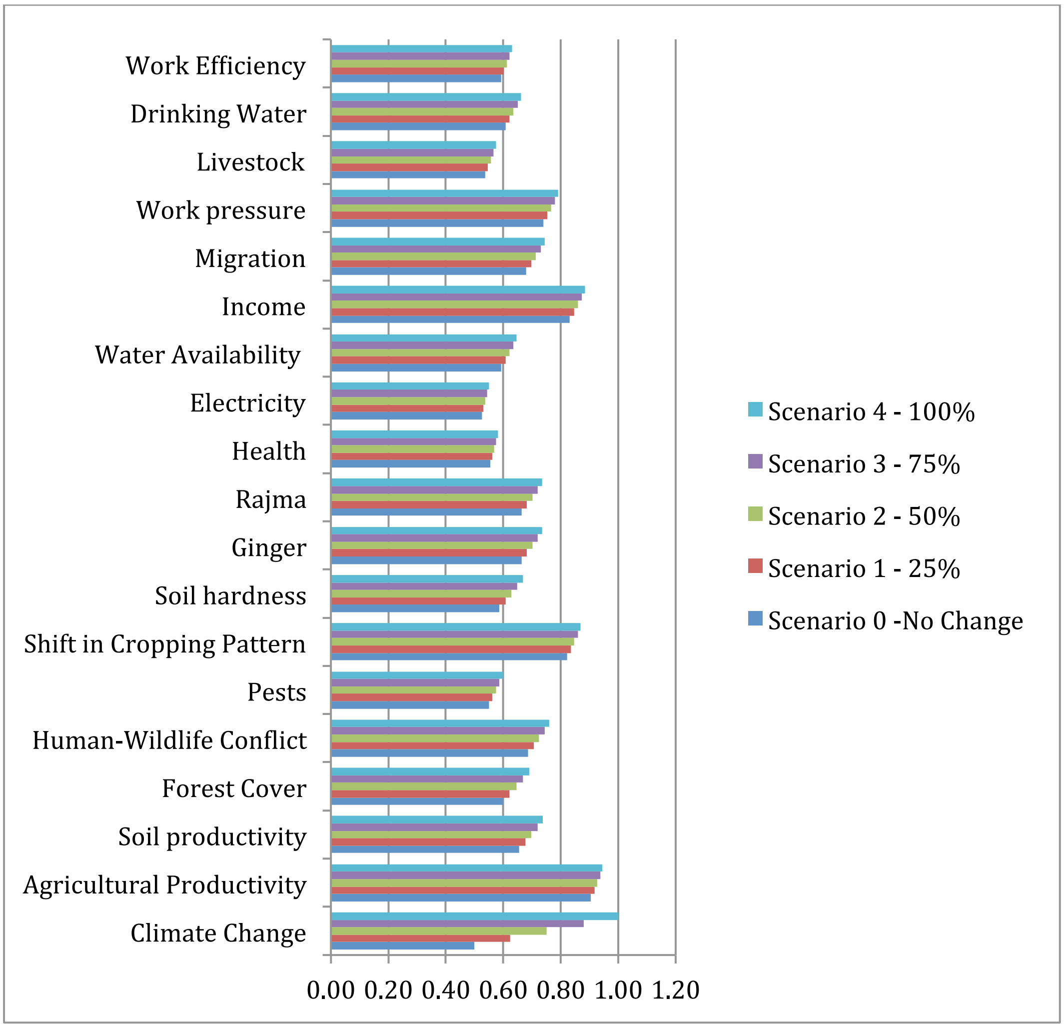

Figure 10: Scenario Generation for Farmers (Mid Elevation)

Looking at the extent of change from a scenario of no change (Scenario 0) to a scenario of 100% change (Scenario 4) for each of the variables (impacts) as perceived by farmers in the mid elevation region, the following will be affected to a great extent in accordance with the scenarios:

1. Natural Assets: Agricultural productivity (overall), rajma and ginger production, soil hardness, forest cover, human-wildlife conflict, water availability.
2. Social Assets: Work pressure.

