UNDERSTANDING DIFFERENTIAL VULNERABILITY TO CLIMATE CHANGE: A CASE STUDY APPROACH

Major Project Thesis

Submitted by

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to my parents, brother and grandmother
for their unending love and support

This study was part of the Himalayan Adaptation, Water and Resilience (HI-AWARE) Programme funded by the UK's Department for International Development (DFID) and Canada's International Development Research Centre (IDRC). The study was undertaken at The Energy and Resources Institute (TERI).

DECLARATION

This is to certify that the work embodied in this thesis "UNDERSTANDING DIFFERENTIAL VULNERABILITY TO CLIMATE CHANGE: 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.

GANESH GORTI

Date: 27th May, 2015

CERTIFICATE

This is to certify that GANESH GORTI has carried out his major project in partial fulfillment of the requirement for the degree of Master of Science in CLIMATE SCIENCE AND POLICY on the topic "UNDERSTANDING DIFFERENTIAL VULNERABILITY TO CLIMATE CHANGE: A CASE STUDY APPROACH" during December 2014 to May 2015. The project was carried out at THE ENERGY AND RESOURCES INSTITUTE (TERI).

To the best of our knowledge the thesis embodies the original work of the candidate.

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List of Abbreviations

HI-AWARE	Himalayan Adaptation, Water and Resilience
IPCC	Intergovernmental Panel on Climate Change
PRA	Participatory Rural Appraisal
FCM	Fuzzy Cognitive Mapping
CID	Cognitive Interpretive Diagram
FGD	Focus Group Discussion
TERI	The Energy and Resources Institute
CD	Causal Diagram
DfID	Department for International Development
IDRC	International Development Research Centre

Abstract

The concept of vulnerabilities has been studied for long now, and has a cross domain application. In climate change context the most accepted definition of vulnerability is the Intergovernmental Panel on Climate Change's, which defines vulnerability in the context of exposure, sensitivity and adaptive capacity of entities in question. This said, the scientific community now largely agrees upon the existence of differences in the levels of vulnerability of various communities and individuals. Climate variability presents different challenges to various individuals and communities leading to differential vulnerabilities. The study's intent was to understand this concept of differential vulnerability being felt across elevations of the Upper Ganga Basin. Rooted in grounded theory, the study had assessed the qualitative data that was gathered to arrive at the various sources of differential vulnerability in each of the study sites that were chosen across pre-defined elevation categories. A perception based assessment of the climatic stressors and the subsequent risks and impacts arising out of them were carried out prior to identifying the sources of differential vulnerability. Fuzzy cognitive maps were used to capture these perceptions. Using on field data and existing literature, the drivers of these sources of differential vulnerabilities were then analyzed post identifying the sources of differential vulnerability. The entire study was encapsulated within the conceptual framework of D-P-S-I-R.

Keywords: *climate change vulnerability, differential vulnerability, fuzzy cognitive mapping (FCM), grounded theory, DPSIR*

Chapter I: Introduction

The global trends of Carbon-di-oxide have seen a rise ever since the industrial revolution, so have the ill-effects arising out of such a rise. Surveys around the world have indicated that, like (Cook, 2015), an overwhelming majority of the scientific community now believes that climate change is for real and that its impacts are already being felt. IPCC Assessment Report 5 predicts that the future global temperatures will see a rise and there will be more frequent hot and fewer cold temperature extremes in almost every part of the world (IPCC, 2014).

In such a scenario it becomes imperative that action is taken now, which has been also highlighted in (IPCC, 2014), in both mitigating and adapting to global climate change. While mitigation can be achieved through technology interventions and other behavioral changes, like Carbon Capture, Storage and Reuse (Howard Herzog, 1997), adaptation to climate change requires improvement of current practices to better acclimatize to the changes and risks associated with climate change. Such changes are currently visible and are set to only increase in the near future.

Adaptation to climate change deals extensively with anticipating the adverse effects of climate and trying to take necessary measures to reduce the ill-effects or damages that are to be inflicted by them (European Commission, 2015). While mitigation happens at a global scale, adaptation is largely local and the lead time is almost immediate. In certain cases this might extend up to years or decades. The very nature of adaptation, being local in scale, demands extensive knowledge of the local setting so that the measures that are being proposed remain relevant to the region, also up scaling of such adaptive interventions is very contextual. An integral part of adaptation is trying to gauge the vulnerability of the communities involved so that relevant interventions are taken up.

Vulnerability is a term that is used in various research domains, including food security, public heath, disaster risk and climate change. Vulnerability has a broad user base and hence the careful description of the term is difficult (Timmerman,

1981). In climate change research, vulnerability has varied definitions, with IPCC defining it as follows (McCarthy, 2001):

> *"The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity."*

Hence, vulnerability deals mainly with the exposure, sensitivity and adaptive capacity of the entity in concern. Understanding these components will eventually shed light on how vulnerable a community is to external perturbations, in this case, climate change. Usually, vulnerability assessments are carried out considering a set of population as homogenous, which is not the likely situation.

While the above few paragraphs have tried to explain how vulnerability studies link to adaptation to climate change, a larger context in which this study is set is that of social justice and equity issues in climate change. While there has been a lot of discussion on equity in climate change mitigation, the notions of equity and justice in climate change adaptation research have been a handful (Adger, 2006). This is despite equity being a core component in the United Nations Framework Convention on Climate Change. In order to deliver equity and justice in adaptation as well, it is important to consider the geographic and demographic heterogeneity among various other factors.

To incorporate equity into adaptation as well, it is important to consider variations among and not just across communities; this can be achieved through exploring the concept of differential vulnerabilities within societies.

Differential vulnerability means that different populations face different levels of risk and vulnerability (Rodríguez, 2011). In climate change context differential vulnerability refers to the differences in impacts of various types induced due to climate change on different strata and segments of the society, which often arise due to differences in age, gender, class and geographic location, among many other factors.

Differential vulnerability usually arises out of "*non-climatic factors and from multidimensional inequalities often produced by uneven development process"* (IPCC, 2014) and due to differences in the exposure levels which is determined by the geographic location within the society.

The current study aims to explore this concept of differential vulnerability, to better understand the factors that contribute to different levels of exposure, sensitivity and adaptive capacity among individuals. This would eventually aid in building adaptive capacity of the least vulnerable.

The case study being presented here is contained within a larger research project- *"Himalayan Adaptation, Water and Resilience (HI-AWARE)"*- being implemented by a consortium of research organizations which aims at contributing towards enhancing climate resilience and adaptive capacities of the poor and vulnerable women, men, and children living in the glacier and snowpack dependent river basins. The structure of the report is as follows:

Chapter II outlines the background of the HI-AWARE project and rationale behind carrying out the study and also the objectives of the study. Chapter III presents the detailed literature review carried out for the study. Chapter IV explains the methodology and tools employed in the study to meet the objectives. Chapter V presents the results and discussion of the study, while Chapter VI concludes the study. Chapter VII and VIII states the area of improvements and references, respectively.

Chapter II: Background, Rationale and Objectives

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. The result is CARIAA. Collaborative Adaptation Research in Africa and Asia (CARIAA) 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 consortium that is working on high caliber research on climate resilience and adaptation in the mountains and flood plains of the Indus, Ganges, and Brahmaputra river basins.

People in these regions have been autonomously adapting to the changes, but more needs to be done. In this light, planned adaptation strategies are the need of the hour which can be achieved by better understanding the drivers of vulnerability and the interplay between them. Adaptation measures have to be tried and tested for their efficacy and implementability. This would ensure in upscaling and out scaling these strategies. The HI-AWARE project aims to achieve this in its study basins of Indus, Upper Ganges and Brahmaputra.

This said, conceptualizing differential vulnerability in the local context is important so that adaptation measures reach the most impacted and needy. This research project will hence try to explore the concept of differential vulnerability and the drivers leading to them in the study basin of Upper Ganga, which would in turn assist future studies on vulnerability and adaptation in the region.

2.2. Rationale and Objectives:

One of the necessities for alleviating the problems issues arising out of climate change is adaptation. Adaptation to a large extent can help communities in bolstering themselves from the impacts induced due to climate change. This said, there is a need for vulnerability assessments to precede adaptation measures so that the key vulnerability sources are addressed. Integral to vulnerability is the concept of differential vulnerability, which as the word suggests is the different levels of vulnerability among various strata of a community. Since differential vulnerability of communities can be driven by many factors, which include socioeconomic status of the communities living in the region, the governance structures, and gender, understanding these drivers and the interplay between them would shed more light on the least opportune communities in these regions and thereby assist in developing appropriate and efficient policy measures.

The current research project aims to achieve this. The study would help in understanding the state and condition of the people and the ecosystem. While this is being carried out, drivers of pressures leading to vulnerabilities would also been done simultaneously. This would help in understanding and documenting the exposure and sensitivity to climate stresses amongst various strata of a community, hence shedding light on differential vulnerabilities of the communities in the study basin. A case study approach would be taken up to meet the objectives of the study, which are as follows:

1. To assess the climatic stressors in the study sites.
2. To assess the risks and impacts associated with climate change in the study sites through a perception based analysis.
3. To arrive at sources and drivers of differential vulnerability in the study sites.

Chapter III: Literature Review

This chapter would try to understand the concepts of vulnerability from the existing literature in the domain. Simultaneously, it will also try to understand if the exiting vulnerability assessments have taken in to consideration the concept of differential vulnerabilities and provided the reader with a method to gauge them. This would help in highlighting gaps in the existing literature, if any.

3.1. Concept of Vulnerability

The term vulnerability is often heard in literature related to climate change. According to the IPCC definition, vulnerability is the *"degree to which the geophysical, biological and socioeconomic systems are susceptible to, and unable to cope with, adverse impacts of climate change"* (Hans-Martin Füssel, 2006). While this is the viewpoint of IPCC on vulnerability to climate change, the FAO in its 1999 report on the Status of Food Insecurity defined vulnerability as the *"presence of factors that place people at a risk of becoming food insecure of malnourished"* (FAO, 1999).

IPCC further notes that there are certain risks, impacts and vulnerabilities which, due to various factors, might be key and require particular attention of policy makers. Many climate sensitive systems are associated with key vulnerabilities (M.L. Parry, 2007). Vulnerability in the most generic terms is defined as the capacity of a system to be wounded; in other words, it is the degree to which, a system when exposed to a hazard (B. L. Turner II, 2003). (Timmerman, 1981) is of the opinion that "vulnerability is a term of such broad use as to be almost useless for careful description at the present, except as a rhetorical indicator of areas of greatest concern". In climate change research the existence of competing terminologies for vulnerability has turned problematic, argues (Füssel, 2007).

This said the various definitions of vulnerability can be categorized into two main dominant ideas: 1.) viewing vulnerability as the amount of damage induced by a particular climatic stressor to a system, 2.) viewing vulnerability as a state that a system exists in before the occurrence of a hazard (Brooks, 2003).

The former approach is more of a hazards and impacts assessment, wherein certain human induced factors leading to alterations in levels of impacts is downplayed. When vulnerability is viewed in the context of the latter, it is the structural factors in human societies and communities that make them susceptible to damage from external factors, which are climate change here (Brooks, 2003). The former can also be called as biophysical vulnerability while the former can be called as social vulnerability.

Studies have also pointed to, like (Brooks, 2003), that the analysis of risks that happens in a natural hazards community and the analysis of vulnerability in the climate change community is essentially the same, and examine the same process. This hence removes the ambiguity in understanding risk and vulnerability. This said risk from a natural hazards perspective is probabilistic in nature, while according to according to IPCC it is a function of certain variables, according to the same study.

3.2. Vulnerability Assessments and Capturing Differential Vulnerability

The literature pertaining to as to how vulnerability assessments have to be carried out is vast. As already stated above vulnerability of any particular system relates back to three components which in turn determine how vulnerable each system is. The components as mentioned in IPCC's definition of vulnerability (M.L. Parry, 2007) are as follows: exposure, sensitivity and adaptive capacity. Most vulnerability assessments try to gauge these three factors to arrive at the vulnerability levels.

Currently there are two dominant perspectives to vulnerability assessments, an "end point" and "starting point" perspective (O'Brien, 2007). The end point approach starts with analyzing the projections of future emission trends which then leads to development of climate scenario and then understanding the impacts associated with this change and eventually looking at the possible adaptation options.

This is in contrast with the end point approach which considers vulnerability as the present inability of a community to cope with changing climatic conditions. Here vulnerability is driven by change in bio-physical parameters and also the social, institutional, economic, and political processes among many other (O'Brien, 2007).

Vulnerability can be assessed through various conceptual frameworks. These frameworks hold good for both climate change and other domains as well. Ramsar has its own conceptual framework to analyze the vulnerability of wetlands (Habiba Gitay, 2011), likewise for gauging vulnerability within sustainability science and separate methodology had been developed (B. L. Turner II, 2003).

Likewise, within the domain of climate change, frameworks for assessing vulnerabilities are many. The United States Environmental Protection Agency has its own vulnerability assessment framework called *"Being Prepared for Climate Change"* (EPA, 2014), while CARE Climate Change has an alternate integrated framework for vulnerability and adaptation (CARE, 2009). These are just an example of a few frameworks in the context of vulnerability assessments available in the academic domain. Apart from differences in the framework employed, the assessments can also differ from being a quantitative to a qualitative data based research approach. Utilization of PRA tools in the latter approach can make it a qualitative data based assessment method, like (Aboagye, 2008).

Diverging from the predominant discussion of vulnerability assessments, I would like to bring forth the concept of differential vulnerability that has seen the light of academic research in the recent years. Since vulnerability of an entity is c0-determined by various factors, the vulnerability of levels for individuals or groups can change over time. Also vulnerability is differentiated between groups and within groups, owing to various institutional and financial factors among many other (Adger, 1998). Differential vulnerability can be understood by an example where communities at the same level of exposure to a hazard face different levels of loss and damage. Hence, it is important that vulnerability

assessments take into consideration the aspects of differential susceptibility and impacts.

