A thesis submitted to the Department of Environmental Sciences and Policy of the Central European University in part fulfilment of the Degree of Master of Science

Adaptive Capacity in a Transforming World: A Case Study of Resilience to Climate Change via Traditional and Local Knowledge in a Mountain Community (Ghanche) of Pakistan

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June 2021
Budapest

Erasmus Mundus Masters Course in Environmental Sciences, Policy and Management

MESPOM

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ABSTRACT OF THESIS submitted by:

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for the degree of Master of Science and entitled: Adaptive Capacity in a Transforming World: A Case Study of Resilience to Climate Change via Traditional Knowledge in a Northern Community of Pakistan

Month and Year of submission: June 2021.

Purpose - The purpose of this study is to investigate local insights on climate change and its impacts in Ghanche, Pakistan, adaptation strategies to overcome these impacts and to explore the potential role and adequacy of traditional and local knowledge to face climate change in future.

Design/methodology – 30 participants were consulted and their observations on changes in seasonal temperature (summer and winter) and annual precipitation were validated using meteorological data from the Earth Engine Data Catalog. Participants' responses regarding changes in snowfall, rainfall, water availability, avalanche and GLOF (Glacial Lake Outburst Flood) events, flash floods, landslides, and crop yield over around the past 25 years were also recorded along with the impacts of these changes and adaptation strategies to overcome them. The role of traditional and local knowledge in overcoming climate change impacts was analyzed using a vulnerability framework and taking into account primary data collected through this research.

Findings – Participants mentioned that summer and winter temperatures, rainfall, flash floods, landslides and GLOF events have increased, while crop yields, water availability and snowfall have decreased. Observed changes in summer and winter temperature matched meteorological data. Some of the major impacts included frequent and intense floods, damage to personal and public property, landslides, reduced water availability and impacts on agriculture, more road obstructions, damage to trees and cattle, lower quality and quantity of meadow grass and influence on daily transportation and communication. Strategies adopted were mostly based on traditional and local knowledge and some of them on external knowledge, such as from NGOs. Overall, keeping in mind Ghanche's persistent loss of human capacity due to outmigration, people's changing priorities and the unpredictable nature of climate change and risks associated with its impacts, this region requires external financial and technical support to overcome future climate change impacts. While important, traditional and local knowledge alone cannot make it more resilient and less vulnerable to future climate change.

Keywords: climate change, Northern Pakistan, Ghanche, traditional and local knowledge, resilience, vulnerability, adaptive capacity

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Acknowledgements

I would like to acknowledge the hard work and support of all those who made it possible for me to conduct this thesis research. I would firstly express my sincere gratitude to my supervisor Laszlo Pinter for his kind guidance, time and understanding throughout this hard journey. I thank my translator Rukhsana Batool for conducting and translating surveys with patience and motivation during harsh winters of Ghanche. I also thank my colleague Isna Pujiastuti for helping with meteorological data extraction and Ali Rawail to provide vector data to draw study area map. I thank Noor Pamiri for the Urdu translation of my questionnaire. I recognize the support of Karakoram International University Hunza campus for providing me space and internet facility to write my thesis. To my family and friends who provided emotional support during this journey and all the participants who participated in the surveys, I thank you for your time and support.

Lastly, I show my appreciation to Central European University (CEU) and Erasmus Mundus Scholarship program for the financial assistance without which, it would not be possible to conduct this research.

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List of Abbreviations

TK	Traditional Knowledge
TLK	Traditional and Local Knowledge
GHGs	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
ARs	Assessment Reports
UNU	United Nations University
UNU-TKI	United Nations University's Traditional Knowledge Initiative
SLR	Sea Level Rise
HKH	Karakoram-Hindukush-Himalaya
GLOF	Glacial Lake Outburst Flood
UNDP	United Nations Development program
NCCP	National Climate Change Policy
CCA	Climate Change Adaptation
RACV	Resilience, Adaptive Capacity and Vulnerability
SES	Socio-Ecological System
CBA	Community-Based Adaptation
CARE	Cooperative for Assistance and Relief Everywhere
DRR	Disaster Risk Reduction
UN	United Nations
PMD	Pakistan Meteorological Department
GEF	Global Environmental Facility
IIPFCC	International Indigenous Peoples' Forum on Climate Change
CIEL	Centre for International Environmental Law
RO	Research Objective
KKH	Karakoram Highway
AKRSP	Aga Khan Rural Support Program
AKDN	Aga Khan Development Network
CC	Climate Change

FAO	Food and Agriculture Organization
ICIMOD	International Centre for Integrated Mountain Development
UNESCO	The United Nations Educational, Scientific and Cultural Organization
CBDR-RC	Equity and Common but Differentiated Responsibilities and Respective Capabilities
CSV	Comma-Separated Values

Glossary

Talis	A village in Ghanche
Hanjour	A village in Ghanche
Shinjaq their	A Balti language word used for a special kind of soil which people put on terraces to avoid water leakage
Zeing	A Balti language word used for water tank

1. Introduction

> "The peaks and valleys of the Hindu Kush Himalaya Mountain ranges are some of the most inaccessible, remote regions in the world today—but even the most isolated valleys have been touched by climate change."
>
> Borunda 2019

> "Even if global warming is limited to 1.5° [Celsius, or 2.7° Fahrenheit] by end of the century—and you could call it a miracle if that happens—the high mountains are likely to warm even more."
>
> Arun Shrestha, ICIMOD (Borunda 2019)

> "Action at the local level is needed to strengthen the adaptive capacity and climate resilience of mountain communities. And let me say here that we must recognize mountain communities for what they are: custodians of key ecosystem services and goods, that often face uphill battles because of their isolation and marginalization. These actions include diversification of food systems and livelihoods options, protection of agrobiodiversity, increase of generation and use of climate and disaster risk information, and strengthening of institutions for climate adaptation."
>
> Carla Mucavi, Director, FAO Liaison Office with the United Nations in New York

The above given quotes point out the special situation of mountain communities facing climate change and the importance of finding solutions at the community level. Human activities have resulted in steep emissions of greenhouse gases (GHGs) thus rising Earth's temperature and causing anthropogenic climate change (Lama and Devkota 2009). Climate change poses serious risks to the livelihood of rural communities in many developing countries where people in the mountainous regions with limited livelihood options and dependence upon natural resources are vulnerable to various hazards. Scientific evidence suggests that global climatic conditions are changing mostly for the worst (Jiri *et al*. 2016) and mountainous regions are particularly vulnerable and sensitive to the impacts of climate change compared to other terrestrial habitats (UNESCO 2020, Fort 2015). Since the start of the 20th century, air temperatures have risen by nearly two degrees Fahrenheit and cold areas have warmed up faster compared to rest of the world across the high mountain regions, stretching from Afghanistan and Pakistan to Myanmar. These changes have resulted in glacial retreat, melting of permafrost, erratic weather patterns and disruption of water

resources for millions thus enhancing the frequency and intensity of natural disasters (Borunda 2019).

Countries with iconic mountain ranges such as Pakistan and Nepal are contributing far less than developed countries, in per capita terms, to the global emissions of greenhouse gases (GHGs). However, climate change has reached even the most isolated corners of such countries and these nations are facing rapidly melting of glaciers, an increasing frequency of glacial lake outburst flood (GLOF) events, floods, droughts and impacts on agricultural productivity due to changes in temperature and precipitation patterns (Lama and Devkota 2009; Fahad and Wang 2020) thus threatening the sustainable development of these regions. Sustainable development contains two key concepts, one being "needs", in particular of the world's poorest and most vulnerable, and the idea of protecting and respecting the environment's ability to meet present and future needs (Denton *et al*. 2014). Unfortunately, it is the world's poorest and marginalized communities who are the most severely affected by climate change and lack the adaptive capacity to face these challenges now and in the future (Mimura *et al*. 2014). Thus, it is clear that any adaptation strategies to face climate change must also address the challenges of sustainable development due to these correlations (Lavell *et al*. 2012).

GHG emissions accumulate over time and they are globally distributed in the atmosphere. Moreover, emissions by one agent such as individual, a company or a community affect other agents around the globe. Therefore, effective adaptation and mitigation to climate change will not be achieved "if individual agents advance their interests independently" (IPPC 2014a). Adaptation requires effective planning and implementation, involving international bodies, national governments, sub-national as well as local governments in order to protect vulnerable groups, support economic development and provide information and financial support. Decision making processes recognize diverse interests and socio-cultural contexts. One way of improving decision making processes to enhance resilience and adaptation to climate change is through the integration of traditional and local knowledge systems and practices with scientific approaches which represent a holistic view of community and their environment (IPCC 2014a).

Raygorodetsky (2011) quotes the 32nd session of IPCC held in 2010:

> "Indigenous or traditional knowledge may prove useful for understanding the potential of certain adaptation strategies that are cost-effective, participatory and sustainable".