7.4.2.2 Combined Livelihood (of Agriculture + Labour)

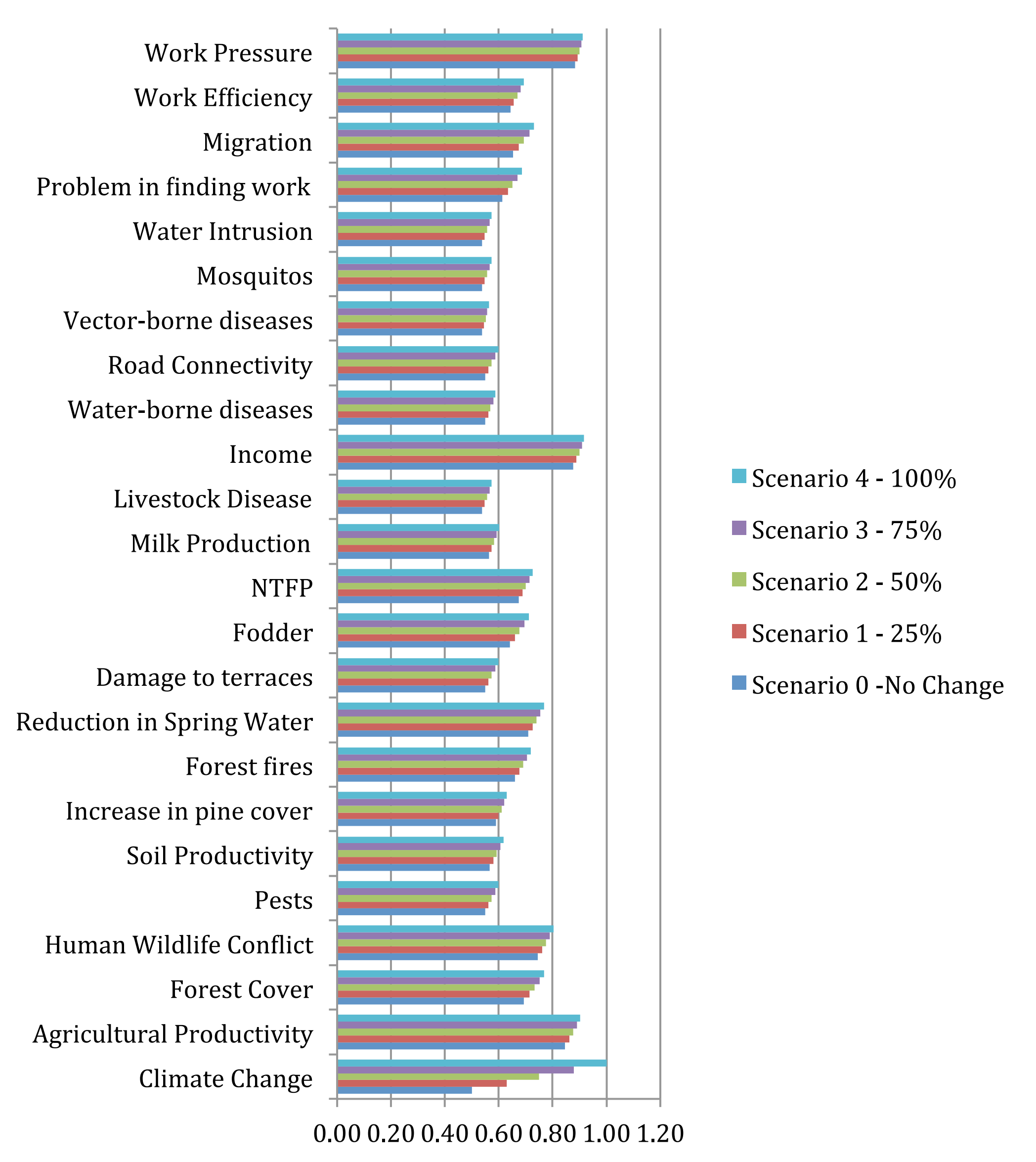

Figure 11: Scenario Generation for Agriculture+Labour (Mid Elevation)

Looking at the extent of change from a scenario of no change (Scenario 0) to a scenario of 100% change (Scenario 4) for each of the variables (impacts) as perceived by the community in the mid elevation region, the following will be affected to a great extent in accordance with the scenarios:

1. Natural Assets: Agricultural productivity (overall), fodder and fuelwood availability, damage to terraces, forest fires, forest cover, human-wildlife conflict.
2. Social Assets: Migration, work efficiency.
3. Human Assets: Problem finding work, road connectivity (in this case, accessibility to markets)