It is to be noted that the CARE Climate Change's Climate Vulnerability and Capacity Analysis (CVCA) handbook integrates the framework with elements which would assist in gauging differential vulnerability among and within communities, while this is not the case with the EPA's framework. Generally, a bottom-up approach to vulnerability assessments help in gauging different vulnerabilities among various social groups which isn't otherwise possible in a top-down approach (CCARAI, 2014).

(o'Brien, 2004) proposes a framework to analyze differential vulnerability, though this is for a particular sector within a nation or a region. This provides a macro level picture of differential vulnerability, but it is also of critical importance that differential vulnerability be considered at a community level and within it as well.

Chapter IV: Methodology

The initial step of the study included identification of potential study sites across the three elevations in the study region. These were identified through expert interviews. Following which the impacts and risks associated with climate change were assessed using focus group discussions and semi structured interviews, which are a part of Participatory Rural Appraisal (PRA), with villagers across the various socio-economic groups in every study site. The impacts and risks were visualized using Fuzzy Cognitive Maps.

The next step was to identify sources leading to differential vulnerability. This was achieved by comparing the data gathered – using the grounded theory approach – through the various components of PRA employed on-field. Causal diagrams of the sources were drawn at the last. The whole study was contained within the conceptual framework of DPSIR and was guided by the Grounded Theory approach. The chapter is structured as follows: Section 4.1 will shed light on the framework employed in the study, section 4.2 will discuss about the approach taken in the study, and section 4.3 will list down all the tools employed within the framework.

4.1. The Framework: DPSIR

To assign a structure to the study, a DPSIR framework has been utilized. DPSIR is a causal link framework that is generally used to describe the interactions between environment and the society. DPSIR, Driver – Pressure – State – Impact –Response, framework was developed by the European Environment Agency (EEA) (Kristensen, 2004) as a strategic tool for integrated environmental assessment.

The framework distinguishes between the drivers, pressures, states, impacts and responses of a particular system. The linkages in the DPSIR framework are causal links which begins with drivers, and then translates to pressures, which reaches to a certain state and eventually result in a certain amount of impact on the system. This impacted that has been induced on the system eventually leads

to a response mechanism which further alters or changes the way the drivers drive the system.

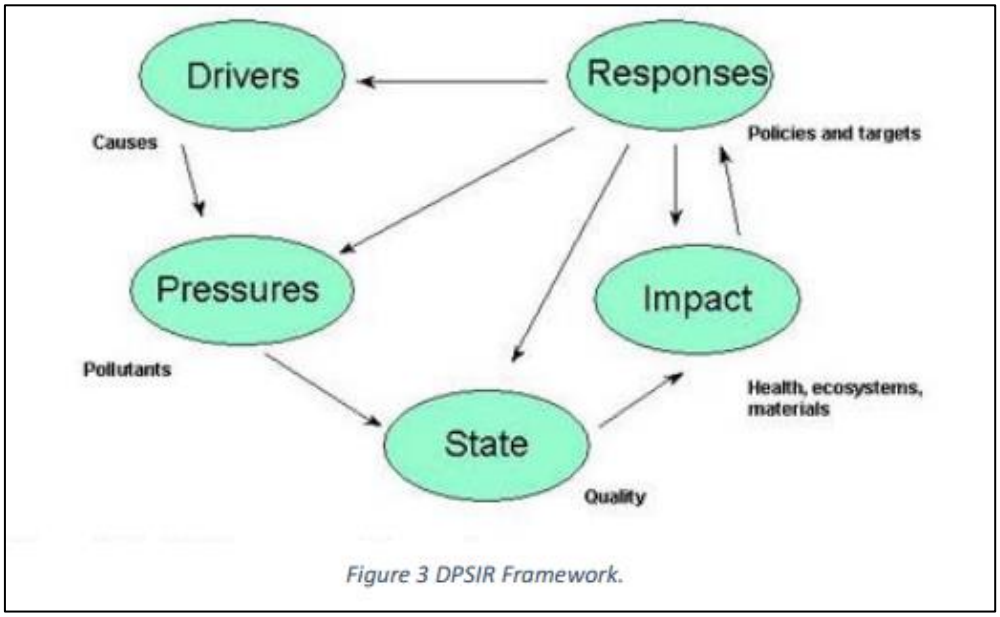

Figure 1: DPSIR Framework
Source: (Kristensen, 2004)

Each element of the framework is defined as follows (Kristensen, 2004)**:**

-Driving forces are changes in the social, economic and institutional systems.
-Pressures are consequences of human activities.
-As a result of pressures, the '**state**' of the environment is affected.
-The changes in the physical, chemical or biological state of the environment determine the quality of ecosystems and the welfare of human beings and hence the **impacts.**
-A '**response**' by society or policy makers is the result of an undesired impact and can affect any part of the chain between driving forces and impacts.

The impacts arising out of climate change have been assessed employing a **risk based analysis**, wherein the change in climate stressors would lead to outcomes which would eventually lead to consequences (read as impacts).

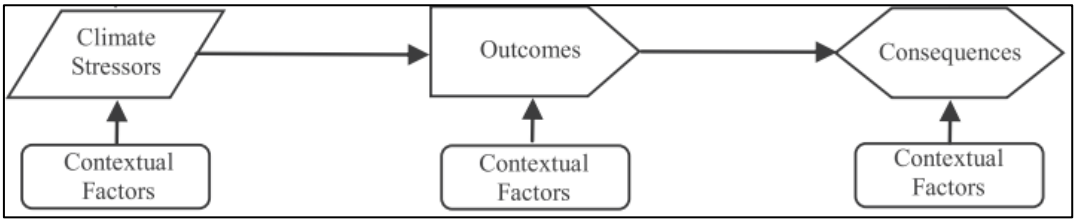

Figure 2: Risk Analysis
Partly adopted from: (Kettle, 2014)

4.2. The Approach: Grounded Theory

Grounded theory approach has been utilized to analyze the qualitative data that was gathered during the course of the study. Grounded theory was founded by Glasser and Strauss in (1967). The aim of grounded theory is to generate or discover a theory (Glasser, 1967). Grounded theory can be defined as *"the discovery of theory from data systematically obtained from social research"* (Glasser, 1967). For this reason grounded theroy has eveolved to be one of the most popular research designs (Mills, 2011).

In its nascent stage, the developers of grounded theory encouraged the use of the startegies associated with it felxibly in their own way (Charmaz, 2006). While there are contradictory viewpoints as to when a literature review can be carried out when employing a grounded theory approach, this study would make use of (Dunne, 2011), which gives the researcher the freedom to decide an appropriate manner to strucutre and present their study.

The principles of grounded theory were employed to analyze the qualitative data generated through the various PRA tools that will be employed (see subsection 4.3.1.). Data was coded into respective categories of the DPSIR framework to better understand the climate risks, exposure, impacts and sensitivity and vulnerability associated with each risk. This data was then used to understand the drivers leading to differential vulnerability among entities. A similar exercise of coding data into relevant categories was carried out in (Kakota, 2011).

4.3. The Tools

This subsection would discuss the various tools that have been used to assist the research, both in terms of data collection and data visualization.

4.3.1. Participatory Rural Appraisal

Participatory rural appraisal has been extensively used in collecting primary data so as to assist the study in meeting its objectives. Participatory rural appraisal represents the growing body of approaches and tools that are being used to enable local people share their knowledge (Chambers, 1994). PRA places critical weightage on empowering local people by giving them an active role in analysing their own living conditions and problems (FAO, n.d.). Among numerous PRA tools and select have been used in this study, which have been discussed below.

4.3.1.1. Focus Group Discussions and Semi Structured Interviews

A focus group discussion (FGD) is an effective way to gather 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 them.

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. (ODI, 2012)

Wherever carrying out focus group discussions wasn't possible, semi structured interviews were conducted with the locals. The guiding questions were related to understanding the impacts induced to climate change, from where subsequent relevant questions were posted.

Following thus, FGDs have been used as a tool for on-field analysis in the study, and have been conducted across various social and economic groups. Asset Mapping, a tool within the PRA approach, and Fuzzy Cognitive Mapping (see section 4.3.2) have also been incorporated within the FGDs/semi structured interviews to better suit the study.

Theoretical sampling was followed for both the FGDs and semi structured interviews in line with the principles of grounded theory. The sample size wasn't predetermined but was rather guided by ***theoretical saturation***, wherein the sampling was stopped once when no new concepts or theories emerged (Morse, 2004).

On the whole, 13 FGDs and 32 Interviews were carried out across the three elevations.

4.3.1.2. Resource Mapping

Resource mapping is an effective tool under the participatory rural appraisal approach, which aims to gauge the resource bases within a community, which can include infrastructure, farmlands, forests, health clinics and special places (FAO, n.d.). This tool was employed to understand the village setting and to identify places where key interactions happen. This helped in shedding light on exposure and sensitivity of various groups to the damage inflicted through perturbations in climate.

4.3.2. Fuzzy Cognitive Mapping

The definition of a cognitive map as given by (Özesmi & Özesmi, 2004) is a quantitative model that depicts how a system operates. The map consists of variables which can be predefined or are defined during the interactions. These variables have a causal relationship between them. The variables needn't

necessarily be measurable physical assets, but can also be abstract ideas such as power relationships. This makes a cognitive map a powerful tool for modeling complex relationships. These maps can be created by either the decision makers or the locals. This inclusion of their perspectives betters the acceptance of the chosen policy options by the public due to inclusion of their inputs in the decision making (Özesmi & Özesmi, 2004). Connecting different FCMs that have been generated allows expansion of knowledge base, as stated by (Kosko ,1986). Fuzzy cognitive maps are hence perceptions of stakeholders that have been translated onto a map, which can be created for any given problem or issue (Özesmi & Özesmi, 2004).

(Axelrod, 1976) devised a means for representing these maps in an adjacency matrix. (Kosko, 1986) has modified Axelrod‟s cognitive maps by replacing binary relations (+, -) with real numbers [-1, 1]. The same has been followed to construct the FCMs in this research.

The primary data used in the study was collected though on-field interactions that were carried out through FGDs and semi structured interviews. All of this was contained within the participatory rural appraisal approach. The tool that has been utilized to visualize the impacts related to climate change in each of the scoped villages is fuzzy cognitive mapping. The following are the steps through which the maps were made:

1) An initial understanding of the village was essential before employing any of the tools. Hence a village setting was understood through interaction with the locals, initially.
2) Post the understanding, the locals were then asked about changes in the climate that they might have observed over the past thirty years. This had given key insights as to how the climatic parameters have changed, and which parameters have resulted into “stressors”.
3) This was then taken as the base criteria to assess the impacts induced due to climate change. This data was also used in the subsequent interactions that had taken place.

4) With the village setting and the climate stressors understood, the locals were then told about the process of making a fuzzy cognitive maps, which included:
    a) To explain to them how climate change will have multilevel impacts, some of which can be direct and the others, indirect.
    b) After the understanding was established, they were then asked to elucidate the impacts that they have been facing in their village due to the established climatic stressors.
    c) Once the elucidation was carried out, the villager were asked to rank each impact on scale of 1 to 10, with 1-3 being low impact, 4-7 being medium impact and 8-10 being high impact.
    d) This was carried out across various socio-economic groups.
5) The variables of these FCMs were later fed into an excel database as adjacency matrices.
6) The matrices were then augmented to yield village level adjacency matrices.
7) These matrices were then fed into FCMappper, a macro enabled excel sheet to obtain Cognitive Interpretive Diagrams (CID). The same software was put to use to carry out statistical network analysis of the maps.
8) Simultaneously .net files were generated using the same software. These files were then fed into Visone, a .net visualizer.
9) Finally, the CIDs were visualized.

4.3.3. Causal Diagrams

The tool, causal diagram, helps qualitative researchers to communicate their findings in a cause-effect relationship, elucidate the ramifications arising out of such a relationship and to derive causal inferences from all these (Pearl, 1994). This has been utilized to represent the data gathered through various PRA tools in cause-effect relationship to in turn derive causal inferences on the sources leading differential impact and vulnerability of the population that is being studied.

4.4. Study Area

The study basins under the HI-AWARE project are Upper Ganga, Gandaki, Teesta and the Indus. The current study was carried out through case studies in the Upper Ganga Basin. The initial stages of the project involved identifying suitable study areas within each study basin to augment the future research components of the project. The sites were identified by understanding the broad level of issues being faced by the locals in the study basin by employing a Climate Change Adaptation Matrix; this was then followed by expert interviews to narrow down on the stretches where such issues might be stark. This was followed by a scoping study, which was carried out by TERI, to identify study sites within the stretches where future research under the project can be carried out. It is to be noted that the identification of the study sites is not a part of the study covered in my thesis.

After the initial scoping study, the following sites have been selected across three elevations (low, mid and high) representing both upstream and downstream sites. The elevation criteria are as follows: low elevation - <500m above mean sea level, mid elevation – 500m to 1500m above mean sea level and high elevation - >1500m above mean sea level. Below is a list of villages that have been for the current study.