Traditional and Local knowledge (TLK) and indigenous communities are often marginalized in climate change policy and decision making because the references on the existing traditional and local knowledge on climate change are scare in the global climate change discourse. These international discourses have failed to consider traditional and local adaptation strategies adopted by marginalized communities around the globe against direct and indirect impacts of climate change (Raygorodetsky 2011). However, more recently, the role of TK in enhancing climate resilience and decision making is receiving more interest, with the IPCC referring to it as "an invaluable basis for developing adaptation and natural resource management strategies in response to environmental and other forms of change" (Raygorodetsky 2011) and including it in its AR (Working Group 2) with the subtitle "Impacts, Adaptation and Vulnerability" (Malone 2009). Institutions such as United Nations University (UNU) also started traditional knowledge initiatives (UNU-TKI) and partnering with IPCC (Raygorodetsky 2011).

Climate change is a global phenomenon. However, in order for effective adaptation-focused capacity building and decision making regarding where to invest and who should invest (government, firms, corporates, citizens etc.), the relationship between exposure and sensitivity to climate change and climate variability needs to be understood at the local level (Malone 2009).

This thesis research considers the case of Ghanche District, Baltistan Pakistan. Its focus is on climate change impacts on this region and adaptation strategies implemented. The aim also is to investigate how traditional and local knowledge has contributed to overcome climate change-induced impacts. Moreover, in order to address whether adaptation strategies based on traditional and local knowledge enhance resilience and overcome vulnerability to climate change and whether these strategies based only upon TK will serve enough purpose to cope with climate change vulnerability in the future, a self-formulated vulnerability framework developed is used.

1.1. Research definition

Vulnerability of mountain communities to climate change

The influence of climate change on the mountain regions is an important topic on the international agenda (Zeidler and Steinbauer 2008). Mountain regions are particularly vulnerable and sensitive to the impacts of climate change compared to other terrestrial habitats (UNESCO 2020, Fort 2015). For instance, glacier sensitivity is the key parameter that not only links changes in the climate, glacier volume and Sea Level Rise (SLR) (Dyurgerov 2006) but also, sensitivity of mountain regions to climate change. Glacier sensitivity to climate depends upon ice mass turnover. For example, in regions with dry climate and small mass turnover, the major driver of the glacier mass balance change is summer temperature. In wetter climates with larger mass turnover, glacier mass balance is sensitive to the changes in the amount of precipitation. Thus, with a warming climate, a different glacier response by region takes place (Dyurgerov 2006). For instance, in continental mountains, a small warming result in a decrease in the snow/rain ratio thus, there is a decrease in albedo and increased ablation rate causes more negative mass balance. Thus, glaciers with a summer peak of precipitation are more sensitive to air temperature change (Dyurgerov 2006). This indicates that glaciers in countries such as Pakistan with most parts arid to semi-arid climatologically and mountain climate ranging from humid to arid (Zeidler and Steinbauer 2008) are highly affected by changing summer temperatures.

Mountain regions are facing substantial ecological and socio-economic impacts due to climate change. About 10% of the world's population directly depends on mountain resources for their wellbeing and livelihood. However, changes in temperature and precipitation patterns presently and also in future projections will increase the occurrence of multiple hazards due to extreme events such as floods, GLOF events, avalanches, and landslides (figure 1) thus threatening both livelihoods and infrastructure (Bhatta *et al*. 2020). In many mountain regions, glaciers substantially control the availability of fresh water. Their growth and shrinkage can have a dramatic impact on the economic, social, and cultural activities close to the mountains (Kaser 2006). Mountain regions in the Karakoram-Hindukush-Himalaya (HKH) are also sensitive to the impacts of climate change. The mean temperature in these regions has changed by 0.10°C per decade and future climate projections suggest that there will be a 1-2°C increase in temperature by 2050 and precipitation patterns will also change causing longer and erratic monsoons and less frequent but intense rainfall (Bhatta *et al*. 2020). The recent GLOF event in Uttarakhand India which killed dozens and destroyed properties downstream on a large scale is at latest example of how climate change-

caused hazards are threatening mountain communities (Sinha 2021). Northern regions of Pakistan such as Hunza in HKH region are also facing extreme flood and GLOF events due to climate change which have not only destroyed human properties but have also displaced families. Some regions are also facing frequent droughts and lack of water availability for agriculture. These regions harbor iconic mountains and glaciers of the Hindukush, Karakoram and Himalayan ranges which ironically are facing water stress due to glacial loss during summers (author's Observation). Thus, due to the increasing climate pressure and related disaster risk, there is an urgent need for better understanding present and emerging vulnerability, the adequacy of present adaptive capacity, and measures that strengthen adaptive capacity that can successfully tackle emerging vulnerability.

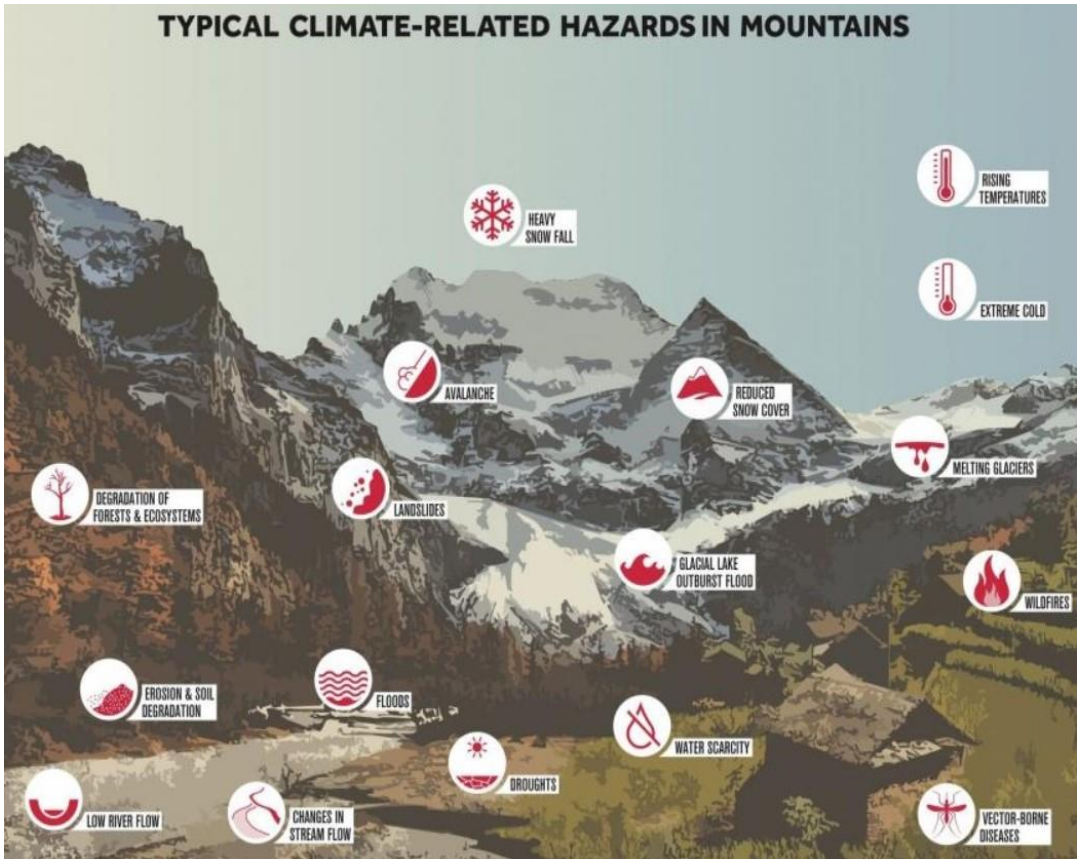


Figure 1. Climate-related hazards in mountains (UNEP 2018).

Mountain communities have wealth of knowledge and strategies which have been accumulated over generations due to people in these regions closely experiencing climate change but also, adapting to it independently due to lack of technical and financial capacities triggered also by their remoteness. Mountain communities therefore should not be viewed only as vulnerable communities but also with wealth of knowledge and indigenous solutions.

This traditional and local knowledge however should be integrated with technical and scientific advances to formulate effective climate change adaptation strategies (Kleiche-Dray 2012). Therefore, if TK is documented on the local level and integrated on higher levels, it can help understand whether TK is successful in enhancing climate resilience of mountain communities and debate on whether these communities now and in future will need further assistance to cope with climate change hazards.

1.2. Case study: Ghanche, Pakistan

Pakistan is an agrarian country which extends over an area of 796,000km^2. Pakistan is climatologically arid and semi-arid with great diversity in temperature and precipitation and is considered one of the topmost countries worldwide vulnerable to the impacts of climate change (Fahad and Wang 2020). Pakistan has faced historic climatic events such as 2010 flood which killed 1600 people and caused around $10 billion in damage. The 2015 heat wave in Karachi city killed 1200 people and severe impacts on agriculture and water availability are expected in future. Pakistan's northern region contains some of the world's highest peaks such as K-2 and glaciers such as Siachen and Biafo which feed Indus River (Chaudhry 2017).