7.4.3 High Hills

7.4.3.1 Agriculture

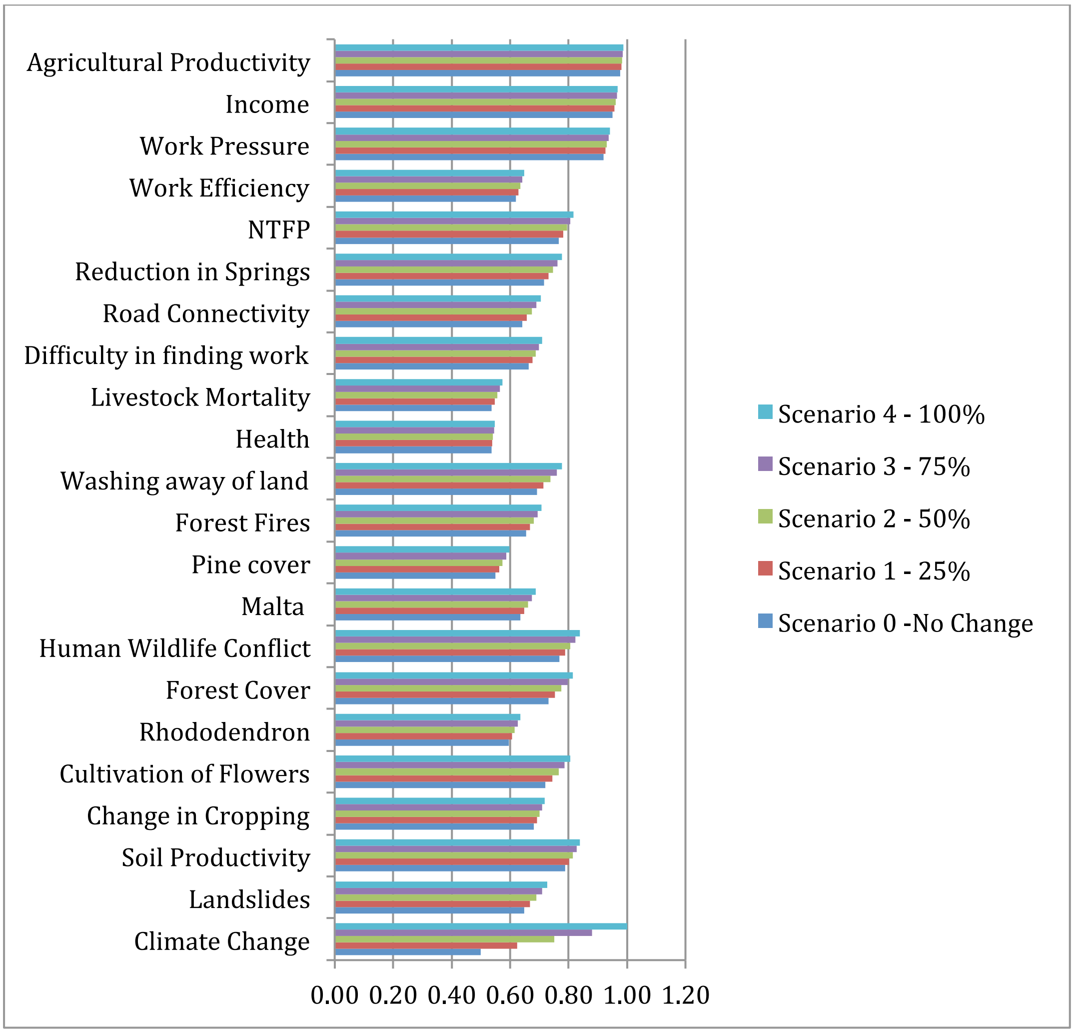

Figure 12: Scenario Generation for Farmers (High Hills)

Looking at the extent of change from a scenario of no change (Scenario 0) to a scenario of 100% change (Scenario 4) for each of the variables (impacts) as perceived by farmers in the high hills, the following will be affected to a great extent in accordance with the scenarios:

1. Natural Assets: Forest cover, human-wildlife conflict, washing away of land, pine cover, forest fires, drying of springs, NTFP availability, landslides (hazard).
2. Social Assets: Work efficiency, difficulty in finding work.
3. Human Assets: Road connectivity/ accessibility to markets.

7.5 Adaptation

The following section deals with identifying the adaptation options from the body of literature pertaining to studies carried out in the Ganga river basin, and discussing the effectiveness and feasibility of these approaches qualitatively on the basis of certain indicators with respect to the study sites in the Upper Ganga Basin. The majority of the published studies on adaptation in the major Himalayan river basins are focused on the Ganges river basin, and flooding has been identified as the principal hazard. Apart from floods, other key vulnerability factors include population density, rampant unplanned development, and human encroachments over floodplains, deforestation, among others. Keeping with the climate change parameters used for the FCMs and the perceived impacts by different livelihood groups in each elevation, various adaptation options have been identified to be appropriate, based on the nature of observed impacts and location within the Ganga Basin. Many of these interventions have been implemented in the Basin, as well in other regions of the world that face similar climate change impacts.

The following table shows the various appropriate interventions that can be implemented through planned adaptations, divided according to the broad sectors impacted by climate change.

Table 7: Possible Adaptation Options for different sectors

Impact/ Risk	Sector	Possible Adaptation Options
Floods, Temperature, Rainfall	Agriculture and Water	Change in cropping pattern
		Bio fertilizers
		Heat resistant crops

		Vermicomposting
		Organic pesticides
		Weather/ crop forecasting systems
		Improved Seed Quality
		Rainwater Harvesting
		Watershed Development
		Micro –irrigation
		Awareness about water- efficient farming practices
		Greenhouses
		High-yielding variety crops
Floods, Temperature	Forest	Afforestation
		Restriction on tree felling
		Nitrogen fixing leguminous plants
		Development of pasture-terraces
Floods, Landslides	Infrastructural Activities	Flood damage preventive structures
		Community Centres
	Livelihood Diversification	Vocational Training

7.5.1 Adaptation Options across Elevations

From the FCMs generated for each livelihood group and the scenario generation, it is clear that certain impacts of climate change are more crucial than others. Hence, in light of identifying implementable adaptation options, addressing acute impacts follows logically. Whereas there are differences in the type and magnitude of impacts felt across different elevations, there are commonalities that arise owing to agriculture being practiced all through the study sites. Following thus, this sub-section focuses on discussing the most pressing impacts and the subsequent possible adaptation options that are similar across elevations. These options are assessed against indicators, arrived at through literature pertaining to similar studies (Snover et al., 2007):

Time frame: Ease of implementation of an adaptation option will depend on time frame and availability of legal and administrative authorities, staff resources, financial and technical resources. Ideally, the time-frame should be low.

Effectiveness: An adaptation option that is sustainable over time is said to be effective. It must be low-risk, and such that it is flexible to changing conditions.

Cost: For effective adaptation action, the cost of implementing the strategy should be low, such that benefits from the adaptation option outweigh the cost.

Equity: An adaptation option must be equitable, in that it should not exacerbate climate change impacts in other areas, or hinder the adaptive capacities of other communities, classes or people.

Social Acceptability: In order for the adaptation option to sustain over time, it must be socially and culturally acceptable. This implies that adaptation planning must be "bottom-up" in order to capture the perceptions and aspirations of communities.

Co-benefits: This indicator aims at exploring the possible co-benefits or other windows of opportunity that the implementation of a particular adaptation option may directly or indirectly possess. An option with high number of co-benefits will be preferred.

The possible adaptation options explored below have been ranked as 'low', 'medium' or 'high' drawing from existing literature, expert opinion and interaction with the communities (on-field data).

Ranking for indicators such as **Cost** and **Co-benefits** have been assessed based on the existing body of literature; **Time Frame** has been assessed on the basis of interactions with government officials from Block Development Offices, Agriculture and Water Departments in different districts of Uttarakhand and professors from local universities (College of Forestry and Hill Agriculture, Rani Chauri, Tehri Garhwal); **Social Acceptability** has been assessed through interactions with stakeholders (livelihood groups) during the process of mapping of perceived impacts and **Equity** has been assessed from field data that captures aspects of equity within and between livelihood groups in an elevation.