Table 1: Study Sites

Village	Elevation Category	Average Elevation
Mathana	Low	250m
Kahdri Khadakmaf	Low	350m
Badal	Mid	620m
Pyunkahri-KimKhola	Mid	1200m
Kalimath	High	1700m
Chaumasi	High	2200m

The study sites map is included below:

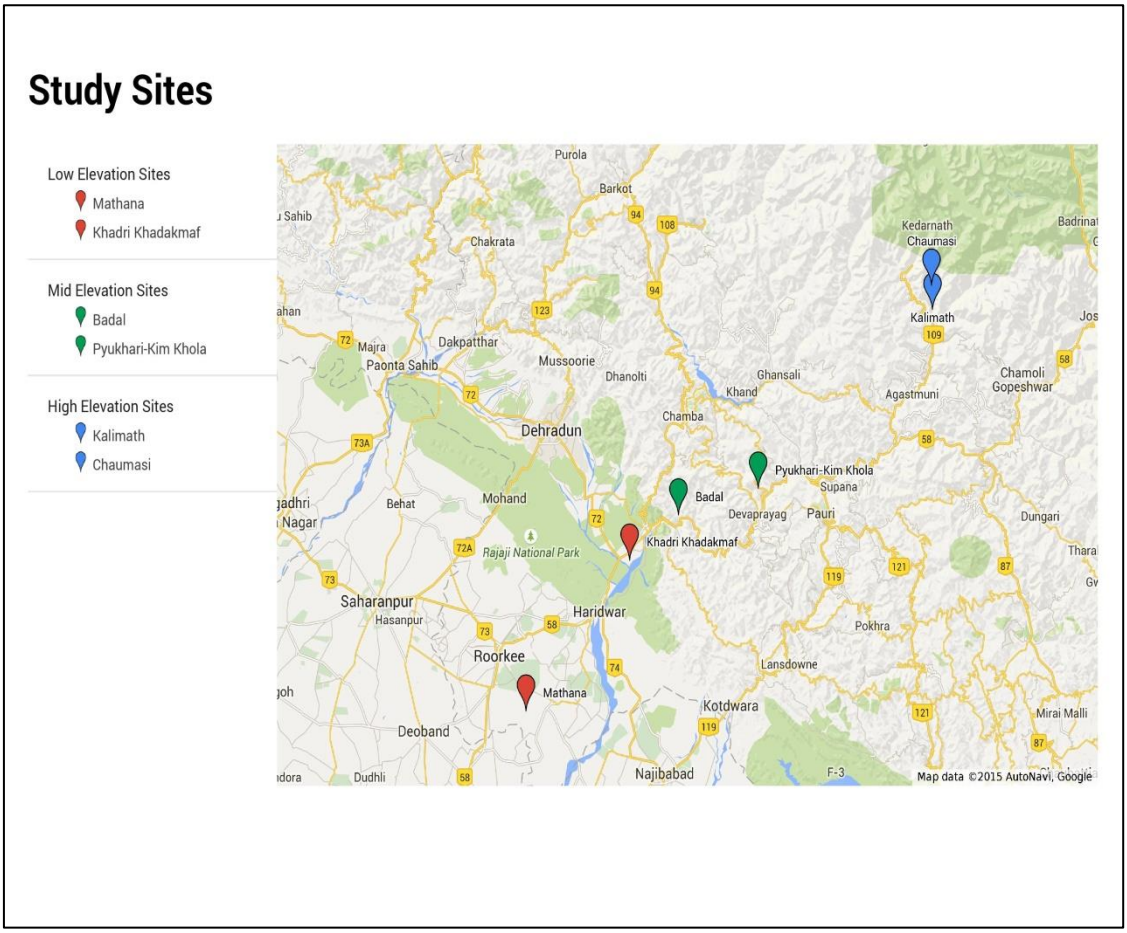

Figure 3: Study Sites Map

4.5. Ethical Considerations

The study was guided by ethical principles of research. The time that the locals had to spare for the interviews and focus group discussions was otherwise invaluable for them; this was the most profound ethical implication that was encountered while data was being collected. Hence, it was made sure that the participants were told of the time that each interview would take, and were allowed to decide whether or not they would want take part in the interviews/discussions. Wishes not to participate in the field work were respected. The principle of informed consent was also followed in all of the fieldwork methods, with the respondents being clearly informed about the nature and the purpose of the research. Additionally, to protect the identity of the respondents, the names of individuals have either been shortened or changed. In some cases as per the researcher discretion the names of the villages and individuals have been completely withheld.

Chapter V: Results and Discussions

This chapter would discuss in detail the results that were obtained from on-field interviews and discussions. Section 5.1 of this chapter would highlight the changes in climate as perceived by the locals in each village. These changes would then act as stressors resulting in subsequent impacts. Section 5.2 would focus on the risks and impacts that were identified through the focus group discussions. Section 5.3 would be a narrative relating to each driver of differential vulnerability, which was understood by employing the grounded theory approach to the data collected through FGDs, resource maps and other PRA tools that have been incorporated within the FGDs.

5.1. Perceived Climatic Stressors

The first step of the study was to understand changes in climatic parameters as perceived by the local communities in the study region. These were established through extensive field interviews carried out in each of the six villages.

On the whole, communities have pointed out to changing trends in climatic parameters that have been witnessed in the recent past only. To establish a baseline, the interviewers were asked to compare the climate in the recent past to what the climate was like thirty years prior to the date of interview. This comparison helped in bringing a temporal dimension in understanding the changes.

In the plains, it was noted that the intensity of every season has witnessed an increase in the past few decades. Both summers and winters have become harsher, according to the villagers. The communities in both Mathana and Khadri Khadakmaf agreed that rains have become more erratic, indicating that while the overall rainfall has increased, the intensity of the rainfall has seen a rise. This aside, while trying to assess the impacts of climate change it becomes imperative for the researcher to also consider extreme events that have and are being induced by climate change. For it is such events that inflict the most damage on societies. For this purpose the communities were also asked whether they have

witnessed any changes in extreme events. Overwhelming amounts of people have indicated to an increase in occurrence of floods. Not just mere occurrence, but also the intensity of such events have increased, the locals noted. Along with this, in the winters, the locals recalled that there have increased occurrences of hailstorms. These climatic stressors were then incorporated into FGDs and FCMs/CIDs which were being carried out in the villages belonging to the low elevation category.

Table 2: Perceived Climatic Changes in the Low Elevation Site

Village Name	**Summer Temperature**	**Winter Temperature**	**Rainfall**	**Extreme Events**
Mathana	Increase	Increase	Increase, with higher intensity	Increased occurrence of floods
Khadri KhadkM-af	Increase	Increase	Increase, with higher intensity	Increased occurrence of floods

In the mid-elevation sites the homogeneity among the climatic stressors was once again maintained, as witnessed in the low-elevation sites. Both the villages scoped viz., Badal and Pyukhari-Kim Khola, have pointed out to an increase in summer temperature and winter temperatures. This is making both the seasons much harsher. While average rainfall has decreased, the intensity of rainfall has increased, the locals also opined. As far as extreme events are concerned, only Badal was prone to them in the form of floods. Pyukhari-Kim Khola were quite distant from the river and hence floods didn't pose a danger, neither did any other extreme event. Locals from Badal have indicated at increased flooding being witnessed in the tributary neighboring their village. These climatic stressors were then incorporated into ensuing FGDs.

Table 3: Perceived Climatic Changes in the Mid Elevation Site

Village Name	**Summer Temperature**	**Winter Temperature**	**Rainfall**	**Extreme Events**
Badal	Increase	Increase	Overall	Increased

			decrease, with higher intensity rains	occurrence of floods
Pyukhari-Kim Khola	Increase	Increase	Overall decrease, with higher intensity rains	No Impact

The high-elevation sites, witnessed a similar trend as far as the climatic stressors were concerned. The locals from both the villages opined that the summer temperatures have been steadily increasing since the past few decades and winters for villagers in Kalimath have turned unpredictable. Though the average winter temperature had gone up, they witness many fluctuations (with sudden dip in temperature) during the season. This wasn't witnessed earlier. One of the interviewers in Kalimath had also pointed out to how seasons are longer stark, meaning there is no clear demarcation between seasons, indicating at how unpredictable weather has become. Also, snowfall in Kalimath had almost come down to zero in the past few decades.

Table 4: Perceived Climatic Changes in the High Elevation Site

Village Name	**Summer Temperature**	**Winter Temperature**	**Rainfall and Snowfall**	**Extreme Events**
Kalimath	Increase	Increase	Rf: Increase, with higher intensity rains Sf: Decrease, almost zero.	Increased occurrence of floods
Chaumasi	Increase	Couldn't gauge	Rf: Increase, with higher intensity rains Sf: Decrease	No Impact

5.2. Risks and Impacts of Climate Change

The following subsections would deal with the impacts of climate change as perceived by locals in each village. Collective village-wise CIDs from the FCMs have been generated and discussed below. These had given the researcher an understanding as to how climate change was impacting the village, which was later used to capture the differential nature of the impacts and vulnerabilities.

5.2.1 Low-Elevation Sites

5.2.1.1. Mathana

Located at a distance of roughly 20 km from the nearest city, reaching Mathana is problematic. The following issues were identified by the locals that are being influenced by changes climate that have brought about in the recent past.

According to the villagers, the recent climatic changes have largely affected agricultural productivity, which is the single largest impact being felt in the village. Along with this, income is also largely affected due to fall in productivity and due to health implications that climate change is having. Agricultural productivity and crop loss due to floods have been identified as separate components by the locals, and are not be mistaken as a single entity.

The locals also identified fodder availability as an issue because of extreme events such as floods. Post such events, which have been increasing in the recent past, fodder availability becomes a major issue since all the fodder is usually washed away or is wet and not fit for animal consumption. This situation persists for the next 15-25 days until fresh fodder is collected or the existing ones are put to dry. Apart from this, road connectivity has also been identified as a problem post such extreme events affecting the labor force the most, posing a difficulty in finding work. Also, through the construction of FCMs with various soci-economic groups, access to proper sanitation facilities for women post extreme events was also identified as an issue.

Agricultural productivity, along with drying of crops and crop loss has shown a major impact on income for the farmers. According to the farming group agricultural productivity is largely being affected by pests. Both pests invasion and new varieties of pests have been pointed as an issue during interactions with farmers. Their understanding is that the changes brought about in the climate are affecting pest invasion. The farmers also noted that increased winter rains are affecting wheat crops extensively. Such high intensity winter rainfall weren't witnessed earlier.

The FCMs also indicated at a decrease in soil productivity over the past many years, which have been attributed to the changes in weather, especially rainfall and extreme heat. While it wasn't possible for them to draw a causal link from changes in weather to decrease in soil productivity, as a researcher one can intuitively link them to fall in soil moisture, soil water retention capacity and other soil fertility indicators. This said, a thorough analysis of the soil quality is recommended to aid future intervention strategies so that they accurately address the possible underlying cause.

Figure 4, in the following page, uses the standard way of representing the fuzzy cognitive maps in the form of a CID.

Network Statistical Analysis for the below CID is as follows:

Number of Maps: 8
Number of Factors: 32
Number of Connections: 63
Average Density in CID: 0.0615
Number of Transmitters: 6.25%
Number of Receivers: 18.75%
Number of Ordinary[1]: 75%

[1] A higher number of ordinary variables indicate a higher degree of interlinkages.

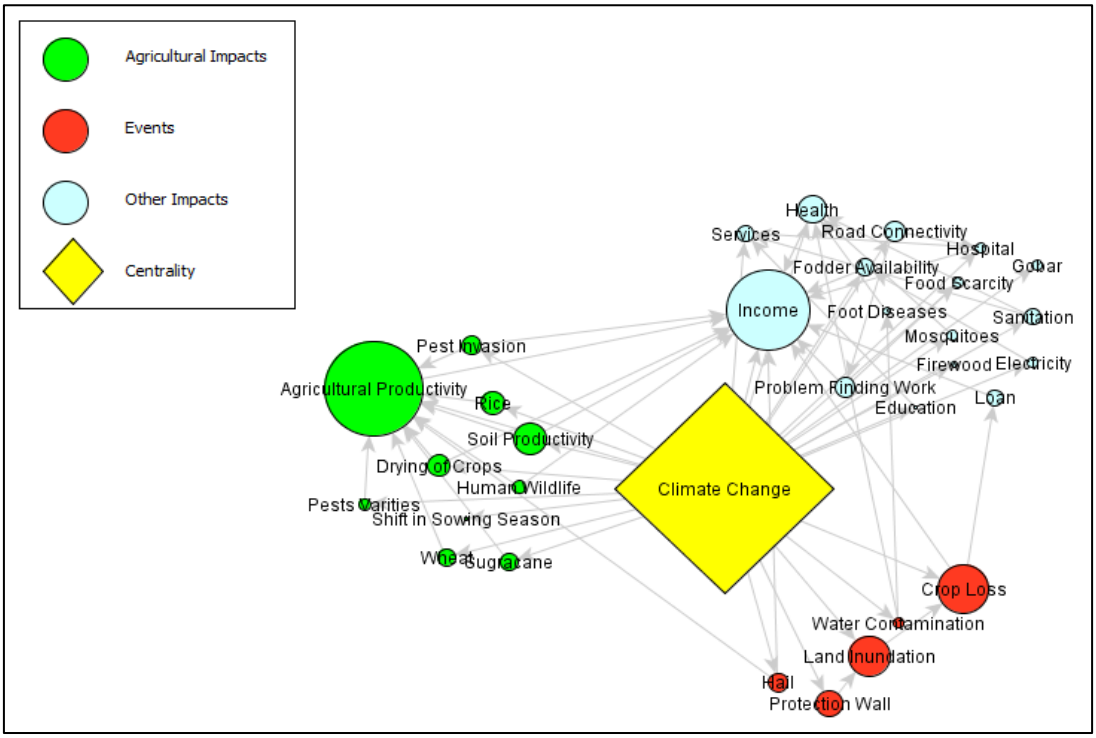

Figure 4: CID of Impacts in Mathana

5.2.1.2. Khadri Khadakmaf

Khadri Khadakmaf, a village set in rural Uttar Pradesh (present day Uttarakhand) thirty years, now has transformed into a large village with concretized roads leading to every corner of the village and having almost all key services within its reach. Khadri is sandwiched between the two important cities in Uttarakhand, Rishikesh and Haridwar. This belt is has many industries in its vicinity, with the premier All India Institute of Medical Science located roughly 7 km from the village. While this is the scene on one side of the Ganges, the other side of the river is covered with dense forests providing a stark scenario. The village has been on an urbanization spree since the past ten years, with a lot of farmers selling their lands off to make use of the reality spike in the region to earn quick and easy money, which was otherwise difficult to earn had they continued with the same livelihood, i.e. farming.

The impacts felt in the village were predominantly related to agricultural productivity. The issues that had come up during the FGDs and the subsequent FCMs that were made were mostly related to pest infestation and loss in soil

productivity which has been observed in the recent past. The farmers felt most of the impact of climate change through loss in productivity of crops. It was also observed that due such changes in soil productivity and urbanization in the region, the local farmers have been forced to give up cultivating certain crops either due to lack of farmlands or due to a disparity in cost of production and profits earned. A region where pulses, vegetables, paddy, wheat was once grown is now predominantly dominated by paddy and wheat.