> "There is an urgent need for simultaneously raising ambition for climate action, while also building resilience and adapting to the inescapable impacts of climate change. Climate action by the developing countries, however, has to be based on the established principles of Equity and Common but Differentiated Responsibilities and Respective Capabilities (CBDR–RC) - as agreed under the United Nations Framework Convention on Climate Change (UNFCCC) and its Paris Agreement."
>
> Prime Minister Pakistan, Imran Khan

Pakistan ratified Paris Agreement (LEAD Pakistan 2016) and has taken multiple initiatives to enhance climate adaptation such as Task Force on Climate Change, One Billion Tree Tsunami Program (Faisal *et al*. 2011) and its National Climate Change Policy (NCCP 2012) which provides a broad set of adaptation measures to the vulnerable sectors such as food, power, water, and health. The government is also coordinating with national and international organizations to enhance resilience against hazards such as floods, water shortages, cyclones, and temperature extremes. However, these policies have hardly reached the far-flung mountainous areas of the north and lack the involvement of multiple stakeholders, community leaders and local community experts in their formulation. This is an indication of

huge knowledge gap (Ali *et al*. 2019). Moreover, Pakistan is largely dependent upon the water flow through the Indus River System which supports one of the world's largest irrigation system. Therefore, the wellbeing of the Indus delta against climate change hazards is a major concern for Pakistan. Indus delta however is already facing CC risks. For instance, salt intrusion is already detected as far as 80km inland and future projections show an increase in evapotranspiration, change in river water flow and sea level rise thus exacerbating salt intrusion. This will threaten agricultural production in the lowlands of Sindh and Punjab province thus affecting the crop yield and overall economic stability of Pakistan (Parry 2016). Some of the crop yield-related CC-induced impacts projected in Pakistan include decline in wheat production by 5-7% with a rise in 1°C in temperature, a decrease in the growing and production season for rice with 15-18% decline by 2080 (Parry 2016).

Water is unevenly distributed among different provinces in Pakistan which has caused inter-province disputes over water rights. Pakistan is expected to face the transition from being water stressed to water scarce due to loss of freshwater resources as a result of climate change (Piesse 2015). Thus, climate change along with the low water storage capacity and lack of hydropower development (figure 2) while experiencing a dramatic population growth (figure 3) (Yu *et al*. 2013) will not only threaten human lives, property, and basic facilities in Pakistan but also, it can worsen the already existing disputes over water rights thus exacerbating social and political disputes in the country.

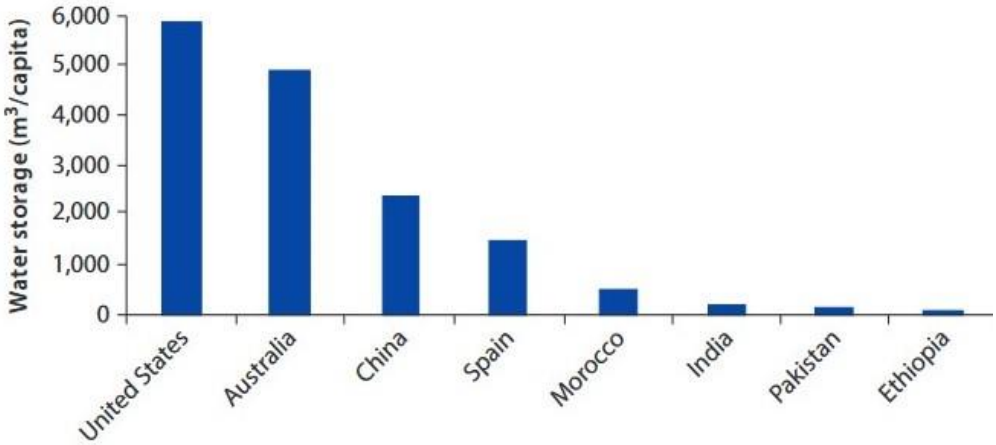


Figure 2. Water storage per capita comparison in semi-arid countries (Yu et al. 2013).

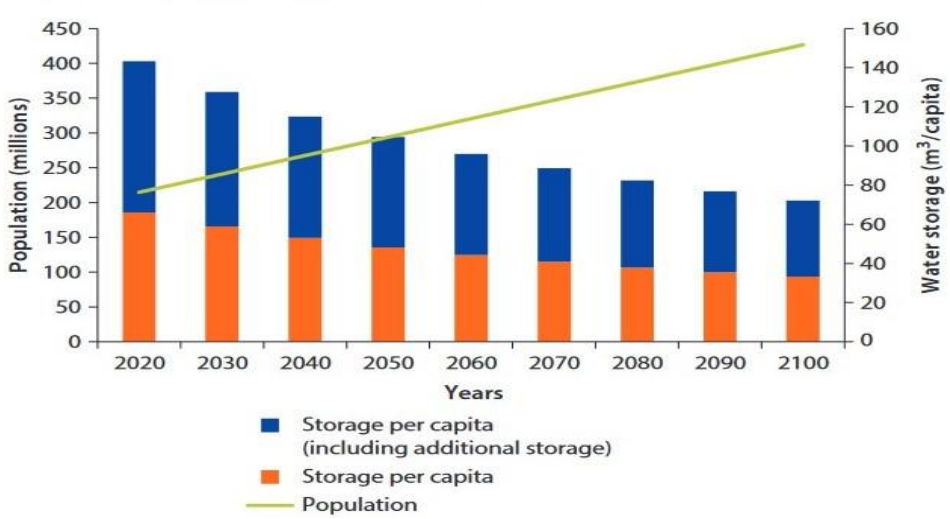


Figure 3. Pakistan's water storage per capita over time (Yu et al. 2013).

Pakistan's vulnerability to climate change makes it an interesting and important case study to understand how its vulnerability can be reduced and resilience can be enhanced. However, what makes this region more interesting is the isolated mountain communities which are facing climate change impacts, but their current resilience and adaptation power distinguishes them from rest of Pakistan. These areas have received negligible attention in terms of adaptation policies to climate change by the government (author's observation). However, these communities have independently formulated strong social norms, a strong civil society, and strategies to face CC risks. Therefore, this research aims to investigate these strategies and whether these communities need further assistance to overcome the impacts of climate change better in future.

One such great region is Ghanche in Gilgit-Baltistan, Pakistan (figure 4) which is divided into further villages (figure 5). Ghanche is a high mountain area in Baltistan region where Karakoram range meets Indian Himalaya. The capital of Ghanche is Khaplu situated in the confluence of Hushe, Saltoro and Skyok river (Mindat.org 2021). The entire valley is home to around 156,700 people. It borders with Xinjiang province of China in the North-East and Ladakh area of Indian Administered Kashmir to the south. Ghanche is believed to be among the coldest inhabited places in Pakistan. It is also known as the 'third pole' where temperature drops below 20° in winter. Khaplu and Hushe valley of Ghanche district are the gateways for the great Muztagh, Baltoro and sub-range of Karakoram which include mighty peaks such as K-2 (8,611 m), Broad Peak (8,047 m), Gasherbrums (8,000+ m) and Masherbrum (7,821 m) (Ali 2017).

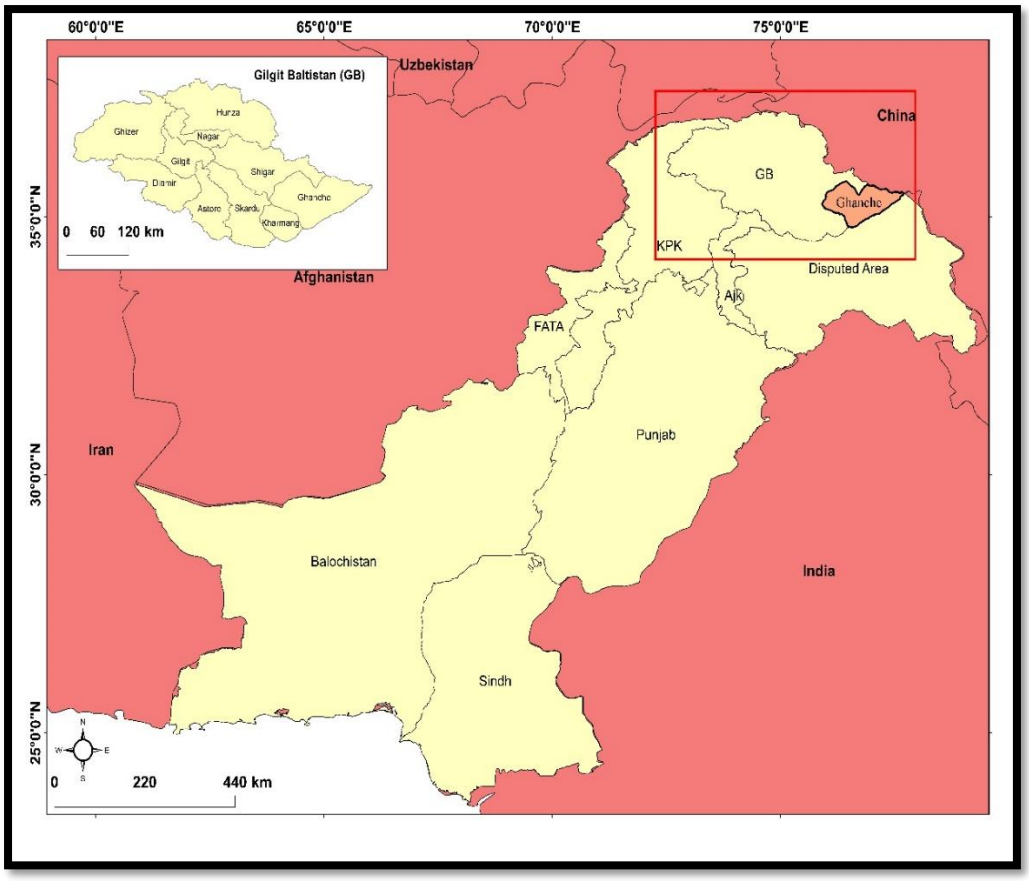


Figure 4. Study area map (Akhtar 2021).