7.5.1.1 Agriculture and Water

Table 8: Possible Adaptation Options addressing issues of Agriculture and Water

Adaptation Measure	**Time Frame**	**Effectiveness**	**Cost**	**Equity**	**Social Acceptability**	**Co-Benefits**
Heat resistant crops	High	Medium	Medium	Medium	High	Medium
Improved Seed Quality	High	High	High	Low	High	Medium
High-yielding variety crops	High	High	High	Low	High	Medium

Adaptation options aimed at addressing crop loss and soil productivity would stand to benefit livelihood groups across elevations.

a) **Heat resistant crops and Improved Seed Quality**: Increasing summer temperatures have been observed to have an impact on total crop yield. The introduction of heat-resistant varieties of crops or developing heat-tolerant variations would suit the gradually increasing mercury levels. The time frame for this method could prove to be high, however the measure will be widely accepted. The costs involved in breeding new varieties of heat or drought resistant crops, knowledge dissemination of the same and obtaining seeds for such crops will be high. Once implemented, the effectiveness, equity and co-benefits of the approach will prove to be medium to high in the plains of the UGB.

b) **High-Yielding Variety crops**: In a bid to increase agricultural yield and income, high-yielding varieties of crops can be introduced as a measure. This could be a long-drawn process, given that it requires distribution of resources between the implementing authorities, State Departments of Agriculture and other agencies, and will therefore involve a high cost as well. While the effectiveness and social acceptability of this measure will be high, the aspect of equity in this case could be low, given that there is a strong caste divide in the plains (but not so much in the mid and high elevation villages), and if there is a situation that requires equitable distribution of resources, there is a possibility that the poor, or the lower caste suffers.

7.5.1.2 Soil

Table 9 Possible Adaptation Options addressing issues of Soil Quality

Adaptation Measure	**Time Frame**	**Effectiveness**	**Cost**	**Equity**	**Social Acceptability**	**Co-Benefits**
Bio fertilizers	Low	Medium	Low	High	Medium	High
Organic pesticides	Low	Medium	Low	High	Medium	Medium

Decrease in soil productivity is another major issue in the basin. Soil degradation, particularly the decline in quality and quantity of soil organic matter, is one of the major reasons linked to stagnation and decline in yields in the most intensive agriculture areas in India (Dawe et al., 2003; Yadav et al., 2000; Ladha et al., 2003). The decline in soil organic matter is related to the improper use of synthetic fertilizers and lack of organic fertilization. Use of bio fertlizers and organic pesticides is a low cost option could address the issue of soil quality, and also reduced contamination of groundwater. This measure scores high on the equity, medium on social acceptability since replacing chemical fertilizers could lead to a decrease in yield. The effectiveness of this measure in terms of increasing agricultural yield will be low, at least initially, but will be medium to high as far as increasing soil quality is concerned. The co-benefits include decrease in pests.

The introduction of bio-fertilizers and organic pesticides also has a positive spillover in reducing the work pressure of labour. Since most labour is farm-labour, it follows logically. This will help in controlling pest invasion to an extent and improve soil quality, thereby reducing work pressure. For the labour force in the Basin, the major impacts of climate change include increased work pressure due to human-wildlife conflict and siltation due to floods, lack of fodder availability and pest invasion.

7.5.1.3 Forest

Table 10: Possible Adaptation Options addressing Decreasing Forest Cover

Adaptation Measures	**Time Frame**	**Effectiveness**	**Cost**	**Equity**	**Social Acceptability**	**Co-Benefits**
Afforestation	High	High	High	High	Medium	High
Restriction on tree felling	High	Medium	High	Low	Low	High
Development of pasture-lands	Medium	Medium	High	Medium	Low	Medium

For addressing the issue of human-wildlife conflict, the forest cover needs to be increased. Afforestation programs though extremely effective with a large number of co-benefits, is a costly and time-consuming measure. Restriction on tree-felling is another way to increase forest cover. Even though there is no rampant cutting down of trees and there is a restriction on tree-felling in the mid- and high-hills, locals do depend on firewood availability from the forests and this has resulted in reduction in the forest cover to an extent. However, such a measure would have low social acceptability and a high cost in terms of formalizing such a restriction, and hence does not seem feasible for the study site in question.

For addressing the lack of fodder availability due to the incidence of floods, development of pasture-lands would be a possible adaptation option. However, due to lack of land availability, especially in Khadri Kharak Maaf, the social acceptability of such a measure will be low, and the cost would be higher. Hence, such a measure may not be feasible in the plains.

However, there could be structures built at a slightly higher elevation for storage of fodder throughout the year. This would ensure the availability of a certain proportion of fodder all through the year, and would reduce impact on livestock as well as on labour.

7.5.2 Elevation-Specific Adaptation Options

This sub-section deals with the discussion of elevation-specific adaptation options, of unique impacts that were felt by communities within a particular elevation.

7.5.2.1 Low Elevation

Floods are a major cause of concern in the plains. With an increase in the incidence of this hazard, it has become imperative to deal with infrastructural activities that could aim at addressing the adverse impacts of floods on livelihoods of communities in question.

Infrastructural Activities:

Table 11: Possible Adaptation Options for Low Elevation (Infrastructure)

Adaptation Measure	Time Frame	Effectiveness	Cost	Equity	Social Acceptability	Co-Benefits
Flood damage preventive structures	High	High	High	High	High	Medium

Since flooding is a major driver contributing to land inundation and crop loss, structural adaptation options such as building of a check dam or protection wall will prove to be an effective adaptation measure. From discussions in Mathana, building a stronger protection wall emerged as a unanimous solution, thus indicating a high degree of high social acceptability. However, Khadri Kharak Maaf is located along the stretch of the river, and building a protection wall all along the length of the river will prove to be exceedingly expensive (construction and labour cost), and hence such an adaptation measure will require to be funded by the government. However, apart from the high cost and time frame, the effectiveness and equity will the high. Co-benefits will be multiple, since the root cause of most the issues pertaining to crop loss has been the incidence of floods, including health and road connectivity.