While soil productivity was an issue that was identified through the focus group discussions in the region, the loss of croplands due to floods in the region was also very high. As mentioned in section 5.1, the region has witnessed increase in flood instances, which have become more intense which is in-turn affecting the crops. Such instances of crops loss and loss in agricultural productivity have been affecting the income of locals. It is also to be noted that the labor who are involved in the farmlands will also be impacted due to fall in agricultural productivity because they eventually will be losing out on the produce which would have been otherwise shared with them. Also, increased occurrence of pests in the region has exacerbated the work burden on the people involved in farming in the region, especially the labor force.

As opposed to Mathana, and noted in the first paragraph, the village is set right opposite huge tracts of forests. The locals were quick to point out to loss in forest land due to the changing climatic conditions in the region. In almost all of the FGDs carried out in the village and was pointed out in the resource maps as well, loss of forests emerged as a variable with a huge centrality. The locals opined that since the communities in the village depend on forest produce for timber and fodder any changes in the forest cover will impact them, which has been happening. They have also pointed out that ever since the forest cover has come down the instances of wildlife invading their farmlands has seen a spike, thereby affecting the agricultural productivity.

Other impacts that the communities felt were in terms of services like schools/colleges shutting down due to extreme precipitation and flooding, health implications that have arisen out of increase in vector and water-borne diseases.

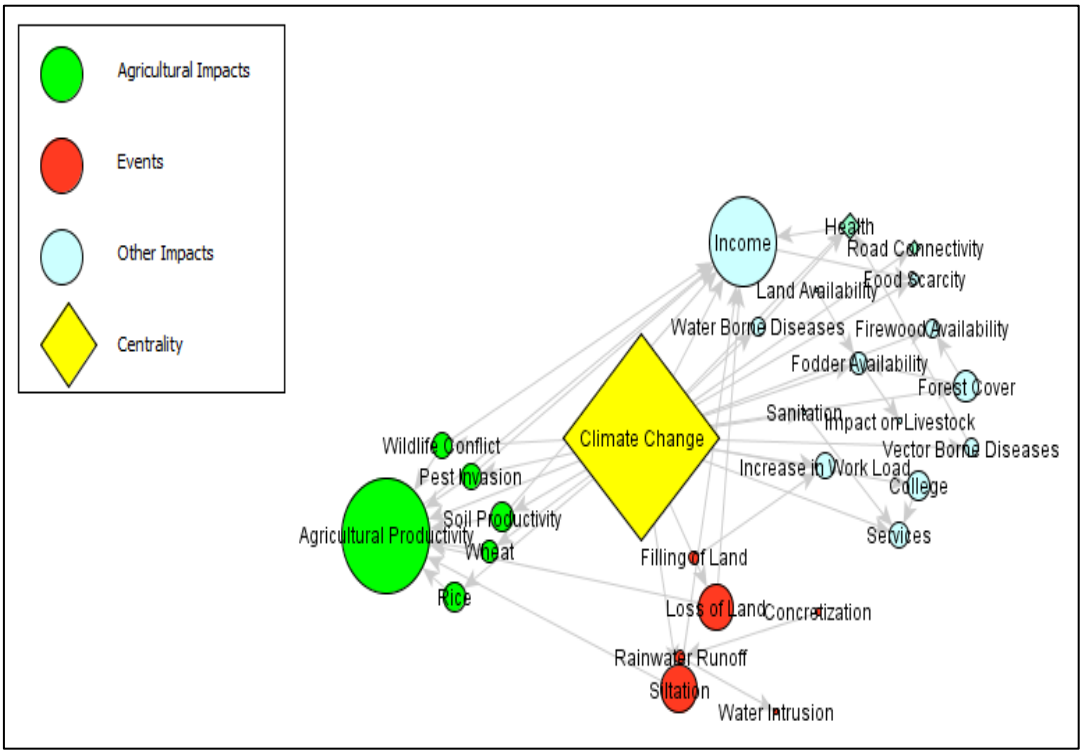

Figure 5: CID of Impacts in Khadri Khadkmaf

Figure 5 uses the standard CID visualization technique in understanding the impacts of climate change..

Network Statistical Analysis for the above CID is as follows:

Number of Maps: 8
Number of Factors: 28
Number of Connections: 47
Average Density in CID: 0.0599
Number of Transmitters: 14.28%
Number of Receivers: 25%
Number of Ordinary: 60.71%

It is to be noted that a higher percentage of ordinary variables indicates a higher degree of interlinkages in the CIDs.

5.2.2. Mid-Elevation Sites

5.2.2.1. Badal

This village is set on the busy Rishikesh-Kaudiyal stretch which is famous for adventure sports, especially river rafting and kayaking. The area is frequented by tens of thousands of people each year, mainly to indulge in the baove mentioned adventure sports, and has therefore served as an alternate source of livelihood for the locals – catering to the needs of the tourists.

The village is set overlooking a tributary of Ganges, on whose beachside a number of beach camps have come up in the recent past. The village is located at an elevation of about 620 meters above mean sea level. In coherence with what has been found in the above mentioned villages, agriculture has also been largely impacted in this village. The locals have complained of a fall in soil productivity and increase in pest occurrence in the region, which is affecting the crop productivity in the region. Also, unseasonal rainfall has been inflicting damage on croplands.

This said, the villagers also highlighted that the forests surrounding the village have come down and this has been impacting their work load since most of them depend on them for obtaining firewood and fodder. A woman had pointed out that she spends roughly six hours a day on average to collect firewood and fodder from forests. Hence, a fall in forest cover has negatively impacted the women especially. Other impacts, such as road connectivity getting affected due to floods and subsequent health implications due to change in weather patterns, including water stagnation arising out of floods and extreme precipitation has been minimum in the region, according to the locals.

The locals had also pointed out that the amount of drinking water gets affected during peak summers, though this hasn’t created so much of trouble for them. Also, reduced flow in the springs around the village was observed. The spring water was usually diverted to form water channels that are being used for irrigation purposes, a reduced spring flow coupled with a decrease in rainfall has

hence negatively impacted the crop productivity in the region, the locals perceived.

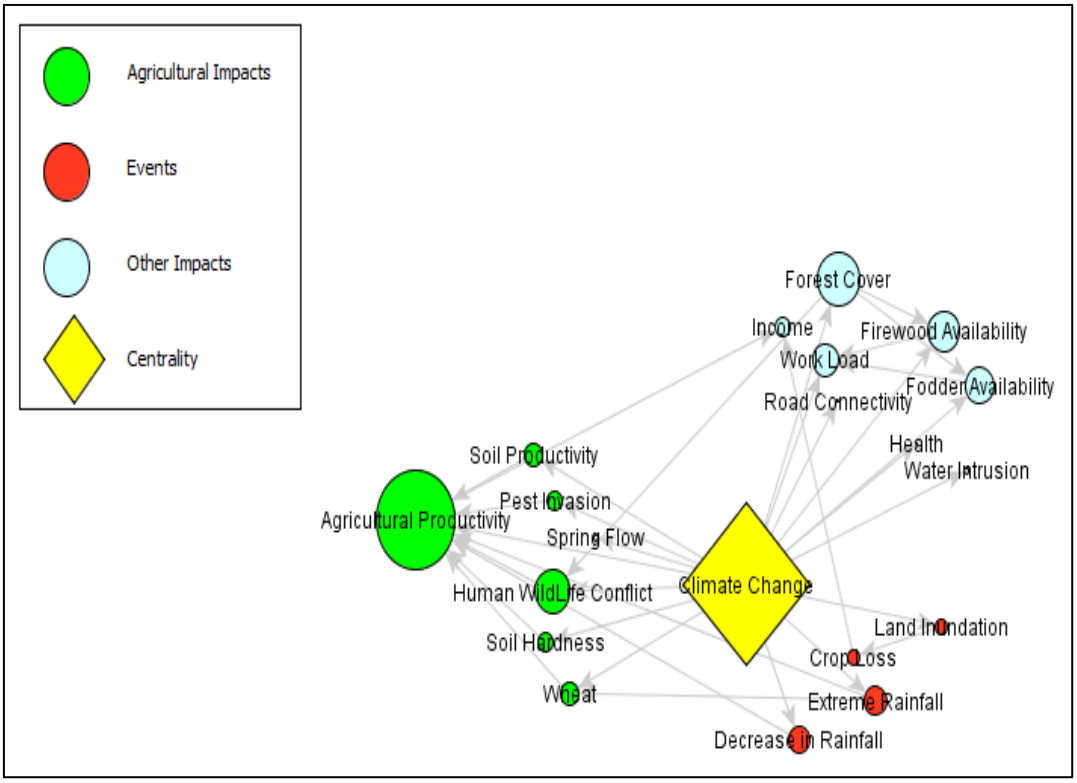

Figure 6: CID of Impacts in Badal

Network Statistical Analysis for the above CID is as follows:

Number of Maps: 8
Number of Factors: 20
Number of Connections: 33
Average Density in CID: 0.0825
Number of Transmitters: 5%
Number of Receivers: 30%
Number of Ordinary: 60%

5.2.2.2. Pyukhari-Kim Khola

Both these villages are located roughly 7 km uphill of Devprayag, a part of the Panch-Prayag, and an important religious location for the Hindus. Devprayag is

the confluence point of Alaknanda and Bhagirathi, which together form the Ganges for the first time here.

Both these villages are located in the water scarce region of Hindolakhal. This region has been facing severe water scarcity since the past many years, adding onto the vulnerability of the locals. Both these villages are located on top of a mountain but on different sides of it, with Pyukhari located at an average elevation of about 1200 meters above sea level and Kim Khola's at 1300 meters. It is also to be noted that the only way to reach this village was by foot and there were no motorable ways through which access can be gained. Hence, availing services was an inherent issue in the region, with women having to carry fully loaded gas cylinders uphill, increasing their already existing work burden.

Yet again, agriculture seems to be largely affected due to the changing climate in the region. This has been captured through the FCMs as well. The locals have pointed out that the farmlands thirty years back were vast and more productive, but this wasn't the situation now, with agricultural productivity declining every year. The locals were of the perception that the decreased rainfall in the region has been affecting their croplands.

They had also pointed out to the problem of human-wildlife conflict in the region, which had been affecting whatever little produce that was being obtained from the croplands. The locals were of the perception that this problem has increased in the recent past, they then pointed towards the forests that surround the village and noted that a decrease in them had led to a spillover of wildlife onto the adjacent farmlands and thereby affecting them. So the reason for a decrease in the forests, according to them was an increase temperature and the subsequent wildfires that they had caused.

The villagers from Pyukhari-KimKhola had also pointed out to the issue of drying springs. According to them, springs in the region had started drying up roughly three decades back and had hardly any flow left in them 20 years back. They had attributed this to a decrease in rainfall and a fall in forest cover as well.

The fall in forest cover had impacted them as the firewood that was usually obtained from these forests was now difficult to find and thereby exponentially increasing the workload of the people involved in their collection.

It was also perceived by the villagers that they had witnessed an increase in disease occurrence in the recent past. Earlier, according to them, they hadn't even known what mosquitoes were, but since the past twenty years the instances of mosquitoes occurrence have increase. Though such an increase hadn't impacted their health, i.e. they haven't witnessed a spike in vector borne diseases. This said, the locals were of the feeling that they had witnessed an increase in water-borne disease in the region, due to unclean water.

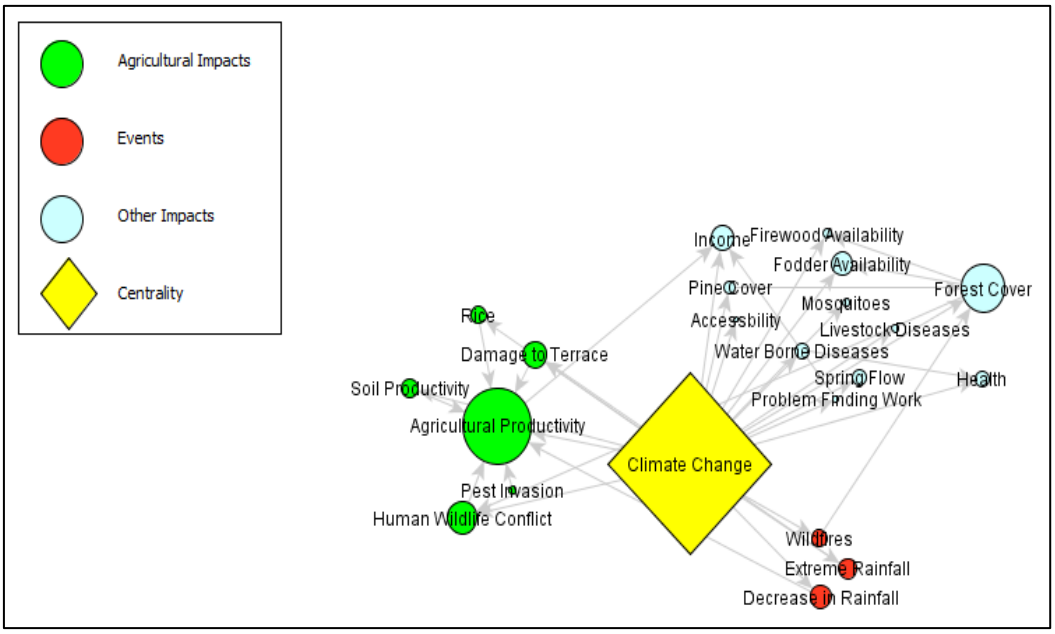

Figure 7: CID of Impacts in Pyukhari-Kim Khola

Network Statistical Analysis for the above CID is as follows:

Number of Maps: 8
Number of Factors: 22
Number of Connections: 35
Average Density in CID: 0.0723
Number of Transmitters: 9.09%
Number of Receivers: 36.36%
Number of Ordinary: 54.54%

5.2.3. High-Elevation Sites

5.2.3.1. Kalimath

Kalimath is a place of religious significance for the Hindu's. It is located on the banks of KaliGanga River, and can be reached through a treacherous road ride from Guptkashi, away from the arterial Kedarnath route. Kalimath is located at an average elevation of about 1800 meters above mean sea level. This road leading to the village has been severely damaged post the 2013 floods that had occurred in the region and is being repaired ever since.