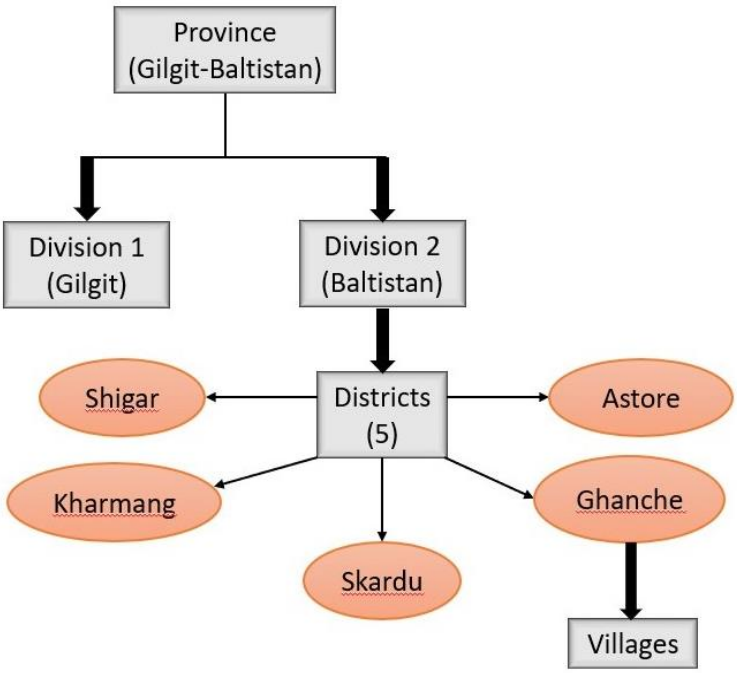


Figure 5. Administrative units of Gilgit-Baltistan and Baltistan division (Akhtar 2020).

Ghanche attracts thousands of national and international tourists every year due to its scenic beauty (lush green pastures, lakes, glaciers, and plateaus) and rich heritage. Touristic areas include Chaqchan Mosque (one of the oldest mosques in Asia and national heritage site in Pakistan), Khaplu Fort (an architectural heritage) and several hot springs (so hot that people boil eggs on the spot) (Figure 6) (Ali 2017). According to some villagers interviewed, apricots, apples and cherries are among major fruits of Ghanche while wheat, maize and barley are among major crops mostly grown in kharif season. Villagers also highlighted that Ghanche lacks major education facilities due to which people and especially young generations migrate to the cities mainly for education and employment purposes. Although there is around 55% literacy rate, the quality of education is poor. Ghanche also lacks major health facilities. There are several examples of patients dying on their way because patients have to travel to far cities for their treatment. Villagers particularly mentioned that the health facilities for the pregnant ladies and infants are worst and many infants die due to unavailability of qualified doctors and gynecologists.

Ghanche just like many other northern mountain regions around the globe is facing major climatic events in both summers and winters. These events make it hard for people to function their daily lives in a normal manner. Some of these events mentioned by the villagers include floods, extreme erosion along riverbanks and of agricultural land due to upsurge of river water and floods, heavy rains, disease outbreak among crops and fruits, landslide and GLOF events in summer while those in winter include heavy snowfall, avalanche, road obstruction and livestock death due to extreme winter (figure 6). Despite receiving negligible attention from the government to enhance climate change resilience, Ghanche is still able to face CC risks based on its strong social norms, civil society, and people's self-formulated adaptation strategies. Therefore, to investigate whether these strategies are based on traditional and local knowledge and whether they will serve enough purpose to face climate change better in future is a major intention of this research.

Figure 6. Graphics showing Khaplu area, a hot spring, the famous Chaqchan mosque, Khaplu fort and some of the flood and avalanche-related events in Ghanche (Mindat.org 2021; Ali 2017; Petley 2012; Gulbtur 2010; Sach News 2015).

1.3. Aims and objectives- Research questions

Complex challenges such as climate change require knowledge generation and documentation on both global and local level. Mountain communities serve as knowledge banks to comprehend climate change risks because these communities include local as well as vulnerable populations. Therefore, their experiences need to be documented and heard on regional and global level to formulate much needed climate resilience policies for remote mountain communities. Thus, the overall intention behind this research is to contribute towards comprehending climate change risks by recording community-based local observations of climate change and understanding how traditional and local knowledge may overcome human vulnerability to climate change hazards. The purpose also is to document the concerns of local population on whether traditional and local knowledge will serve enough purpose to cope with climate change risks better in the future. This aim is achieved through a qualitative research approach and formulating a vulnerability framework to analyze participant's responses in Ghanche. Moreover, some of the major components of vulnerability are linkages between human and biophysical (environmental) conditions, perturbations and stresses that emerge from these conditions and coupled human-environment systems in which vulnerability resides, including exposure and responses (coping

mechanisms, adjustments, and adaptations). Therefore, to understand these components, and achieve the overall research aim, the following objectives were intended to be achieved:

1. To understand the changes in the variables: snowfall, temperature, flooding, rainfall, landslide, avalanche, water availability, GLOF events, and crop yield through community perceptions and observations for the period of around 25 years and whether changes in temperature and precipitation patterns observed by the participants compliment the scientific data.
   - This objective was fulfilled by documenting responses of the participants regarding changes in climate variables based on close ended questions.
   - Data validation was done through data analysis using R-programming for around 25 years of temperature and precipitation data retrieved from Earth Engine Data Catalog (https://developers.google.com/earth-engine/datasets)
2. To document what adaptation strategies are implemented by the locals to overcome the impacts of changes in these variables.
   - This objective was fulfilled by asking follow-up questions regarding participants' coping mechanisms or adaptation strategies to face the impacts of change in the above-mentioned variables.
   - To investigate whether these adaptation strategies are based on the traditional and local knowledge of the locals.
3. To differentiate traditional and local adaptation techniques from those non-traditional, participants were enquired using follow-up questions regarding history and emergence of each technique.
   - To record the opinions and concerns of the local population on whether traditional and local knowledge is serving enough purpose to cope with climate change.
4. Keeping in mind the unpredictable nature of climate change and out-migration of people from these mountain communities, participants were asked follow-up questions to share opinions on whether adaptation strategies based only upon traditional and local knowledge will serve enough purpose to cope with climate change risks.
5. To understand how effective traditional and local knowledge (TLK) may be to overcome vulnerability of mountain communities to climate change, a vulnerability framework based on the survey data was formulated to discuss the results.

1.4. Thesis structure

The first chapter introduces the context of the research problem and following aims and objectives. This chapter presents an overall background of this research, a bit of its methodology and the conceptual framework to be used for data analysis. This background information is followed by chapter 2 which via literature review allow a deep exploration of the background and key concepts for this thesis research. Some of these concepts include resilience, vulnerability, exposure, and traditional and local knowledge which also provide background information for the conceptual framework (vulnerability framework) been used which then enables an understanding of the role of traditional and local knowledge in enhancing resilience to climate change hazards and exposure which is explored through the research data itself.

Further details and information about methodological approach and conceptual framework are given in chapter 3 which also includes detailed description of methods used and analysis done. Research limitations are also presented in this chapter.

Chapter 4 presents results and detailed analysis of the data. This chapter slightly links role of traditional and local knowledge and climate change while presenting participant's responses from the fieldwork. The research objectives will be addressed, and analysis will be presented.

Chapter 5 then presents the discussion of the results.

Chapter 6 offers the conclusions and future considerations and applications of the research.

2. Literature review

2.1. Adaptation to climate change

This is not the first time that earth's climate has changed but this is the first time that human greed and development activities have triggered climate change. Climate is often defined as the 'average weather' and is usually described in terms of the mean and variability of temperature, precipitation, and wind over a period of time ranging from months to millions of years. The temporal evolution of climate is due to the influence of its own internal dynamics and external parameters called 'forcings'. External forcings include natural processes such as volcanic eruptions and solar variations but also, these forcings include human-induced changes in the composition of the atmosphere (Treut *et al*. 2007). According to IPCC (2007),

climate change is defined as a ‘statistically significant in the state of the climate that persists for decades or longer’ (UNFCCC 2011).