7.5.2.2 Mid Elevation

There is an acute shortage of water in the mid elevation villages. The reasons include the elevation and the rugged terrain with lack of resources or adequate road connectivity. The issue of water shortage could be addressed by the following adaptation measure:

Table 12: Possible Adaptation Options for Mid Elevation (Water)

Adaptation Measure	Time Frame	Effectiveness	Cost	Equity	Social Acceptability	Co-Benefits
Watershed management and development	Medium	High	Medium	High	High	High

Integrated watershed management and development aims to restore the ecological balance by harnessing, conserving and developing degraded natural resources such as soil, vegetative cover and water. Hence, it involves the prevention of soil run-off, regeneration of vegetation, rainwater harvesting and recharging of the ground water table. This ensures multi-cropping and the introduction of diverse agro-based activities, hence indicating a high number of co-benefits. The time-frame and cost for setting up structures for rainwater harvesting pits or storage tanks, will be medium on the scale, given the difficult terrain. The social acceptability will be high, since there is an inherent issue of water storage and supply and an intervention to address the same shall be widely accepted. Equity will remain medium to high depending upon the system of resource (in this case, water) allocation and distribution that the locals and the Panchayat follow. However, since there is no such caste divide in the mid elevation villages, this should not pose a problem. Co benefits would include rejuvenation of natural springs and an increase in forest cover, which in turn would hinder human-wildlife conflict.

Livelihood Diversification:

Due to poor soil quality over time and dependence on rainfall, hill agriculture is far from being productive. Hence, most agriculture practiced in the mid- and high- hills is subsistence. However, with an increase in summer temperature and erratic rainfall, the crop yield has reduced to one-third of the yield ten years ago.

The lack of a stable source of income from agriculture calls for livelihood diversification in the mid- and high- hills.

Table 13: Possible Adaptation Options for Mid Elevation (Livelihood Diversification)

Adaptation Measure	Time Frame	Effectiveness	Cost	Equity	Social Acceptability	Co-Benefits
Vocational Training	Medium	High	Medium	Medium	High	High

It is an established fact that agriculture is not an income-generating livelihood, and hence people in the mid- hills are involved in rafting (particularly in Badal). However, since the rafting business has taken a hit since the 2013 floods and there is no stable source of income in Pyunkhari and Kim Khola, diversification into livelihoods are that less vulnerable to climate change impacts is required. Women can be trained in activities such as stitching and knitting, the products of which could be sent to urban hill markets such as Rishikesh. The cost and time involved in training men and women in the village will be medium, and the effectiveness, equity and social acceptability will be high, thus making it a feasible adaptation option.

7.5.2.3 High Elevation

Water is a cause of concern for the high hills as well, however unlike the mid elevation villages, this elevation faces high intensity erratic rainfall. This has said to exacerbate the existent threat of landslides, and washes away forest cover and small tracts of subsistence agriculture. Given the undulating terrain, high elevation and cost, it becomes difficult to execute adaptation interventions that aim at increasing forest cover. Nevertheless, following are a few interventions that have been observed in the high hills:

Livelihood diversification:

Table 14: Possible Adaptation Options for High Elevation (Livelihood Diversification)

Adaptation Measure	Time Frame	Effectiveness	Cost	Equity	Social Acceptability	Co-Benefits
Vocational Training (Juices, Jams)	Medium	High	Medium	Medium	High	High
Greenhouses	Medium	High	Low-Medium	High	High	High

Since agriculture in the high hills is not productive, there is a need for livelihood diversification. The Piramal Foundation, in collaboration with an NGO called Pragya, as part of their CSR activities is working towards improving livelihoods in the villages of Kalimath and Chaumasi. The aim is to train men and women in making juices (rhododendron, malta) from the trees in the village and the Piramal foundation provide market access. This has led to employment generation among women and has been widely accepted as an adaptation measure. Additionally, the foundation plans on executing a pilot intervention to aid in off-season vegetable production by involving locals in building greenhouses from bamboo. This not only generates employment for locals (building the greenhouse and the maintenance over time), but also ensures a source of income from vegetable production during the otherwise lean season of winter.

In Chaumasi, local adaptation measures to address drying of crops include making a ‘shade’ over the crops. This includes a structure made of sticks and logs around the croplands, and the ‘shade’ is provided but a bed of leaves. To prevent washing away of fodder during the intense rains, small protective structures have been made for the storage of fodder.

Himalayan Alder for regeneration of landslide-affected sites: Increased landslides have been wrecking havoc to land and property in the high hills, and adaptation options to address this hazard are very few. An increase in forest cover does little to prevent landslides. Interestingly, *Alnus nepalensis* D. Don (known as Alder) is a common native species in the Himalayas and has properties of nitrogen fixation. Studies indicate that Alder is predominant in natural and managed ecosystems and colonize denuded habitats and freshly exposed landslide-affected sites. Although it is found at altitudes between 1000-2500 m above sea level, it grows best at 1500-2000 m (Kalimath and Chaumasi lie within this elevation range). These plants are known to generate fast on such sites and hold the soil together, while also fixing nitrogen. Hence, this is a natural adaptation measure to address landslides, and policy makers should consider conservation of the plant as a low cost, viable option for adaptation.