In stark comparison to the situation in the mid-elevation sites, Kalimath is very prone to extreme events like flooding and landslides arising out of extreme precipitation. The local weather patterns seem to be also shifting, as noted in section 5.1. The impacts of such changes have been captured through FCMs, to assist better understanding of how it is being differentially felt among individuals in the village. The resource maps that were generated and the FGDs, along with the FCMs, helped in understanding this, which will be discussed in detail section 5.3.

The locals perceived that with increase in temperature, soil productivity has reduced by a great extent. This was in coherence with what was observed in other elevations as well. Moreover loss of land due to extreme events is also very high in the region. This had resulted in vast agricultural lands getting devastated in the region due to terraces getting damaged from loss of base soil, thereby decreasing the stability of layers present above the and eventually leading to landslides. Apart from this the locals had also identified wildlife conflict as an external stressor that has been affecting the crops in the region. This said, the reason for considering wildlife conflict as an external stressor is that while the FCMs were being mapped, the locals haven't linked this variable to fall in forest cover, unlike the mid-hills.

This said, health implication arising out of climate change has been minimal in the region, though increased incidences of mosquiotes has been witnessed in the

region. It is to be notes that due to lesser variables in the fuzzy cognitive maps generated on field, CIDs haven't been created for this village.

5.2.3.2. Chaumasi

Chaumasi is the last village before the mighty Kedarnath range. Located at an average elevation of about 2200 meters above mean sea level, the location of the village is distant from the nearest urban settlement. Roughly two hours of treacherous ride from Guptkashi, a head stop on the way to Kedarnath, leads you to this village. The village is surrounded by dense forests, which remain under protection. One can witness a helipad, constructed by the Border Security Force of the Indian Army to airlift victims and drop in needs during the 2013 deluge, perched on top of the mountain neighboring Chaumasi. This sheds light on how remote the village is.

The village had also been witnessing a fall in agricultural productivity, whether it be due to increase in extreme rainfall or a fall in soil productivity. Frequent and recurrent landslides have also damaged agricultural crops and taking away precious top soil with it, rendering the remaining land redundant. The locals were of the opinion that the soil quality was also getting affected due to changes in weather. Unseasonal rain for them is an issue, and has been damaging their crop. Due to lesser variables in FCMs, CIDs haven't been generated for this village as well.

5.3. Sources and Drivers of Differential Vulnerability

This section will try to highlight the sources and drivers of differential vulnerability by using the information gathered from FGDs (especially for response measures, which can double up as adaptation measures, like crop loss compensation), Resource Maps (See Annexure), the CIDs and literature as well. By looking at the impacts gauged through the CIDs through a differential lens, sources leading to differential vulnerabilities will be highlighted by employing a Causal Diagram (CD). Subsequently the drivers leading to these sources, wherever applicable, being a factor determining differential vulnerability would

be discussed. Changes in these drivers would then be analyzed in the local context, i.e. either the block level or the district level, depending on the data availability. Both the drivers and trends would be obtained from existing literature.

5.3.1. Age

While looking at the impacts of climate change it is necessary to understand the implications and interplay among various factors which would eventually determine how vulnerable each individual or community is.

The communities in Mathana, a village in the low-elevation sites, have witnessed an increase in health diseases in the past few years, and the same had been identified in the CIDs that has been represented above. These health implications due to climate change have been affecting almost every social group in the village, the labor force has experienced difficulty in attending to work during the day time due to extreme heat, and the men who had visited farmlands soon after a flood event complained of skin diseases. While these remain an issue and the hardship they instill in the lives of people is unquestionable, the issue of vector-borne diseases differentially impacting children has been identified through the FGDs. The locals in the village pointed out to the fact that children have been falling sick more often ever since the occurrence of floods. Susceptibility to diseases in hence high in the two extremes of the age scale: the young and the old. Hence, age has been identified as source of differential vulnerability in the above context.

In addition to the above said impact, in the mid and high hills, the impact on agricultural productivity has been very high, as evident from the CIDs, which is differentially impacting the old. In villages like Badal, Kalimath and Chaumasi agricultural productivity has gone down. This fall in productivity coupled with changes in temperature has increased the work burden of people working in the farmlands, especially the older generation. The capability to carry out intense work is low in older people, and the increased work pressure arising due to climate change is exacerbating the vulnerabilities of this social group. Not just

climatic stressors but non climatic stressors are also adding onto their woes. Out-migration was identified as being quite rampant in these villages, with the elderly being left behind. This had in turn created a huge burden on them, making them responsible to take care of both household chores and also looking into their farmlands. Such non climatic factors have acted as a catalyst in this context to exacerbate their vulnerabilities. Hence there was an equal impact of agricultural productivity on all, but it was being felt differently by different social groups, in this case the old.

Existing literature identifies the factors that drive age to be a source of differential vulnerability. (Seth Tuler, 2008) identifies the factors driving the levels of vulnerability of the elderly population within a community. According to the research increased *out-migration* and a decrease in *birth rate* (to be considered as population growth rate here). These become especially relevant to the mid and high elevation sites in the study area, since the levels of outmigration are high in the region.

This was backed with primary data from on field interactions with the locals in the mid and high elevation villages. The villagers had pointed to high rates of out-migration in the region for better employment opportunities. This arguably had benefitted a few, since there is a source of remittance from the out-migrated population which is bolstering their economic needs; but it has also increased the workload of the elderly population that has been left behind to take care of the farmlands and the livestock. The elderly in Badal had complained of inability to take care of large farmlands and livestock due to increased work burden. Instead they had opted to take care of only small tracts of land and a fewer number of livestock which they could manage.

> *"When I first came to this village after my marriage we had huge tracts of land, we also had a large number of livestock. The workload was divided amongst my husband and the in-laws. But now, since I am only caretaker left, I have reduced*

the number of farmlands and livestock that I manage."

- *Rama (name shortened), respondent in Badal*

This primary data can also be backed with secondary data available at a district and state level. According to Census of India, the number of migrants in Uttarakhand in the year 2001 was at 3.07 million, with 2.06 million being women and 1.01 million being men (Grunawalt, 2012). While this is the picture of migration at the state level, the population growth rates at a district level for Tehri Garhwal and Rudraprayag had shown almost a net zero change for the years 2001 to 2011, indicating at a very low birth rate and an aging population in the region (Census of India, 2011).

This said, the local's perception for an increased out-migration as understood from on-field interactions was for better employment opportunities, since farming in the region had become unproductive and unviable in most of the cases. Hence, outmigration though is being considered as a demographic driver, is being influenced by an impact arising out of climate change, i.e. a fall in agricultural productivity. Below is a depiction of the causal links that have been discussed thus far.

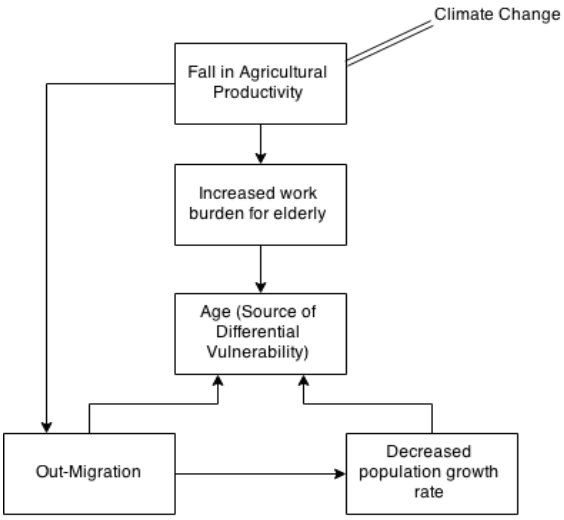

Figure 8: Differential Vulnerability and Age: Interlinkages among Sources and Drivers

The reasons stated above shed more light on why age is a source of differential vulnerability. They also shed light on the interlinkages amongst climate change impacts and demographic trends, which can better understood through Figure 8.

5.3.2. Proximity to Hazard Source

In all but two villages, extreme events were identified as a cause of concern which had been impacting their livelihoods in various ways. Impacts from floods were felt across various dimensions of life, from crop loss to fodder availability to impact on services. This said, by understanding the village setting and the way these impacts were being felt by various pockets of societies in the each village it was arrived upon that distance from the hazard source is largely exacerbating the vulnerability. The farther away one is from the source of hazard the lesser is the impact. This concept can be better understood through the following narrative.

In Mathana farmlands are spread out in all directions of the village. To the west of the village is river Solani that usually becomes active during the rainy season, and just beside the river are huge tracts of farmlands, behind which is a protective wall. Now, this village has been facing crop loss due to land inundation (induced due to floods) in the recent past. But it has to be noted that land inundation is greater in farms which are in the immediate vicinity of the river as opposed to the farmlands that are located behind and farther away from the river. Land inundation usually happens in farmlands located farther away from the river only when the protection wall is damaged. So, in this case people with farmlands in close proximity of the hazard source which here is the river are more impacted and vulnerable.

The same was felt in another village, Badal (Mid Hills), where the village was transected by two streams that originate from the top of the hill and the farmlands in the immediate vicinity of these canals were more impacted during heavy rainfall events as opposed to other farmlands, as water runs down through these streams and spills over to the adjacent farmlands.

Kalimath, a village in the high-elevation category had also witnessed such massive devastation due to occurrence of floods. Large tracts of land that were once located just beside the river before the occurrence of floods have now been completely devastated. Infact, so stark is the situation now that one wouldn't even imagine that there were once lands in the region. The river bed had expanded causing large scale inundation and cutting away terraces that were located close to the river.

Literature points out to increase in *flood plain encroachment*, due to rise in *population*. This rise in population is hence in turn driving this source of differential vulnerability.

For villages set near a water system like a river, a stream in its vicinity, proximity to this will remain as a source of differential vulnerability.

5.3.3. Land Holding

Land holding plays a critical role in determining who is more vulnerable and this has a strong interrelationship with another driver; proximity to hazard source. While land holding in itself will determine who is more vulnerable in a society, to better understand who might be differentially impacted due to climate change within the same subgroup having the same land holding size it is important to consider it in combination with proximity to hazard source as well. Since it is the interplay between these both that eventually determines as to who is more vulnerable.

It is to be noted that this driver is a source of differential vulnerability mainly in the floodplains and not the hills. The average land holding size in the hills is almost the same, with minor differences, while this isn't the case in in the plains, and land holding sizes fluctuate greatly. For instance, Khadri Khadakmaf has farmers ranging from marginal to small to large farmers.

To understand the concept of land holding as a driver of differential vulnerability the following narrative from Khadri Khadakmaf shall be elaborated. While

marginal and small scale farmers in the village had issues relating to growing pest invasion and fall in soil productivity impacting their agricultural produce in an adverse way, the same wasn't pointed out as an issue for the medium and large farmers. Surprisingly, a medium scale farmer Tiwari (name changed) with about 12 hectares of land in his possession had mentioned of no such impacts being felt by him. He had mentioned about an increase in pest instances but had opined that his hasn't impacted him much. Hence, for a farmer with a greater land holding though climate change does impact him he is more insulated from income fluctuations as opposed to a marginal farmer who usually survives from hand-to-mouth. Hence, hand-mouth existence increases your susceptibility to fluctuations in income arising out of fall in agricultural productivity. All of which was backed by the views of the locals.

This was also witnessed in Mathana, where such a situation arose between marginal farmers and small scale farmers. Marginal farmers opined that when floods occur and their croplands get destroyed, they are left in a lurch, since that would have been otherwise been their source of food. While where of the opinion that even after the crop loss due to floods, they are still left with some amount crop which would fill their household needs, hence not leaving them in a dire situation like the marginal farmers were in. Below is a quote from an interaction with a small farmer in the same village.

> *"We aren't impacted as much as mazdoors (labor) are.*
>
> *Because they have less land and hence the impacts*
>
> *of crop loss post floods is zyaada (more) on them and*
>
> *it leaves them in a food scarce situation."*
>
> - *Kumar (name shortened), Mathana*

Land holding also becomes an issue from a different context, the context of being able to obtain firewood and fodder. This was observed in Khadri Khadakmaf, which was once a silent village in rural Uttar Pradesh (present day

Uttarakhand) but has since transformed into a village with a peri-urban setting. While trying to gauge the impacts of climate change on people in the village, it was noted that the landless or people with less land had complained of difficulty in finding fodder and firewood, this wasn't brought up as an issue by people with relatively larger land holdings. The reason behind this was pointed out by one farmer, Negi (name shortened), who had mentioned that people with relatively larger tracts of lands usually set aside certain portion it for cultivation of grass (for fodder) and other trees (for fuelwood) and hence aren't dependent externally for them. But people with the smaller tracts of land couldn't afford this, since they needed every bit of available land for cultivation of staple crops which were later used and consumed at the household level. This had increased their dependency on external resources, exacerbating their vulnerability as fluctuations in these resources (a fall in forest cover and subsequent impact on fodder and firewood availability was recorded in Khadri Khadakmaf) had direct implications on the population dependent on them. This is in particular reference to the Bhoksa tribe that resides in the villages, who are currently landless but had land earlier, which was sold off to make quick money.

Apart from this, scattered land holdings in the hills, has exemplified the menace of human wildlife conflict in the region. The locals opined that due to scattered land, tackling wildlife conflict in their farmlands becomes problematic. It is to be noted that this scattered landholding might not be realized in every individual, hence exacerbating the vulnerabilities of the ones with such lands.