The concept of climate change adaptation (CCA) has become increasingly important in climate negotiations. The terms incremental and transformational adaptation are integral concepts of climate adaptation. “Incremental adaptation refers to actions where the central aim is to maintain the essence and integrity of the existing technological, institutional, governance, and value systems, such as through adjustments to cropping systems via new varieties, changing planting times, or using more efficient irrigation. In contrast, transformational adaptation seeks to change the fundamental attributes of systems in response to actual or expected climate and its effects, often at a scale and ambition greater than incremental activities. It includes changes in activities, such as changing livelihoods from cropping to livestock or by migrating to take up a livelihood elsewhere, and also changes in our perceptions and paradigms about the nature of climate change, adaptation, and their relationship to other natural and human systems” (Denton *et al*. 2014).

Adaptation planning and implementation initiatives demonstrate that diverse stakeholders in the governance structures of countries have different roles such as those with high political and economic power to those with minor roles in decision making. Climate change adaptation has received an overwhelming response from stakeholders at local levels as well as from rural and urban communities in both developed and developing countries. Actions on the community and local government level are predominantly linked with climate adaptation because it is context dependent and linked to location (Denton *et al*. 2014). The consideration of these responses at local level includes utilization of traditional and local knowledge to formulate adaptation plans. Local and traditional knowledge holds a great importance in CCA because it not only helps formulate effective adaptation plans but also helps highlight impacts and vulnerabilities at the local level which may not be well known especially in remote places which are poorly monitored (Denton *et al*. 2014). Some of the examples of adaptive actions implemented around the globe utilizing local and traditional knowledge are to: compile observed changes, enhance monitoring, and manage water resources in Australia, document local observations in Bolivia, analyze historical context and increase monitoring in USA and enable adaptive decision making and enhance community awareness in Fiji.

Indigenous and local communities are those populations which have cultural and historical ties to their homeland. They experience changes in their environment and biophysical factors

closely. Moreover, some of these communities have negligible political power and right in decision making. These characteristics make them particularly vulnerable to the impacts of climate change. Therefore, when assessing vulnerability of indigenous and local communities and developing CCA for these communities, the following important issues need to be addressed:

- Degree of migration or displacement of indigenous and local communities
- Relationship of these communities to their land

(Denton *et al*. 2014)

Maladaptation

The concept of 'maladaptation' needs to be understood while understanding CCA. This concept refers to actions which increase the risk of climate change hazards, increase vulnerability, and diminish welfare. This kind of adaptation considers short term gains and ignores long term impacts and risks (IPCC 2014b). According to Thomsen *et al.* (2012), actions which do not respect integrity and self-regulation of social-ecological systems are maladaptive. Maladaptation arises in many forms due to multiple causes. For instance, actions which are focused only upon particular groups at particular time might prove to be maladaptive to those groups facing similar phenomena in future or other groups facing existing climate change. Some other maladaptive actions include short term economic benefits but ignore long term vulnerability and reduce the flexibility of future adaptation options. Another important cause of maladaptation to be considered is the failure to recognize and consider multiple feedbacks and interactions between the systems which leads to the development of inadequate and inaccurate information thus forming strategies which are maladaptive. Maladaptation may also occur if technology is over-emphasized (Denton *et al*. 2014). Thus, recognition of maladaptive strategies and their avoidance is necessary in order to formulate effective plans for CCA and to promote sustainable adaptation.

The concept of sustainable adaptation indicates that environmental and social externalities will be created as a result of responses to climate change which may include trade-offs and negative consequences. Sustainable adaptation therefore considers the impacts of these adaptive responses on other groups, socio-ecological systems, and places in present and future. How is sustainable adaptation different from general adaptation? Sustainable adaptation considers actions in terms of their effects on social justice and environmental

integrity. Adaptation in general on other hand is sustainable only if it fulfills these two features (Eriksen *et al*. 2011). Vulnerability literature has highlighted three main problems sustainable adaptation is necessary for. Firstly, climate change is a global challenge for both current and future generations. Thus, adaptation responses must consider both spatial and temporal consequences. Such as, these actions targeting one group or sector might undermine the ability of access of other groups to same resources. Secondly, poverty makes many individuals and households vulnerable to even small stressors or shocks. Therefore, only poverty as a means of vulnerability to climate change should not be used as a justification to implement certain adaption actions. Instead, in order to make these actions sustainable, links between vulnerability and poverty should be effectively assessed. Afterall, not every adaptation action will assist poor in a better manner. Thirdly, adaptation measure should emphasize on low emission actions and solutions and alternative development pathways should be promoted. Some of the examples include ecological sanitation, organic agriculture and use of renewable energy (Eriksen *et al*. 2011).

2.2. Resilience, adaptive capacity, and vulnerability (RACV)

Resilience, adaptive capacity, and vulnerability are the central concepts in the field of climate change because they help understand the linkages between biophysical, socio-economic, and political factors of a region and around the globe and their relation to climate change. The inadequacy of the studies related to climate change and its impacts on natural systems, their vulnerability, resilience, and adaptive capacity to climate change hazards led IPCC include a separate title ‘Impacts, Adaptation and Vulnerability’ in its AR3 (working group 2) which was previously ‘Impacts, Adaptation and Mitigation’. This shows an increased focus on the research and studies related to vulnerability and its associated terms – resilience and adaptive capacity (Malone 2009).

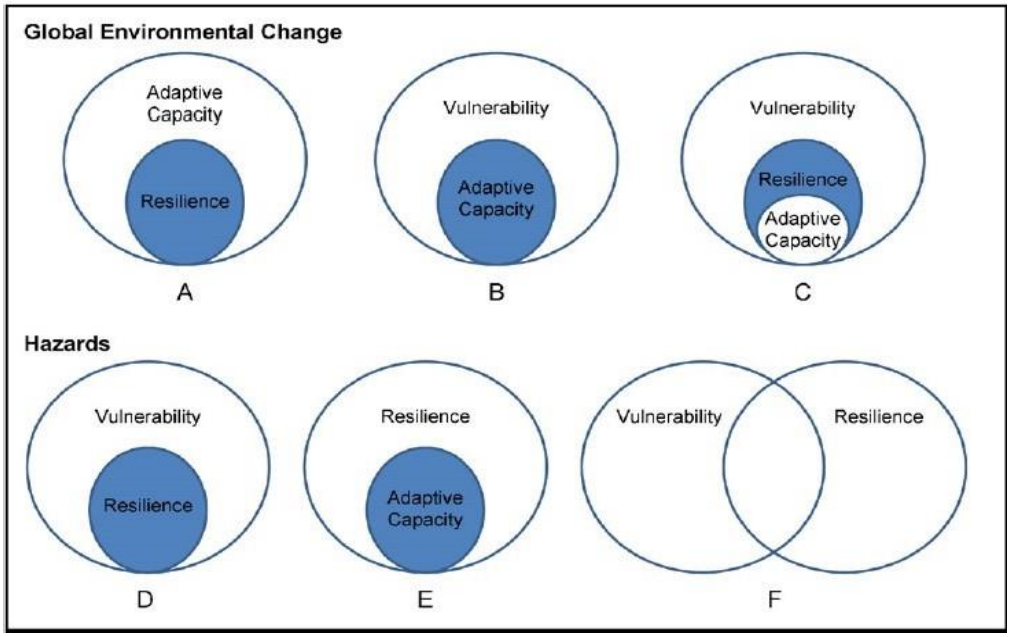


Figure 7. Conceptual linkages between resilience, vulnerability, and adaptive capacity (Cutter et al. 2008).

The relationship between resilience, vulnerability and adaptive capacity is still not well-articulated (Figure 7). This is because some researchers, resilience is an integral part of adaptive capacity (figure 7a) while some other researchers think adaptive capacity is a main component of vulnerability (figure 7b). A third perspective (figure 7c) seems to have a nested concept of resilience, vulnerability, and adaptive capacity. In hazard research, 'resilience is considered an outcome when it is defined as the ability to bounce back or cope with a hazard event and it is imbedded within vulnerability' (figure 7d). hazard researchers however embed the concept of adaptive capacity within resilience when comparing to the global change perspectives (figure 7e). However, these three concepts are often integrated (figure 7f) with one another (Cutter *et al*. 2008; Mace-Snaith 2018) and actions that affect one of them generally affect the other two (figure 8) (Mace-Snaith 2018).