8.0 CONCLUSIONS

The current study explicated the relationship between climate change impacts and livelihoods found in the Upper Ganga Basin. The study sites were selected in three different elevations of the Basin, with two low elevation villages, three mid elevation villages and two high elevation villages. The kinds of livelihoods were identified in each of the villages, and impacts of climate change on each of them were mapped through FCMs on the basis of stakeholder perceptions. The exercise of consolidation of multiple FCMs per livelihood into a single CID for each livelihood in each elevation, helped in a more comprehensive understanding of the collective direct and indirect impacts of climate change and their inter-linkages in each elevation, and also explored differences in impacts felt between two livelihood groups in the same elevation, given similar climatic stresses.

Climate change induced risks such as increased temperature, variable rainfall and hazards such as floods and landslides have seen an increase over the past decade and adversely affected aspects such as agricultural productivity, soil quality and forest cover across elevations. Additionally it was observed that there was an inherent understanding within livelihood groups and local governing bodies that adaptation options are essential in tackling climate change issues and that the absence of the same could possibly serve as a means of exacerbating negative impacts and vulnerability of the marginalised sections or groups.

The predominant livelihood groups in the low elevation villages were farming and labour, in the mid elevation villages rafting was the main source of income and farming practiced was mainly subsistence in nature. In the high elevation villages, religious tourism, subsistence farming and pastoralists were among the major livelihood options. The study aims to bring to light the importance of bottom-up impact based adaptation action, which takes into consideration the perceptions and needs of stakeholders in question.

Another conclusion from the study is the need to move away from the overemphasis on agriculture in adaptation literature. While such an emphasis is justified given that India is predominantly an agrarian economy, the current study submits that while this is not incorrect, it is inadequate. Main sources of livelihood such as tourism in the mid and high elevation villages for instance

have suffered a major setback due to impacts of climate change and there is not enough literature regarding the same. Hence, a contextual consideration of livelihoods is essential in order to move from a mode of reactive adaptation and thinking to one that is proactive.

Consultations with livelihood groups indicate a large number of asset categories that are being adversely impacted by climate change, and would subsequently imply that the impacts need to be addressed. However, given the lack of adequate funds for execution of multiple adaptation options and the existing inter-linkages between the perceived impacts, it is logical, and to an extent realistic, to focus on key areas that require immediate adaptation attention. The exercise of scenario generation carried out for this purpose, identifies areas that will be drastically impacted if the present scenario of climate change is projected to increase. This narrows down the number of impacts to address and makes for a smarter policy choice as regards planned adaptation action. While certain possible adaptation options listed in the study are relevant to all elevations, elevation-specific adaptation options as observed from the fieldwork include addressing the issue of floods in the low elevation villages, water availability in the mid elevation villages and livelihood diversification in the high elevation villages. It must be noted here however, that the study does not claim that the adaptation options discussed in light of the study sites are the best possible or most recommended for the area. It is merely narrowing down of the vast number of adaptation options carried out or recommended for the Himalayan region and discussed with regards to the villages scoped. These options have been found to be most suited to the terrain and the perceived impacts. The adaptation options listed are in no way conclusive or decisive but are indicative of a general sense of direction, thereby warranting the need for further research to test the efficacy of the concepts.

Limitations/ Areas of Improvement:

1. The Fuzzy Cognitive Maps of livelihoods such as rafting and religious tourism, though main sources of income for communities in the mid- and high-elevation villages, could not be generated owing to the 2013 GLOF event, that has been the most devastating flood that the communities had witnessed. Owing to the unimaginable loss to property and family, the affected communities were unable to perceive climate change impacts on their livelihoods other than the flood, and probing further seemed insensitive.

2. Due to the shortage of time, a more comprehensive ranking for the possible adaptation options could not be conducted. However, the adaptation options discussed in the current study provide for further research direction and can be taken back to the field and explored in greater detail, in terms of livelihood groups and government feedback and opinions.

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10.0 ANNEXURES

10.1 Fuzzy Cognitive Maps:

Following section provides a brief description of the variables obtained from the five maps:

Variable	**Description**
Climate Change	Climate change parameters such as rainfall, temperature and extreme events
Work Load	Increase in work load or work pressure
Work Efficiency	Decrease in work efficiency
Siltation (K)	Increase in extent of siltation in Khadri Kharak Maaf
Forests	Decrease in forest cover
Gobar	Washing away of gobar/fuel during floods
Water contamination	Increase in levels of water contamination
Fuelwood	Decrease in/ difficulty in obtaining fuelwood
Land Inundation: washing away of land due to floods	Washing away of land due to floods
Pest varieties: increase in pest varieties	Increase in pest varieties
Shift in sowing season	Shift in sowing season
Loan	Increased instances of communities requiring a loan
Crop Loss	Increase in crop loss
Hail	Increase in instance of hail
Mosquitos	Increase in number of mosquitos
Human-wildlife conflict	Increase in conflict
Protection wall	Breaking of protection wall
Soil productivity	Decrease in soil productivity/ yield
Fodder availability	Decrease in availability of fodder
Pest invasion	Increase in pest invasion
Road connectivity	Lack of proper road connectivity during/ post floods
Hospital	Access to hospitals
Income	Impact on income
Drying of crops	Increase in drying of crops due to increase in summer temperature
Wheat	Decrease in wheat productivity
Rice	Decrease in rice productivity
Agricultural productivity	Impact on agricultural yield
Sanitation	Impact on access to sanitation facilities