The following instance shall highlight another dimension of how land holding gives rise to differential vulnerability among individuals of a society. Badal, a village in mid-hills is being impacted by fall in agricultural productivity due to various reasons, ranging from poor soil quality to increased instances of human-wildlife conflict. This said, the village is located on the Rishikesh-Kaudiyala stretch which is famous for river rafting and beach camping, and hence a few locals have diversified from farming to such tourism-based activities, which is lucrative. But this diversification, from farming to tourism, was only possible for farmers who had previously held comparatively larger tracts of land. This is so because the space required for setting up camps is large and hence people with

smaller tracts of land cannot diversify. This was highlighted by marginal farmers in the village. One farmer, beside whose land a new beach camp had come up, responded in the following manner when asked if he would be willing to sell off/lease his land for setting up such beach camps:

> *"I will be willing to, but we do not have enough zameen(land) to lease our land off for such activities. How many beach-camps can one set up on my land? One or two. No one would want to set up only one or two camps, so it's not possible."*
>
> - *Bhandari (name shortened) (marginal farmer), Badal*

Thus, land holding size can also inhibit the capability to diversify from a particular livelihood source to another and thereby exacerbating the vulnerability of the least opportune.

Land holding sizes in the study sites usually driven by *poverty*. In the study sites, the landless or the ones with lesser landholding size belonged to a economically weaker sections, hence, poverty is taken to be a driver, particularly in low-elevation sites of the study area. Additionally, *family size* also determines the land holding, which was observed through interactions on-field. It has been observed in the plains that due to increase in family sizes, there are continued subdivisions of land within the family and hence shrinkage of land holdings was observed. In Khadri Khadakmaf a respondent noted that his father had land measuring close to 8ha, but since the land was subdivided among his brothers who were five in number, he had received only ~1.5ha of land, which categorizes him as a small scale farmer. Such drivers lead to land holding to be a source of vulnerability.

5.3.4. Resource Dependency

Resource dependency is another factor that determines as to who is more vulnerable in a society. The resource maps helped in understanding the natural resources in and around the village and who interacts more with them, and on the

other hand the FCMs/CIDs helped in understanding which resource has borne the brunt of climate change in the region. By understanding this, the study could conclude that resource dependency was acting as a driver leading to differential vulnerability.

Take this example for instance:
Villages Pyukhari-Kim Khola had witnessed a fall in forest cover over the past many years. Increase in temperature had resulted in forest fires which had greatly impacted the forest cover. This reduce in forest cover had inturn led to difficulty in finding fodder and firewood. Communities and house-holds that are more dependent on these resources for their livelihoods are in-turn differentially impacted than those who aren't. Among these communities itself there are many who depend on both Liquefied Petroleum Gas (LPG) cylinders and firewood for cooking purposes, but there are a few households, owing to their poverty are over dependent on firewood for cooking purposes and hence rely heavily on forests for obtaining them. In this case, the families that are over dependent on firewood tend to be differentially vulnerable as opposed to the ones who are relatively less dependent on them. Though this is seen only when the particular resource in question is depleting, like in this case forests.

A similar situation was observed in almost all the villages scoped. Four out of the six villages scoped had the same plight of resource depletion and a few households, usually the poor, having to depend more on the same depleting resource hence exacerbating their vulnerability.

At a micro level, intangible assets like *inter-household power dynamics* play a role in determining who is more dependent on a particular resource. Across all the study sites, it was observed that the women are more resource dependent since they are responsible for collecting fodder. In the mid and high elevation sites, women have an additional burden of looking at farm work and collecting water. This work sharing between men and women is driven by inter-household power dynamics and hence makes a certain portion of the society more resource dependent than the others.

5.3.5. Gender

Through the impacts that were gauged it was understood that most of the issues were gender differentiated. Certain impacts were being felt by women more than men. Hence, Gender in itself has been identified as a driver of differential vulnerability. This said, the factors feeding into gender and thereby making it a source of differential vulnerability are numerous.

Evidence from field suggests that there are numerous feedback loops which end up driving gender to yield differential vulnerability, including cross linkages among drivers. The factors included inter household dynamics, social customs among many other factors. The following narratives will aim at shedding light on these factors and also justifying gender as a source of differential vulnerability.

As stated in section 5.3.4., resource dependency is a driver of differential vulnerability at a house hold level, but within a household level gender plays a critical role in determining who is more vulnerable. Take this situation for example; a fall in forest cover and a subsequent difficulty in finding firewood were identified as impacts of climate change in Pyukhari-KimKhola through the FCMs. Though the level of resource dependency determines who is more vulnerable to fluctuations in the resource, at a micro level it is more complex congregation of factors that determine the vulnerability, which is usually down to gender. In Pyukhari-Kim Khola, and in most places in the hills, women are usually responsible with collecting firewood from the surrounding forests, and hence at a micro level it is the women who are directly impacted due to a change in resource and it is not the men. This situation was observed in Badal and Kalimath as well, where women are usually associated with collecting firewood from the forests.

Adding onto the responsibility of gathering firewood, women are also largely involved in farming. In fact, in almost all the villages scoped in the mid and high hills it was the women who were more involved in farming activity, hence making them more vulnerable to fluctuations in productivity. Any fall in productivity has direct implications on work pressure, which would

proportionally go up with fall in productivity which might arise due to any reason, ranging from pests invasion to fall in soil productivity to unseasonal heavy precipitation.

Such customs of *"who does what"* has been identified as the reason that is contributing to gender being a source of differential vulnerability.

While this remains one aspect of gender, another aspect is directly related to how certain impacts of climate change are differentially felt. Through the FCMs in the floodplain villages, access to sanitation facilities during extreme events was brought up as an impact by the women who were interviewed. Clearly, the men in these villages had no such issues. This is usually driven by both anatomical and social disadvantages.

Gender as a source of differential vulnerability can be driven by two main factors, one would be a fall in *sex ratio* resulting from male out-migration and the other would be *out-migration* of men in itself, the latter being more prominent in the villages scoped. It has been observed that it is the men who usually out-migrate, resulting in feminization of agriculture, which in turn has increased the work burden on these women. More over *power relationships*, as stated in section 5.3.4, also have a critical role in driving gender to be a source of differential vulnerability.

A fall in child sex ratio and changes in the total sex ratio have been recorded in exiting literature pertaining to one of the districts where two of the villages in the mid elevation fall. The child sex ration in Tehri Garhwal district, where the mid elevation sites fall under, declined from 927 females per 1000 males to 888 for the years 2001 to 2011, while the total sex ration increased from 1049 to 1078. (Grunawalt, 2012)

Below is a depiction of the interlinkages between the drivers and sources of gender leading to differential vulnerability. Outmigration in the mid and high elevation sites is resulting in feminization of agriculture and thus leading to

differential exposure of women to impacts induced due to climate change, which is a fall in agricultural productivity here.

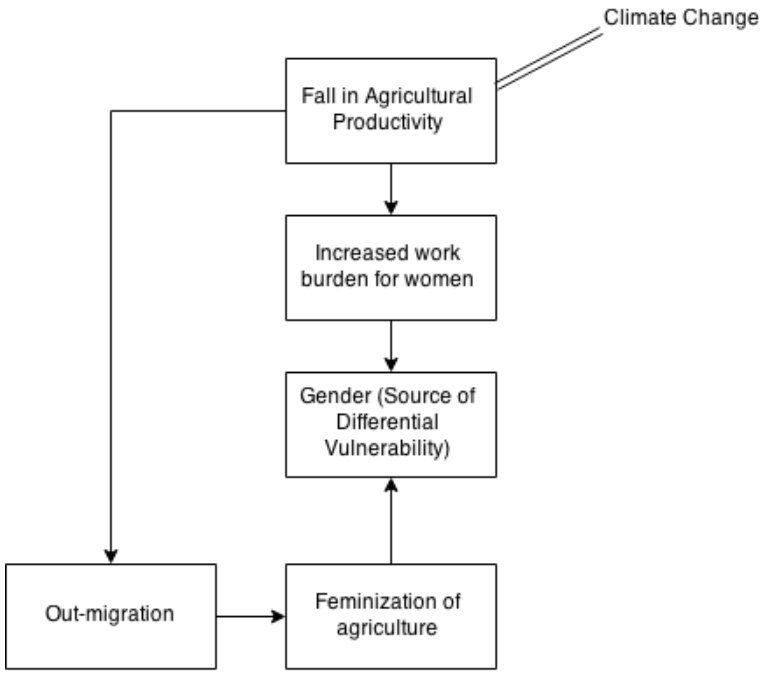

Figure 9: Differential Vulnerability and Gender: Interlinkages among Sources and Drivers

5.3.6. Social Status and Power Relationship[2]

Social status and power relationships has been identified as a driver by understanding how critical initiatives by the government to address the issues of farmers are being distributed disproportionately among the needy. Those individuals who had known members of local government tended to receive preferential treatment in accessing official government assistance and relief, according to the locals' perception.

In village X (see footnote), when the locals were asked if any institution was responding to the crop loss that the communities were facing due to recent increase in flood events, the response from the locals was balanced on wither sides. A few positive tones were heard about the crop loss compensation while a few disgruntled voices complained about the way crop loss compensation wasn't given to the needy but rather to the ones who are well off and can withstand the impacts of such events. The people who received this apparent compensation

[2] Names of the villages and the respondents in this particular section shall be withheld as per researcher's discretion.

enjoyed higher social status as opposed to the others and also were influential at the administrative level. Such disparities in social status and lapses in the institutional structure have affected the delivery of key policy measures, with the most vulnerable being not affectively compensated and hence remain a source of differential vulnerability.

Hence, power-relationship at a political/administrative level will disproportionately affect the deliverability of policy measures.

Additionally, a micro level manifestation of social and power relationships is the "who does what" factor which on a whole drivers *gender* as source of differential vulnerability. In the low-elevation and mid-elevation sites, as already discussed, a reduction in forest cover is negatively impacting the women since they are associated with collecting firewood and fodder. Likewise, it was also observed that in the mid and high elevation sites, women are more associate with farm work, hence increased pests instances will increase the exposure of women to such impacts of climate change and hence exacerbate their work burden. These are manifestations of household power relationships that have become a commonality to the community as a whole. Social Status and Power Relationships is a source and a driver of differential vulnerability in itself; driving many other sources.

5.3.7. Other Sources and Drivers

One might also observe that ***"poverty"*** hasn't seen a special reference as a driver in the above discussions, but it is to be noted that issues pertaining to land holding, resource dependency and social and power relationships "might" stem out of poverty as a root cause and hence it is considered integral to the system of differential vulnerability.

Apart from poverty, the discussions that were carried out in Mathana, a low elevation site, pointed out to **"*education*"** acting as a source leading towards differential vulnerabilities among the communities in the village. This was evident through the discussions that were carried out to gauge the level of

governmental assistance to the farmers in the region. One such discussion pointed towards the presence of a Short Messaging Service from the Krishi Vigyan Kendra, a part of the Indian Council of Agricultural Research, which contained information regarding key farm issues. While this is beneficial when viewed through a macro lens, the deliverability of such service is very contextual depending heavily on the receiver's ability to read. The same was pointed out in the discussion. The locals were of the opinion that such a service is only benefitting ones who can read (therefore meaning educated), while the ones who are uneducated and thus cannot read a particular a language see no benefits arising out of the service. This therefore makes the service partially effective, with education acting as both a promoter and an inhibitor towards availing the service and in turn exacerbating the vulnerability of a few. Education can be considered as source of differential vulnerability, but what actually drives this is the *inequal access* to education facilities.

A "causal diagram" of the factors leading to the sources (marked in yellow) is given below. The diagram also depicts interlinkages arising out of the sources/drivers (marked in red).

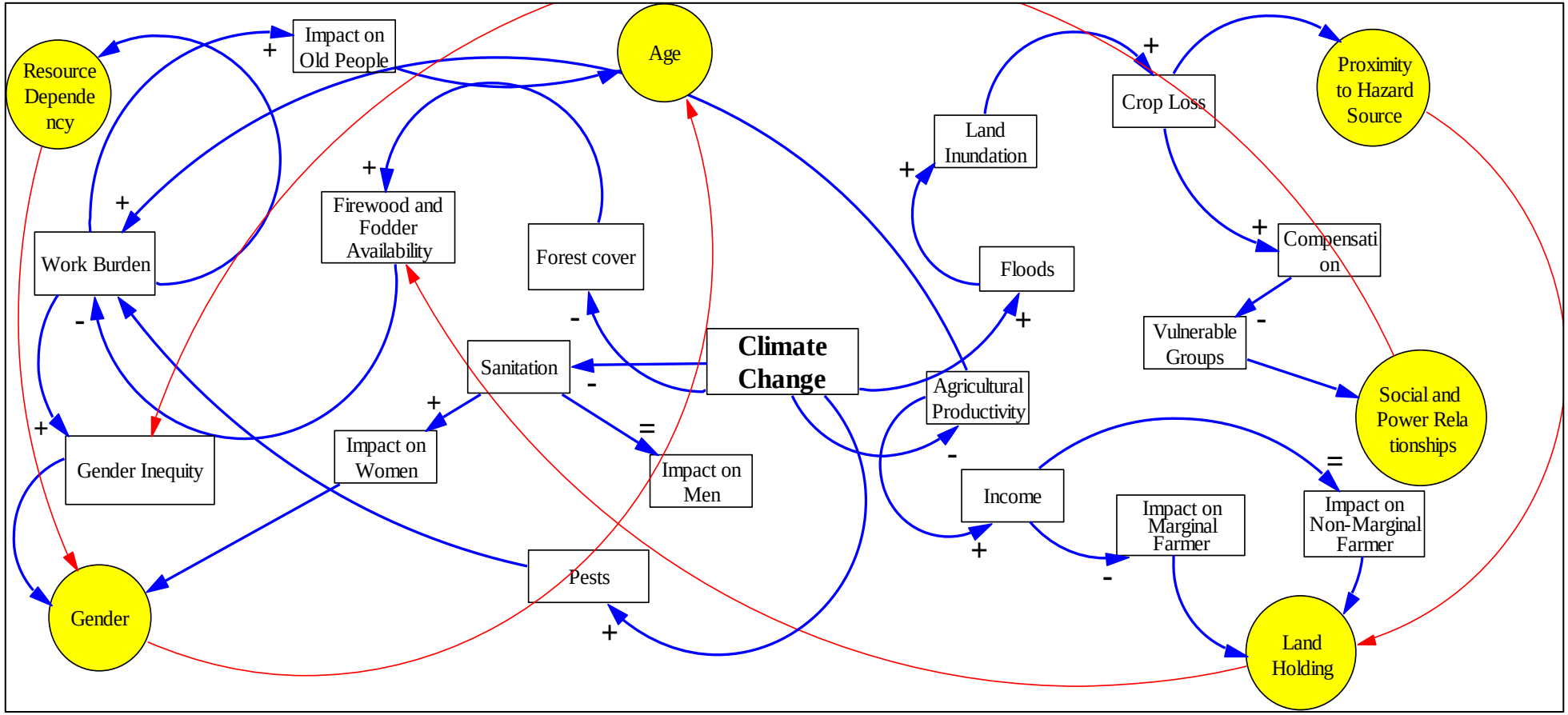

Figure 10: Causal Diagram of Sources of Differential Vulnerability

Table 5: Sources of Differential Vulnerability, Impacts and Elevation

Driver	**Contributing Impact**	**Elevation**
Gender	- Sanitation - Gender inequity - Farm work burden	- Low elevation Sites - Mid and High elevation sites - Mid and High elevation sites
Age	- Increase work burden on old - Migration	- Mid Hills
Resource Dependency	- Work burden due to decrease in firewood availability	- Low (Khadri) and Mid elevation sites
Proximity to Hazard Source	- Crop loss	- Low elevation sites (Mathana)
Social and Power Relationships	- Crop loss compensation - Who does what	- Low elevation sites - Mid and High elevation sites
Land Holding	- Income fluctuations induced by fall in agricultural productivity - Inability to shift away from livelihood	- Low elevation sites

Table 5 in the previous page tries to highlight the sources of differential vulnerability that have been identified in both the discussions and the causal loop diagrams. Village specificity has also been mentioned alongside the elevation. Table 6 depicts the drivers of differential vulnerability that have been discussed above.