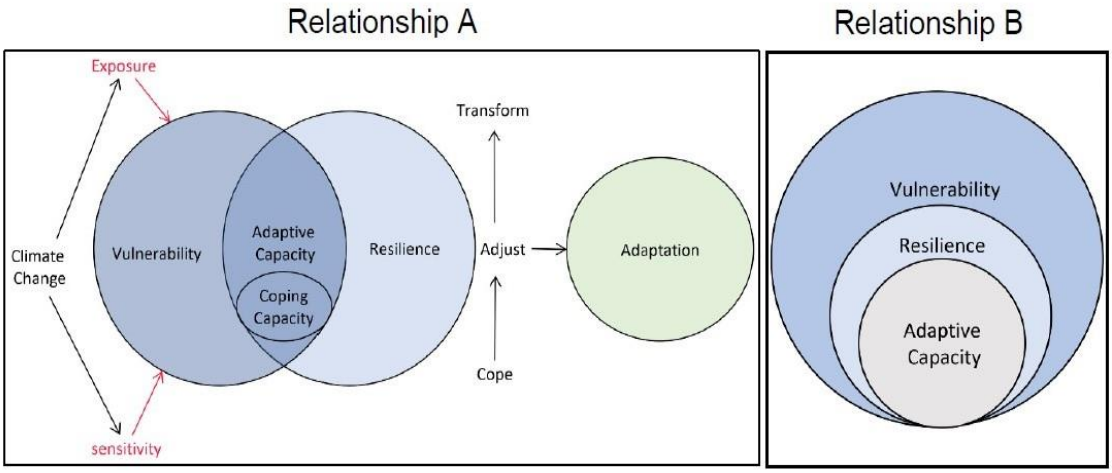


Figure 8. Linkage between adaptive capacity, vulnerability, and resilience (Mace-Snaith 2018).

2.2.1. Resilience

Based on literature, there are at least four distinct themes in resilience studies: 'Resilience as a biophysical attribute, a social attribute (social resilience), a socio-ecological system attribute and an attribute of specific areas.' Engineering resilience and ecological resilience are two types of resilience discussed in literature. The speed of return to a steady state after facing a perturbation is engineering resilience while the magnitude of disturbance a system absorbs before it is restructured is ecological resilience (Dalziell and Mcmanus 2004). According to IPCC 2008, resilience is defined as:

> "The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change."

(Smith 2021)

'Re-building when necessary' is a vital aspect of resilience in the context of climate change. The uncertainties and unexpected shocks and stressors related to climate change mean that there will be unexpected impacts and surprises. Climate change impacts might also put communities across thresholds. When such uncertain events happen, climate resilient communities and nations have the capacity to transform which help them re-build ways in new conditions. Therefore, climate resilience equips people with the ability to transform quickly when uncertain shocks happen (Smith 2021). complex systems function within the 'domain of attraction' and the tipping point is represented by the boundary of this domain of attraction' (Engle 2011). Resilience captures the ability of a system to 'fluctuate within the

domain of attraction without being pushed over the boundary'. An important aspect of the resilience perspective includes human contributions to the system. This is because, human element in the ecosystems in the most change-causing force. Therefore, study of complex coupled socio-ecological systems (SESs) and human-environment interactions play an important role in understanding system's resilience (Engle 2011).

Community-level resilience is of special interest. This is because community level is relatively neglected and therefore requires more attention. Community resilience is defined as "existence, development and engagement of community resources by community members to thrive in an environment characterized by change, uncertainty, unpredictability and surprise." It is often understood as the ability of a community's social system to come together to work towards a communal objective (Berkes and Ross 2013). A community that is resilient is called a resilient community which "takes intentional action to enhance the personal and collective capacity of its citizens and institutions to respond to and influence the course of social and economic change." Thus, resilience building can be enhanced by actively engaging in an environment that is characterized by change (Berkes and Ross 2013).

Structured scenarios and adaptive management are two tools for resilience building in socio-ecological systems. Scenarios play an important role because they are used to envision and predict alternative pathways to be reached. This prediction helps formulate multiple alternative actions which might lead towards avoidance of certain maladaptive outcomes. Adaptive management facilitates social context with flexible institutions and multi-level governance systems that allows learning and enhances adaptive capacity (Folke *et al.* 2002).

The concept of resilience thinking is also closely related to complex adaptive systems. According to this theory of resilience thinking, ecosystems are constantly changing and therefore, it focuses on reorganization and renewal of complex socio-ecological systems. Moreover, the concept of resilience is applied to coupled human-environment systems and not just ecosystems alone. This integration of human and natural systems and their interactions enhance the importance of learning from past events thus developing the consideration of key ideas of adaptive capacity and learning ability of social systems (institutions) to adapt to perturbations (Berkes 2007).

2.2.2. Adaptive capacity

Adaptability or adaptive capacity was originally defined in Biology which meant an 'ability to become adapted (to be able to live and reproduce) to a certain range of environmental contingencies.' (Gallopin 2006). The foundations of this concept lay as far back to Darwin's seminal work in evolution and natural selection. To Darwin, the response to the environment or 'special climate' an organism lives in was adaptation. Later, scientists perceived that natural selection takes place on a genetic level meaning that genes are selected based on the ability of persistence by an organism in the environment it faces. Adaptation on the other hand encompasses learning and adjustment broadly referring to the development of genetic or behavioral characteristics which enhances organism's ability to cope with the environmental changes for their survival or reproduction (Engle 2011). Origins of understanding human adaptations to past climate variability are also provided by the field of anthropology (Engle 2011; Zhou *et al.* 2016) because many anthropological works elaborate on the subjects of societal and cultural adaptations to past climate changes. Interestingly, the primary message of these works is that human beings are inherently adaptive creatures.' When faced with diversity and stresses such as climate stress, human species will adapt (Engle 2011). This innate ability to adapt to the changing environment is called reactive adaptation which means a response to a change or a stress that has already occurred. However, reactive adaptation does not always end up well thus causing 'maladaptation', an adaptation that exacerbates harm. Proactive adaptation is another form of adaptation which refers to the unique ability of humans to anticipate future changes or stresses and thus proactively initiate adaptation strategies to lessen the negative impacts from future events (Engle 2011) – adjustments in SESs to lessen the impacts of expected changes (Zhou *et al.* 2016).

Currently, adaptation has gained a valuable status in the fields of disaster and one of the main reasons is the high frequency of and more severe damages and loss caused by natural hazards, at global as well as regional scales (Zhou *et al.* 2016). Whether it is natural disasters or climate change, a system can adapt to changes and stresses in various ways:

- Application of existing available responses: This category includes utilization of existing resources and/or functionality of the system.
- Application of an existing response in a new context: For instance, if a region is facing economic downturn due to natural hazards, organizations may develop new

markets in other economies to offset the lost revenue. Thus, the already available skills and knowledge are utilized in a new region.

- Application of novel responses: This response may include new investments in research and development to find alternative options and solutions.

(Dalziell and Mcmanus 2004)

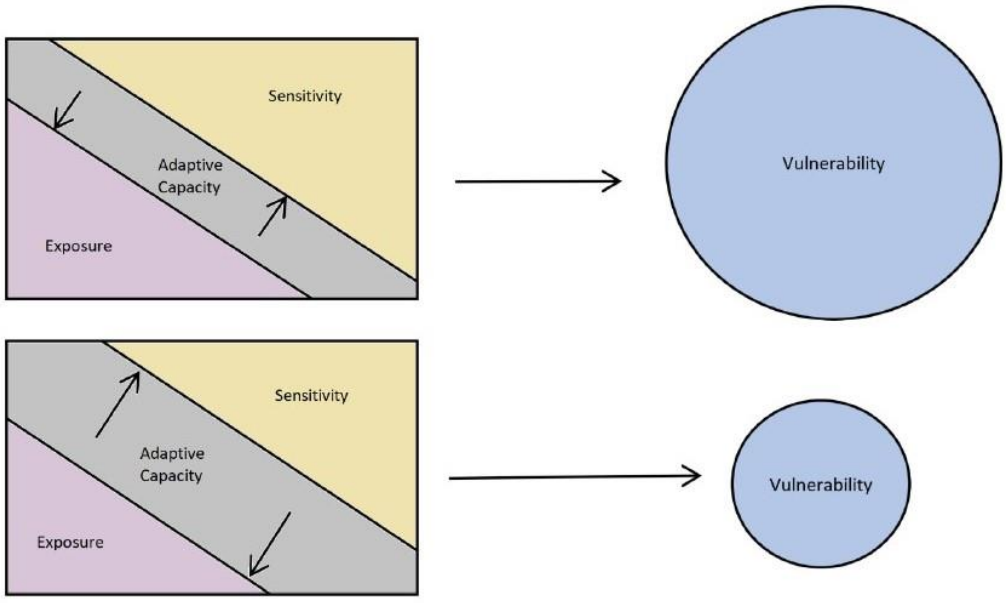


Figure 9. Figure depicting the role of adaptive capacity in modulating exposure and sensitivity thus affecting vulnerability (Engle 2011; Mace-Snaith 2018).

Adaptive capacity plays an important role in adjusting the stress mainly to lessen the negative impacts. In other terms, adaptive capacity affects vulnerability by moderating exposure and sensitivity of a system (figure 9) (Adger *et al*. 2007; Engle 2011; Yohe and Tol 2002). Adaptive capacity is considered critical for reducing vulnerability due to its unique position of influencing both social and biophysical elements of a system. For instance, the greater the adaptive capacity of a system is, the less sensitive and exposed it is to the stresses and perturbations thus reducing the system's vulnerability and vice versa (figure 9) (Engle 2011).