Education	Impact on access to education
Services	Impact on basic services
Health	Impact on health of communities
Electricity	Impact on access to electricity
Infrastructural Damage	Extent of damage to infrastructure
Livestock	Damage to livestock
Water intrusion	Extent of intrusion of water in houses
Foot Diseases (M)	Impact of foot diseases in Mathana
Problem finding work	Extent of problem in finding work during/ post floods
Food scarcity	Level of food scarcity
Drinking water	Problem of clean drinking water
Migration	Extent/ rate of migration from the village
Rajma	Extent of damage to rajma crop
Ginger	Extent of damage to ginger crop
Soil hardness	Extent of soil hardness in Badal
Vector borne diseases	Increase in vector borne diseases
Water borne diseases	Increase in water borne diseases
Milk production	Impact on milk production
NTFP	Impact on NTFP
Damage to terraces	Extent of damage to terraces (for farming in high elevation sites)
Decrease in spring water	Decrease in level of spring water
Forest fires	Increase in forest fires
Increase in pine cover	Increase in pine cover
Malta	Impact on production of malta
Rhododendron	Impact on production of rhododendron
Cultivation of flowers	Impact on flower cultivation
Landslides	Increase in landslides

10.2 Scenario Generation

Values of scenarios generated for different livelihood groups:

1. **Low elevation**:

   a) Agriculture

Variable	Scenario 0 - No Change	Scenario 1 - 25%	Scenario 2 - 50%	Scenario 3 - 75%	Scenario 4 - 100%
Climate Change	0.50	0.63	0.75	0.88	1
Electricity	0.537429845	0.546738152	0.556013891	0.565619325	0.574442517
Health	0.693392524	0.708165779	0.722499058	0.736921428	0.749783834
Services	0.537429845	0.546738152	0.556013891	0.565619325	0.574442517
Education	0.538360216	0.544798002	0.551220043	0.557879848	0.564007929
Sanitation	0.577185206	0.586986477	0.59671694	0.606753459	0.615935739
Agricultural Productivity	0.941851175	0.951328027	0.959275699	0.966163274	0.971467242
Rice	0.598688	0.622459331	0.645656306	0.669074026	0.689974481
Wheat	0.574443	0.5926666	0.610639234	0.629016523	0.645656306
Drying of Crops	0.586618	0.60766317	0.628316188	0.649308265	0.668187772
Income	0.973634	0.977278	0.980367	0.983085	0.985218
Hospital	0.559243	0.564658	0.570053	0.575642	0.580778
Road Connectivity	0.549834	0.562177	0.574443	0.587102	0.598688
Pest Invasion	0.556014	0.569853	0.583583	0.597726	0.610639
Fodder Availability	0.712351	0.739925	0.765672	0.790453	0.811514
Soil Productivity	0.574443	0.592667	0.610639	0.629017	0.645656
Protection Wall (M)	0.598688	0.622459	0.645656	0.669074	0.689974
Human Wildlife Conflict	0.598688	0.622459	0.645656	0.669074	0.689974
Mosquitoes	0.562177	0.577495	0.592667	0.608259	0.622459
Hail (M)	0.562177	0.577495	0.592667	0.608259	0.622459
Crop Loss	0.755987	0.778068	0.798436	0.817854	0.834253
Loan	0.548528	0.548709	0.548862	0.548996	0.549102
Shift in Sowing Season (M)	0.512497	0.515620	0.518741	0.521986	0.524979

b) Labour

Variable	Scenario 0 - No Change	Scenario 1 - 25%	Scenario 2 - 50%	Scenario 3 - 75%	Scenario 4 - 100%
Climate Change	0.50	0.63	0.75	0.88	1
Agricultural Productivity	0.80302295	0.823049182	0.841337743	0.857958006	0.87299796
Health	0.582428517	0.59230526	0.602064703	0.611701275	0.621210308
Food Scarcity	0.729975399	0.741011333	0.75154551	0.761595487	0.77118097

Problem Finding Work	0.777041241	0.794690972	0.811058615	0.826202345	0.840188065
Foot Diseases (M)	0.574442517	0.5926666	0.610639234	0.628316188	0.645656306
Income	0.804431052	0.818300576	0.831142145	0.843017727	0.853991916
Road Connectivity	0.562177	0.577495365	0.5926666	0.60766317	0.622459331
Pest Invasion	0.562177	0.577495365	0.5926666	0.60766317	0.622459331
Fodder Availability	0.622753	0.64886684	0.674118946	0.698399102	0.721617252
Increased Work Pressure	0.782509	0.797215	0.811020	0.823936	0.835984
Siltation	0.586618	0.607663	0.628316	0.648511	0.668188
Electricity	0.512497	0.515620	0.518741	0.521861	0.524979
Forest Cover	0.633359	0.657442	0.680719	0.703105	0.724530
Human Wildlife Conflict	0.691403	0.711145	0.729991	0.747908	0.764880
Change in Cropping Pattern	0.657351	0.673493	0.689047	0.704013	0.718392
Water Intrusion	0.537430	0.546738	0.556014	0.565251	0.574443
Less Livestock	0.500000	0.500000	0.500000	0.500000	0.500000
Infrastructure Damage	0.562177	0.577495	0.592667	0.607663	0.622459
Sanitation	0.524979	0.531209	0.537430	0.543639	0.549834

2. Mid elevation:

a) Agriculture

Variable	**Scenario 0 - No Change**	**Scenario 1 - 25%**	**Scenario 2 - 50%**	**Scenario 3 - 75%**	**Scenario 4 - 100%**
Climate Change	0.50	0.63	0.75	0.88	1
Agricultural Productivity	0.904522819	0.916883279	0.927647025	0.937344922	0.945107352
Soil productivity	0.655501034	0.677286969	0.698287871	0.71923177	0.737708811
Forest Cover	0.59868766	0.622459331	0.645656306	0.669074026	0.689974481
Human-Wildlife Conflict	0.685453798	0.70536279	0.724426324	0.743312894	0.75987231
Pests	0.549833997	0.562176501	0.574442517	0.58710249	0.59868766
Shift in Cropping Pattern	0.822135159	0.835249141	0.847338103	0.858902557	0.868734145
Soil hardness	0.586618	0.60766317	0.628316188	0.649308265	0.668187772
Ginger	0.663480	0.682591357	0.701029458	0.719451378	0.735748572