Table 6: Drivers of Differential Vulnerability, Elevation

Driver	**Source**	**Elevation**
Out Migration	– Age – Gender	– Mid and High Elevation – Mid and High Elevation
Reduction in Population Growth Rate	– Age	– Mid and High Elevation
Child Sex ratio and Total Sex Ratio	– Gender	– Mid and High Elevation
Poverty	– Resource Dependency – Land Holding	– All Elevations – All Elevations, but more relevant to low and mid elevation sites
Family Size	– Land Holding	– Low Elevation
Social and Power Relationships	– Gender – Resource Dependency	– All Elevations – All Elevations

5.3.8. Differential Vulnerability across Elevations

While the above mentioned sources have led to differential vulnerability within the villages scoped, the sources that have led to differential vulnerability among and across elevations have been discussed below:

Irrigation Facilities and Rainfall Dependence: Among elevations, rainfall dependence drives differential vulnerability. It has been observed that in the low-elevation sites there are better irrigation facilities; hence issues relating to access to water for irrigation purposes haven't been raised as an issue during the FCM construction and the FGDs as well. Farmers in the plains depended largely on ground water or other canals/channels to irrigate their lands. With this isn't being possible in the mid and high elevation sites owing to the topography, coupled with poor to almost nil canal networks has increased their dependence on rainwater as a source of irrigation. With decreased rainfall being witnessed in the mid-elevation sites, such reliance will negatively impact them and hence drive their vulnerability.

Urbanization and Access to Services: Urbanization has played a key role in determining access to services and markets in the region. The low-elevation sites, owing to the better topography have been conducive for incubating industries and bringing about a turnaround in the local market. This is especially true in the case of Khadri, which has witnessed over the the past many years and hence access to services and markets are better in this region, while this hasn't been seen in any other village as such. Urbanization has also helped in expanding the scope of work for the labor force, since they could now be involved in work as construction, industrial and allied labor force, which is more income generating than being a mere a farm labor. Such opportunities existed in the low-elevation sites and not the mid or the high elevation sites, hence furthering vulnerability across elevations.

Access to services becomes even more critical during cases of extreme events. This has been observed in the high-elevation sites, where the 2013 deluge had resulted in severe damage to road networks. Since external dependence in these regions was high, access to services had been hindered due to damage to existing road networks, hence exacerbating their vulnerability. It was noted by villagers in Kalimath that since agriculture produce in the region is not even sufficient to meet their needs, most of their needs are met from importing their needs from elsewhere. During flood events and landslides, such a possibility of external

dependence exists not longer, hence increasing the sensitivity of the villages in these elevations to impacts arising out of climate change.

Differential vulnerabilities in and among these villages are determined by the drivers that have been discussed above. It becomes imperative to consider these drivers in unison to improve the effectiveness of adaptation interventions. More over such an understanding will eventually help in addressing the sources of vulnerability which in most cases doesn’t just arise from exposure to climate stressors but also from various social drivers.

In the following page an augmented DPSIR framework is depicted containing components as understood from the field surveys. It is to be noted that the impacts arise out of complex interactions between various drivers and pressures and not just from a single driver. Such complex interactions are often difficult to be visually depicted and understood and hence as a researcher I refrained from depictingthem.

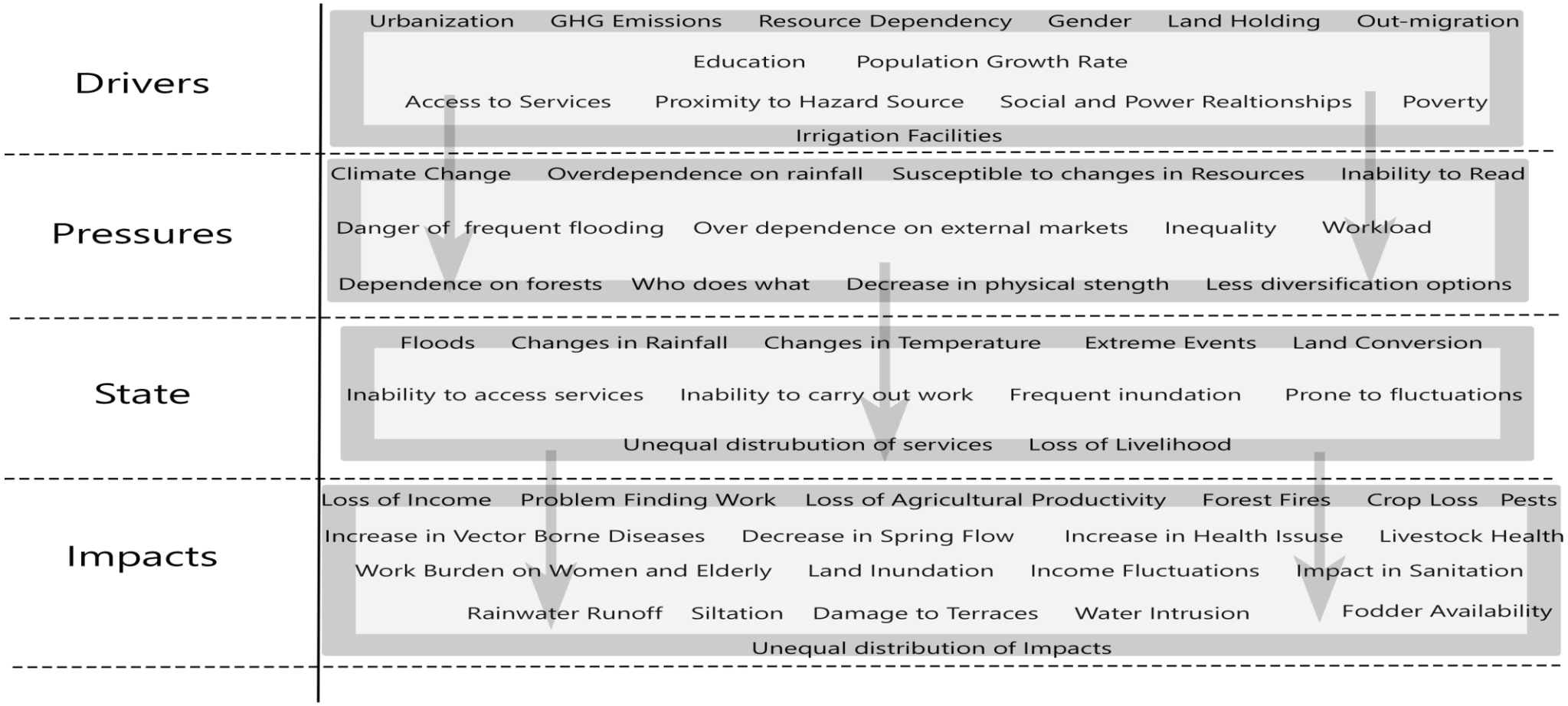

Figure 11: Abridged DPSIR Framework of Findings

Chapter VI: Conclusions

Impacts arising out of climate change are now being felt across regions, giving more voice to take up adaptive interventions in the vulnerable regions. The efficacy of such adaptive interventions will increase when it is delivered in-line with the outcomes of a vulnerability assessment. This said, the concept of differential vulnerability contained within the scope of a vulnerability assessment has also gained researchers eyes in the past few years. The factors that shape differential vulnerability among individuals and communities are many and are often interlinked. This study had aimed to understand these factors that are responsible for bringing about geographic and demographic heterogeneity and thereby giving rise to differential impacts.

Based on the findings of this report, a lot of emphasis must be also placed on understanding these factors and the inter-linkages amongst them, the absence of which might lead to adaptation policies addressing the non-needy or the less impacted. While there have been only a few studies aimed at understanding the concept of differential vulnerability in detail, this study has tried to bridge this gap by applying a bottom up approach to understanding impacts arising out of climate change and analyze how these impacts are being differentially felt among different strata of societies and thereby identify the responsible drivers. This would aid in achieving equity in climate change adaptation policies by addressing the most vulnerable.

Sources such as land holding, social status and power relationships within a community play a huge role in exacerbating the vulnerability of communities/entities in question. These sources coupled with various drivers like out migration and population growth, interact with all three components of vulnerability, viz. exposure, sensitivity and adaptive capacity, at various levels, eventually either acting as a constraint or an opportunity for coping with risks associated with climate change, hence altering their vulnerability levels. Therefore, it is important to understand these sources and drivers in context of

the given location and to incorporate them within the existing vulnerability assessments to ensure adaptive measures reach the least opportune.

Finally, the study has achieved in showcasing the intricacies involved between various sources of differential vulnerabilities and the drivers that lead them to being a source. This highlights the interplay between numerous tangible and intangible assets which determine the differential vulnerabilities among communities.

The findings of this research initiative are complimentary to the results of another study- *"Understanding Livelihood Impacts of Climate Change in the Upper Ganga Basin: A Case Study Approach"*- that was conducted alongside. Both these studies together try to enhance the existing literature on livelihood impacts, adaptation strategies and differential vulnerabilities among communities in the Upper Ganga Basin through a case study approach.

Chapter VII: Areas of Improvement

1. The drivers that have been identified in this study might not include several other drivers that eventually lead to differential vulnerability or susceptibility to climate change, given that these have been identified in lieu with the impacts identified by the locals. Carrying out such studies in diverse geographic locations might highlight new drivers, given the varied set of impacts and social settings associated with the locations, which together drive differential vulnerability.

2. Due to paucity of time, carrying out an in-depth analysis into the current sources and drivers wasn't possible. Hence, it is recommended that an in-depth analysis be carried out in the current study site to better understand the hidden factors, if any, leading to the current drivers.

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Annexure

Photos from Field:

Figure 12: Focus Group Discussion in Pyukhari

Figure 13: Interaction at Pyukhari

Figure 14: Interaction in Kalimath

Figure 15: Interaction at Chaumasi

Figure 16: Focus Group Discussion in Mathana

Figure 17: Respondents in Chaumasi

Cognitive Interpretive Diagrams (CID) Variables:

Table 7: Variables in CID - Mathana

Variable	Description
Climate Change	Factors relating to changes in temperature, rainfall and extreme events
Electricity	Irregularities in electricity supply
Health	Negative impact on human health
Services	Difficulty in accessing services
Education	Difficulty in accessing schools due to infrastructural damage/flooding
Sanitation	Difficulty in availing sanitation facilities
Agricultural Productivity	Negative impact on agricultural productivity
Rice	Negative impact on rice productivity
Wheat	Negative impact on wheat productivity
Drying of Crops	Explicit in itself – Drying of crops
Income	Negative impact on income
Hospital	Negative impact on and arising out of availing hospital services
Road Connectivity	Impact on road connectivity
Pests Invasion	Increase instances of pest invasion
Fodder Availability	Difficulty in obtaining fodder
Sugarcane	Negative impact on sugarcane productivity
Soil Productivity	Negative impact on soil productivity
Protection Wall	Damage to protection wall
Human Wildlife	Human Wildlife conflict
Hail	Increase in instances of hail
Crop Loss	Crops loss due to floods
Loan	Need to take loan
Shift in Sowing Season	Shift induced due to change in climatic parameters
Pests Varieties	Increase in pest varieties
Land Inundation	Land inundation due to floods
Firewood	Difficulty in obtaining firewood

Water Contamination	Water contamination
Gobar	Impact on gobar stored
Food Scarcity	Food scarcity
Foot Diseases	Food disease occurrence
Mosquitoes	Increase in mosquitoes
Problem Finding Work	Problem in finding work due to various interlinked factors

Table 8: Variables in CID - Khadri Kharakmaf

Variable	Description
Climate Change	Factors relating to changes in temperature, rainfall and extreme events
Health	Negative impact on human health
Road Connectivity	Negative impact on road connectivity
Loss of Land	Land loss due to floods
Filling of Land	Requirement to fill lands due to flooding
Firewood Availability	Difficulty in obtaining firewood
Agricultural Productivity	Negative impact on agricultural productivity
Pest Invasion	Increase instances of pest invasion
Rice	Negative impact on rice productivity
Wheat	Negative impact on wheat productivity
Food Scarcity	Food scarcity
Income	Negative impact on income
Services	Difficulty in accessing services
College	Difficulty in accessing colleges due to infrastructural damage/flooding
Land Availability	Land availability issues due to urbanization
Forest Cover	Decrease in forest cover
Fodder Availability	Negative impact on fodder availability
Increase in Work Load	Increase in work load
Vector Borne Diseases	Increase instances of vector borne diseases
Water Borne Diseases	Increase instances of water borne diseases