The relationship between resilience and adaptive capacity holds multiple views and one of them states that adaptive capacity is a human capacity to manage resilience by making desirable basins of attraction wider and/or deeper and shrinking undesirable basins, creating new desirable basins, or eliminating undesired basins (Gallopin 2006).

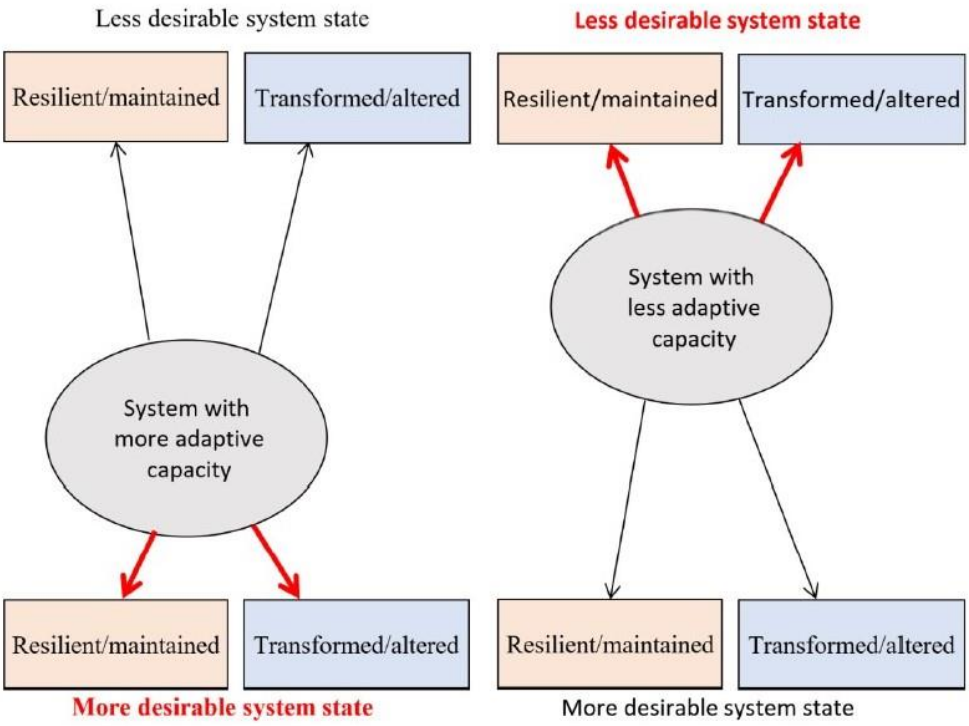


Figure 10. Role of adaptive capacity in managing resilience (Engle 2011; Mace-Snaith 2018).

Engle (2011) states that the more adaptive capacity a system has, the more it is that the system is resilience to face climate stresses or perturbations. Adaptive capacity also facilitates transformations or transitions (help a system move to a different system state if the current state is undesirable). 'Desirability' is a socially constructed concept and depending upon how it is negotiated within a system, 'more adaptive capacity increases the likelihood of desirability'. For instance, a system with greater adaptive capacity results in a desirable system state while system with less adaptive capacity is less likely to form desirable system state (figure 10).

2.2.3. Vulnerability

According to IPCC, "Vulnerability is the degree to which a system is susceptible to, and 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 change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." (Malone 2009). In the context of disaster, vulnerability is the result of human exposure of to a disaster that results in some degree of loss. Vulnerability describes the degree of 'risk, susceptibility and resilience' to a hazard or a stress (Dalziell and Mcmanus 2004). Modern vulnerability and disaster research states that one of its biggest challenges is to assess

'inherent vulnerability that exists in the daily lives of the population'. There are several ways to evaluate vulnerability such as:

- The identification of things or reasons which actually make communities or individuals vulnerable on day-to-day basis
- Assessment of inherent vulnerability of these reasons or things
- Assessment of the interactions between these elements which affect their vulnerability and
- Finding solutions and ways to enhance adaptive capacity to cope with the stresses or crisis

(Dalziell and Mcmanus 2004)

Vulnerability holds diverse views regarding its precise meaning and therefore, it is necessary to clarify the differences between certain terms which greatly hold the concept of vulnerability within themselves.

Perturbation, hazard, or stress

In terms of the concept of vulnerability, hazards are threat to a system and hazards comprise of stress and perturbations (Turner *et al*. 2003). Perturbations are a change or a major spike in the pressure that is beyond the normal range in which the system functions and perturbations commonly originate beyond the system or a location in question. Perturbations are assumed to originate outside the system (Gallopin 2006). Stress on the other hand originates within the system. Thus, hazard that acts on a system may be internal, external or both (Gallopin 2006).

Change or transformation of the system

Transformation in general is taken in the meaning of harm or damage to a system (including human systems, natural systems, and SESs). However, there are diverse interpretations to this based on the concept of vulnerability (Gallopin 2003). For instance, vulnerability is not always negative. A system might transform in such a way that leads to a positive or beneficial transformation which is called positive vulnerability. One such example is the emergence of a social group from extreme poverty. Another important aspect to transformation is the degree to which a system transforms. For instance, a system would not be vulnerable if the impacts of perturbations cause limited changes which hardly transform or damage a system (Gallopin 2006). However, it is also important to consider the environment and the human and natural systems that face this degree of transformation. Some systems might be so fragile, any degree

of transformation might damage or transform them on a large scale. Therefore, system's resilience level is important to be understood.

Sensitivity

Adger (2006) defines sensitivity as "the extent to which a human or natural system can absorb impacts without suffering long-term harm or other significant state change." Some authors such as Smith and Wandel (2006) argue that sensitivity and exposure are not separable. Sensitivity is also linked to a system's resilience or coping capacity because the properties of sensitivity such as its ability to respond to external disturbances as well as its ability to resist change and return to previous state after facing stress are associated with resilience and coping capacity (Luers 2005). In terms of sensitivity and climate change, IPCC (2001) discusses sensitivity as the degree to which a system affected, and this could be either beneficial or harmful. This effect may be direct, such as change in crop yield due to changing climate or indirect such as increase in the coastal floods due to sea-level rise. Sensitivity is an inherent property of an SES and it is distinguished from its capacity to respond (Gallopin 2006).

Exposure

Exposure is another central concept related to vulnerability. Exposure in general is the degree, duration and/or extent to which a system is subject to stress or perturbation (Adger 2006; Kasperson *et al.* 2005). Gallopin (2003) however does not consider exposure a component of vulnerability. He argues that vulnerability is the function of a system's sensitivity and coping capacity and the transformation a system suffers is a function of its vulnerability but also properties of a perturbation and exposure of a system to the perturbation. For instance, a system may be highly vulnerable to stress; however, it may persist for long if it is not exposed to the stress. Thus, a system that is not exposed to a stress would be called non-vulnerable. Moreover, the difference between sensitivity, exposure and response capacity can also be further clarified with the following example: If a flood hits an area, the most precarious homes are hit harder than the solid ones (sensitivity). The poorest homes are located in the places most susceptible to flood (exposure) and the families with greater resources have greater chances of repairing damage caused by water (response capacity) (Gallopin 2006).

2.3. Adaptation strategies

In order to face complex challenges such as climate change, adaptation strategies need to be learning processes and not competing, short and long-term interventions. These are a continuous effort which require diverse knowledge sources and learning processes to understand complex SESs (Zambrano-Barragan 2021). Adaptation strategies and approaches present all the possible adaptation actions which help sustain resources and achieve climate change management goals. Moreover, adaptation strategies also serve as a list for people and managers to select best suited actions for specific goals and regions. These strategies provide opportunities for multiple stakeholders such as team members and other collaborators to discuss CC-related topics and issues (Butler *et al*. 2021). Jones *et al*. (2012) categorize adaptation actions as 'soft' and 'hard' approaches. Soft approaches generally include institutional functions, policies, and information. These majors encourage behavioral changes to reduce climate change impacts (such as installation of early warning system for floods). These majors enhance resilience of communities including capacity building of vulnerable communities. Hard approaches on the other hand are technical and infrastructure-based interventions to overcome the impacts of climate change such as sea walls to protect vulnerable coastlines (Jones *et al*. 2012).

Adaptation strategies however should consider the uncertain nature of climate change. This is because certain strategies which are applicable today might fail to overcome climate change impacts in future. Therefore, we need to understand the circumstances in which a hazard might cause a non-linear response and a response that might cause unanticipated impacts (Berkes 2007). Living with uncertainty is developed with the observations which lead vulnerable communities towards developing adaptations to deal with disturbances (Berkes 2007). There are multiple strategies suggested by Hallegatte (2009) which may tackle uncertain phenomena such as climate change:

- No-regret strategies: Which cause benefits in the absence of climate change (development of flood or drought resistant crops)
- Reversible strategies: These strategies are flexible and keep the cost of being wrong as low as possible (early warning systems)
- Safety margin strategies: Strategies that reduce vulnerability at low costs (improved irrigation systems)

- Soft strategies: These are non-technical solutions which are likely to be reversible (institutional approaches)
- Strategies that reduce time horizons: These strategies reduce lifetime of investments and decision-making (cheaper houses with shorter life)

(Mace-Snaith 2018)

Community-based adaptation (CBA)

There are several types of adaptation strategies to climate change. However, one of the most relevant ones to this research is community-based adaptation.