Rajma	0.663480	0.682591357	0.701029458	0.719451378	0.735748572
Health	0.555181	0.562040	0.568862	0.575915	0.582384
Electricity	0.524979	0.531209	0.537430	0.543887	0.549834
Water Availability	0.593778	0.607481	0.620977	0.634767	0.647254
Income	0.830762	0.846018	0.859950	0.873137	0.884221
Migration	0.679671	0.697082	0.713782	0.730404	0.745082
Work pressure	0.740456	0.753849	0.766579	0.779138	0.790136
Livestock	0.537430	0.546738	0.556014	0.565619	0.574443
Drinking Water	0.608134	0.622220	0.636050	0.650134	0.662843
Work Efficiency	0.591975	0.601964	0.611821	0.621928	0.631124

b) Combined livelihood (agriculture + labour)

Variable	Scenario 0 - No Change	Scenario 1 - 25%	Scenario 2 - 50%	Scenario 3 - 75%	Scenario 4 - 100%
Climate Change	0.50	0.63	0.75	0.88	1
Agricultural Productivity	0.846397164	0.863017181	0.876915067	0.890510066	0.901807768
Forest Cover	0.692518721	0.713851047	0.732682272	0.752115671	0.769141871
Human Wildlife Conflict	0.74421065	0.760688707	0.775094127	0.789835984	0.802661385
Pests	0.549833997	0.562668708	0.574442517	0.58710249	0.59868766
Soil Productivity	0.567316769	0.580433491	0.592426734	0.605279693	0.617001725
Increase in pine cover	0.589702531	0.60028662	0.609930359	0.620233558	0.629605318
Forest fires	0.659887	0.675945477	0.690391718	0.705611295	0.719245823
Reduction in Spring Water	0.709119	0.725531668	0.74006498	0.755132247	0.768413331
Damage to terraces	0.549834	0.562668708	0.574442517	0.58710249	0.59868766
Fodder	0.640379	0.660055	0.677667	0.696111	0.712520
NTFP	0.673305	0.687619	0.700425	0.713844	0.725807
Milk Production	0.564018	0.574057	0.583268	0.593179	0.602259
Livestock Disease	0.537430	0.547110	0.556014	0.565619	0.574443
Income	0.877166	0.888949	0.898823	0.908525	0.916640
Water-borne diseases	0.550760	0.560628	0.569694	0.579461	0.588422
Road Connectivity	0.549834	0.562669	0.574443	0.587102	0.598688
Vector-borne diseases	0.538360	0.545055	0.551220	0.557880	0.564008
Mosquitos	0.537430	0.547110	0.556014	0.565619	0.574443
Water	0.537430	0.547110	0.556014	0.565619	0.574443

Intrusion					
Problem in finding work	0.614188	0.633393	0.650749	0.669103	0.685595
Migration	0.652319	0.673957	0.693232	0.713312	0.731078
Work Efficiency	0.643192	0.656507	0.668565	0.681361	0.692917

3. High Elevation

a) Agriculture

Variable	Scenario 0 -No Change	Scenario 1 - 25%	Scenario 2 - 50%	Scenario 3 - 75%	Scenario 4 - 100%
Climate Change	0.50	0.63	0.75	0.88	1
Landslides	0.647068169	0.66835061	0.688898719	0.70943617	0.727604052
Soil Productivity	0.787965718	0.8015234	0.814255976	0.826659287	0.837384615
Change in Cropping Pattern	0.681919994	0.691368638	0.700551258	0.709831816	0.718164548
Cultivation of Flowers	0.720801841	0.744044847	0.765813122	0.786879526	0.804919631
Rhododendr on	0.595413295	0.605385718	0.615212569	0.625274685	0.634417524
Forest Cover	0.731049626	0.753996219	0.775436201	0.796133771	0.813813917
Human Wildlife Conflict	0.768524	0.788068564	0.806147489	0.82345035	0.83812977
Malta	0.634533	0.648125521	0.661395852	0.674840977	0.686919796
Pine cover	0.549834	0.562176501	0.574442517	0.58710249	0.59868766
Forest Fires	0.654723	0.668130	0.681257	0.694593	0.706605
Washing away of land	0.691051	0.714663	0.737041	0.758963	0.777958
Health	0.535425	0.538683	0.541923	0.545276	0.548356
Livestock Mortality	0.537430	0.546738	0.556014	0.565619	0.574443
Difficulty in finding work	0.663495	0.675411	0.686962	0.698580	0.708944
Road Connectivity	0.640592	0.657305	0.673545	0.689904	0.704504
Reduction in Springs	0.715611	0.731845	0.747323	0.762619	0.776022
NTFP	0.766967	0.780740	0.793701	0.806344	0.817289
Work Efficiency	0.620170	0.627393	0.634491	0.641743	0.648323
Work Pressure	0.919381	0.925423	0.930884	0.936013	0.940302
Income	0.950268	0.955520	0.960128	0.964328	0.967740
Agricultural Productivity	0.975774	0.979715	0.982958	0.985730	0.987845

10.3 Photos from Field Visits

Village: Mathana

Village: Khadri Kharak Maaf

Village: Badal


Village: Pyunkhari


Village: Kalimath


Village: Chaumasi

Interactions at Mathana

Interactions at Khadri Kharak Maaf

Interactions at Pyunkhari


Interactions at Kalimath


Interactions at Chaumasi

Guptkashi, Uttarakhand