Impact on Livestock	Negative impact on livestock due to various factors
Wildlife Conflict	Increase instances of human wildlife conflict
Concretization	Increase in concretization leading to various troubles
Rainwater Runoff	Increase in rainwater runoff
Soil Productivity	Negative impact on soil productivity
Sanitation	Negative impact on availing sanitation facilities
Siltation	Increase in siltation
Water Intrusion	Water intrusion into houses

Table 9: Variables in CID - Badal

Variable	Description
Climate Change	Factors relating to changes in temperature, rainfall and extreme events
Forest Cover	Decrease in forest cover
Soil Productivity	Negative impact on soil productivity
Spring Flow	Decrease in spring flow
Work Load	Increase in workload
Pest Invasion	Increase in pest invasion
Soil Hardness	Soil Hardness, resulting from heavy rainfall
Firewood Availability	Difficulty in obtaining firewood
Health	Negative impact on human health
Water Intrusion	Water intruding into houses
Wheat	Impact on wheat productivity
Road Connectivity	Impact on road connectivity
Land Inundation	Land inundation due to floods
Agricultural Productivity	Impact on agricultural productivity
Fodder Availability	Impact on fodder availability
Extreme Rainfall	Instances of extreme rainfall
Decrease in Rainfall	Increased instances of reduced rainfall
Human WildLife Conflict	Increase instances of human wildlife conflict
Crop Loss	Crop Loss due to various factors

Income	Impact on Income

Table 10: Variables in CID - Pyukhari KimKhola

Variable	Description
Climate Change	Factors relating to changes in temperature, rainfall and extreme events
Forest Cover	Decrease in forest cover
Pine Cover	Decrease in pine cover
Spring Flow	Changes in spring flow
Soil Productivity	Impact on soil productivity
Mosquitoes	Increase in mosquitoes
Accessibility	Problems due to acccessibility
Damage to Terrace	Damage to terraces due to rainfall
Human Wildlife Conflict	Increase instances of human wildlife conflict
Health	Negative impact on human health
Water Borne Diseases	Increase instances of water borne diseases
Fodder Availability	Impact on fodder availability
Problem Finding Work	Difficulty in finding work
Income	Impact on income
Decrease in Rainfall	Increased instances of reduced rainfall
Extreme Rainfall	Instances of extreme rainfall
Wildfires	Increase in wildfires
Rice	Impact on rice productivity
Livestock Diseases	Increase in livestock diseases
Firewood Availability	Impact on firewood availability
Agricultural Productivity	Impact on agricultural productivity
Pest Invasion	Increase in pest invasion

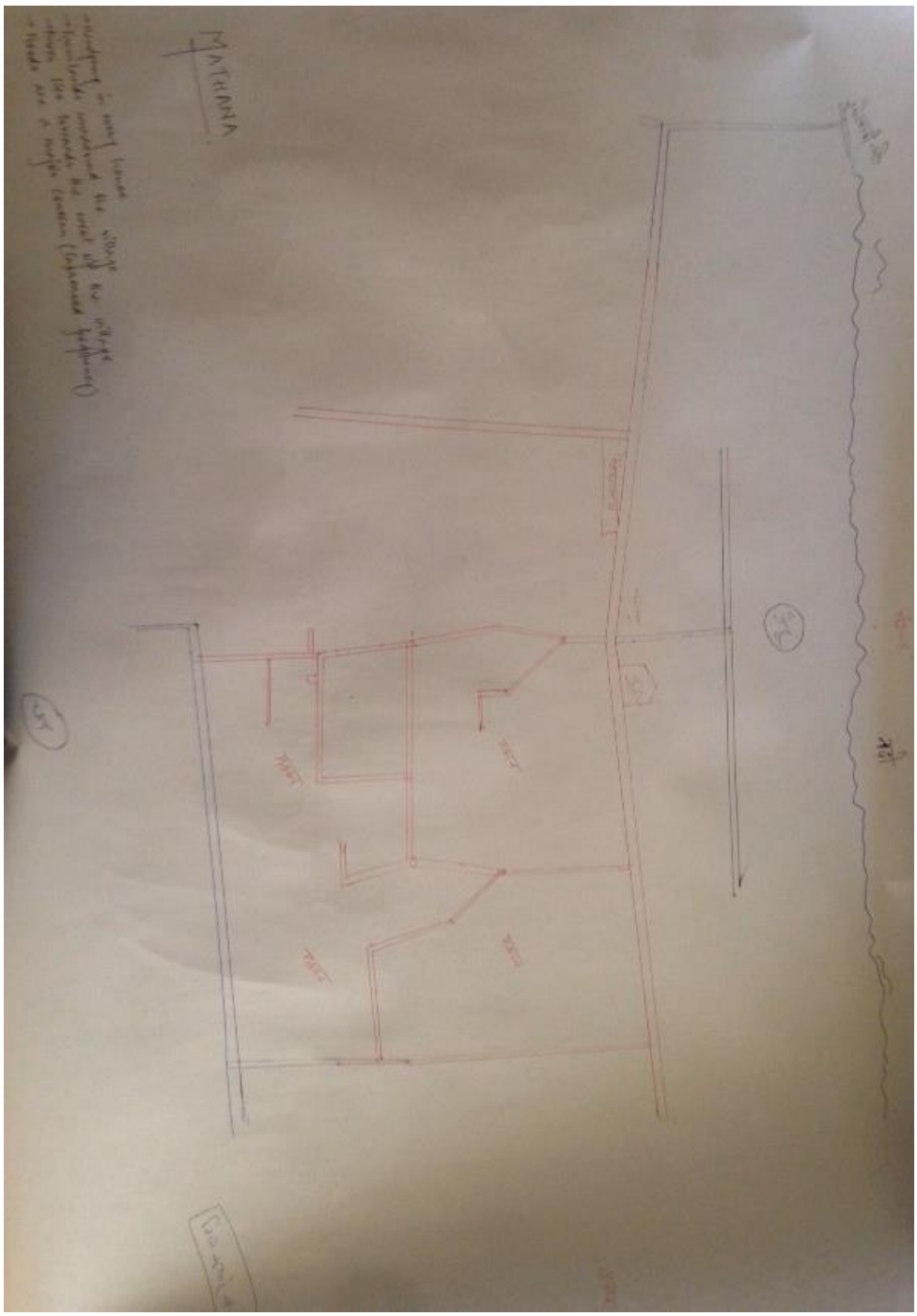

Figure 18: Resource Map of Mathana

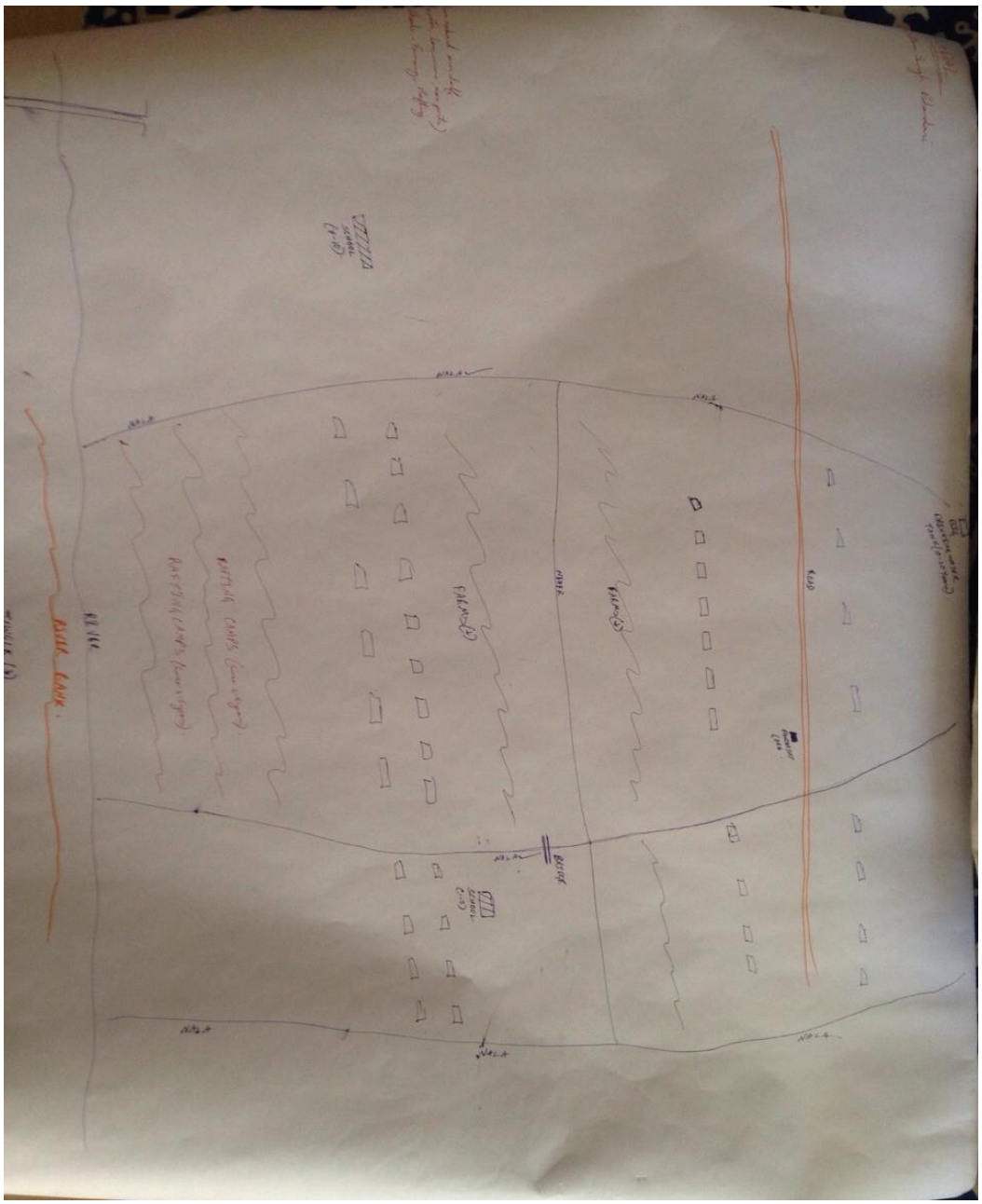

Figure 19: Resource Map of Badal

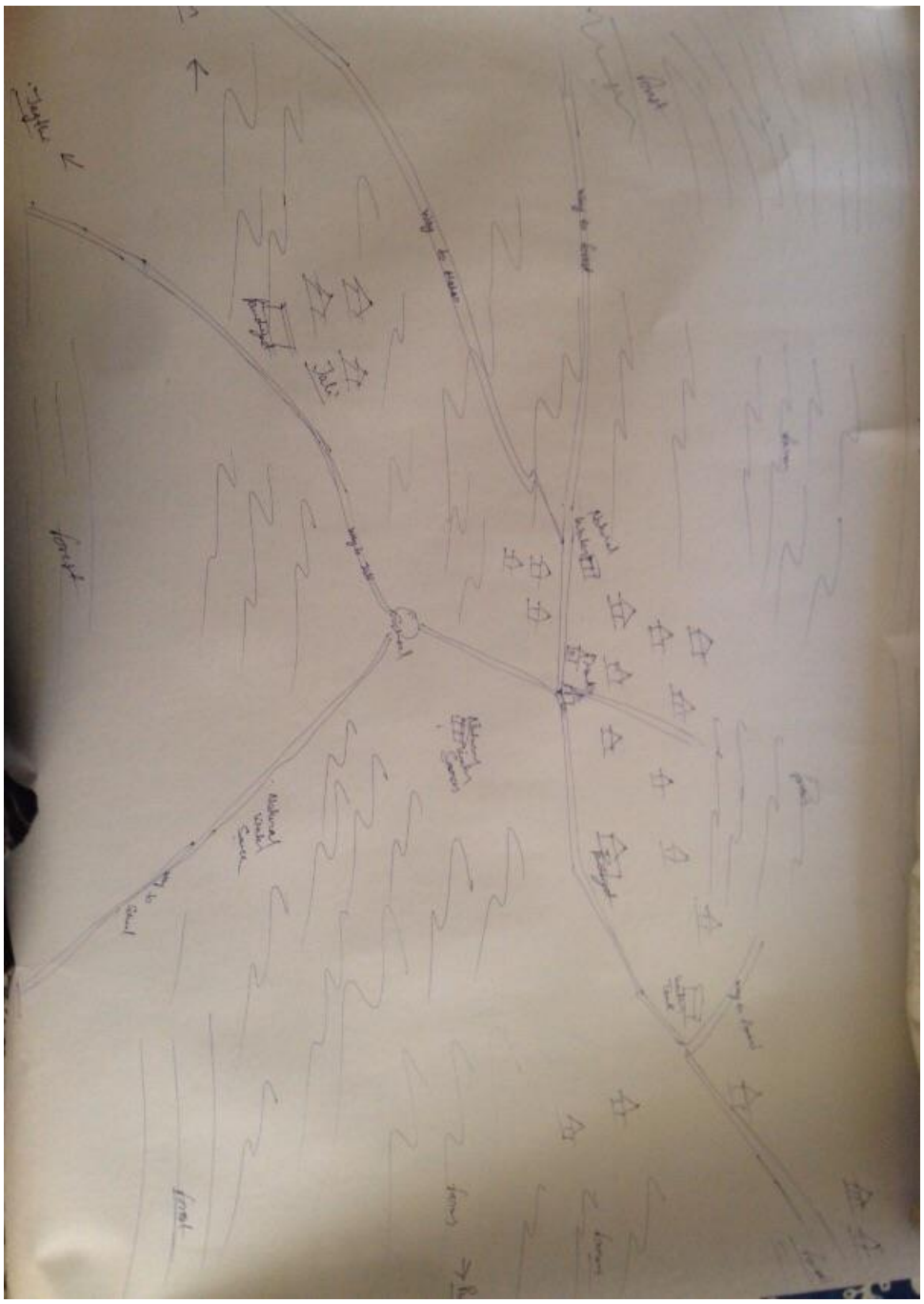

Figure 20: Resource Map of Kim Khola