Most adaptation efforts to overcome the impacts of climate change have been top-down and little attention has been paid to 'community experiences' of climate change and their efforts to overcome these challenges. Community-based adaptation is one such community-led process which is based on local community's needs, knowledge, capacities, and priorities that must empower them to cope with climate change (Reid *et al.* 2021). CBA is an important component of the large picture of climate change management which provides information and practical examples regarding impacts of climate change and adaptation and mitigation measures which are based on local communities' efforts and experiences (The GEF Small Grants Programme 2021).

According to CARE (Cooperative for Assistance and Relief Everywhere) international (2014), climate-resilient livelihoods, disaster risk reduction (DRR), local adaptive and organizational capacity development, an enabling national policy environment, a good knowledge of climate change and addressing underlying causes of vulnerability are the enabling factors which need to be in place for effective CBA to occur. Moreover, a special emphasis is given to understanding uncertain nature of climate risk and use of climate information which includes community and local level information (figure 11). These enabling factors which help achieve CBA are achieved via the following four strategies:

- Strategies that promote climate-resilient livelihoods
- DRR strategies which help reduce impacts of hazards on vulnerable communities
- Strategies which help in capacity development for local communities and government institutions
- Strategies to implement advocacy and social mobilisation to address and understand underlying causes of vulnerability

(CARE 2014)

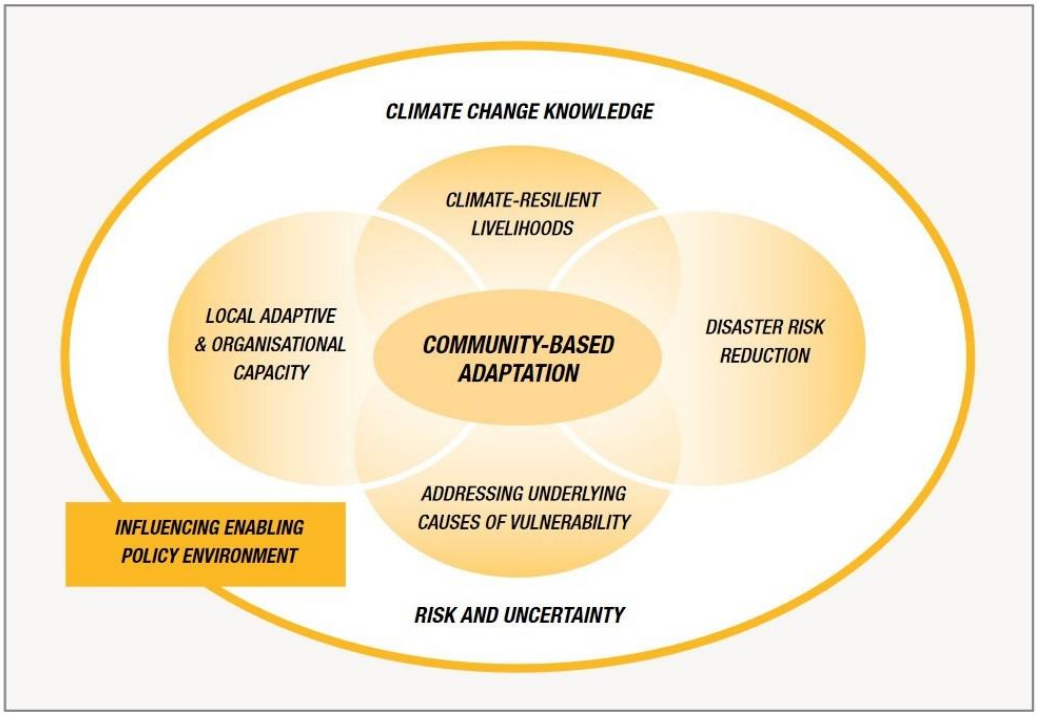


Figure 11. CBA flower diagram (CARE 2014).

Community-based adaptation is one aspect of resilience building that includes incorporation of climate change knowledge at multiple levels as well from diverse platforms as discussed below.

2.4. Resilience building and traditional and local knowledge in climate change

This chapters discusses critical factors that help in resilience building of complex SESs as well as traditional and local knowledge and its role in enhancing resilience to climate change impacts around the globe including mountain communities.

2.4.1. Resilience building

According to Folke *et al*. (2003), the following are the four critical factors what interact at multiple spatial and temporal scales and are seemed to be important in building resilience in complex SESs.

Living with change and uncertainty

How do traditional and local communities deal with uncertainty is a major question to be understood and investigated. Living with uncertainty is based on observations that lead local communities to formulate adaptation strategies. Some examples include flood-adapted

populations in Bangladesh (Haque 1998), Cambodia's rural communities who migrate seasonally to higher levels to avoid high water levels, build houses on stilts (5-6 m above ground level) and some people live in floating villages which float on the lakes in high water seasons. Such local responses are embedded in the local institutions and are alive in the social memory of the elders thus transferring from one generation to the other. 'Memory' or 'social memory' is an important concept because it helps predict the unexpected and enhances the capability to learn from crisis (Berkes 2007). Thus, resilient systems hold the elements of renewal (Folke *et al*. 2005) and social memory and ecological memory are parts of these elements of renewal thus bringing opportunity for change (Berkes 2007).

Nurturing diversity

Diversity not only provides new opportunities in the renewable cycle but also increases options for coping with stresses thus overcoming s system's vulnerability. Many traditional and local communities have adopted specialized resource management practices in which they use diversity of resources. Range of economic opportunities available is another important aspect of diversity. Local economic diversification is considered an important policy objective especially in the northern countries where local economies are affected by recourse development for global economy. Thus, diversity including diverse resource management systems, diverse economic systems as well diverse players have a huge potential of providing platforms for new thinking, dialogue, education, and information sharing (Berkes 2007).

Creating opportunities for self-organization

A community's ability of self-organization is closely related to its resilience. Berkes (2007) discusses several aspects of self-organization such as community-based management, building cross-scale management capabilities, strengthening institutional memory and nurturing learning organizations and adaptive co-management. The first involves community response and adaptation through its own institutions, the second involves horizontal and/or vertical levels of organizations working at all levels to overcome complex challenges such as climate change, the third involves emergence of new structures and strategies to deal with stresses based on institutional memory and the fourth involves knowledge testing and revision in a dynamic and self-organized process through learning-by-doing (Folke *et al*. 2002).

Integration of different kinds of knowledge

Collaboration and integration of science and traditional and local knowledge is one critical factor that helps in resilience building of complex SESs. This integration includes documenting and combining climate change observations of local and indigenous communities and presenting and validating them with the scientific knowledge. Climate change is a complex phenomenon which needs to be understood at multiple and across scales including global and local. Thus, community-based monitoring and local and indigenous observations are significant in filling the knowledge gaps (Berkes 2007). Alexander *at al*. (2002) raise the concern that traditional and local knowledge is minimally included in the IPCC and climate change studies because these observations are not frequently documented and lack of local knowledge integration in climate science will bring sustainability into question (Makondo and Thomas 2018). Although local and indigenous communities need assistance to adapt to climate change, they have knowledge and experience to cope with this change and integration of this evidence into the main-stream science promises to formulate sustainable strategies to climate change hazards (Makondo and Thomas 2018).

2.4.2. Traditional and local knowledge in climate change

Traditional and local knowledge

> "Indigenous people and their communities…have a vital role in environmental management and development because of their knowledge and traditional practices. States should recognize and duly support their identity, culture and interests and enable their effective participation in the achievement of sustainable development."
>
> Rio Declaration on Environment and Development (IIPFCC and CIEL 2019)

> "Traditional knowledge is still under-used by science, although it is of great value and can contribute significantly to the development of humankind."
>
> Chief Vyacheslav Shadrin of Russia

> "Traditional knowledge is part of the heritage of humankind. It is the library of knowledge that people have of the environments they live in. We need different knowledges. Future generations will need this to survive."
>
> Betancaro, a local man from U'wa while defending his territory (Vidal 2019)

Ironically, many indigenous and local communities that have no contribution in the industrial activity (the primary cause of climate change) are experiencing the impacts of climate

change. Unfortunately, impacts of climate change on traditional and indigenous communities are not limited to disrupting food supply and health facilities and disease outbreak but also, these perturbations caused by CC cause long-lasting cultural disturbances among these communities and affect their well-being (Alexander *et al*. 2011).

Traditional knowledge and indigenous knowledge are often mentioned together or interchangeably (Kudngaongarm 2009; Huntington *et al*. 2009). The difference depends upon interpreter's point of view and scale that is considered. However, there are some subtle points of distinction between both knowledge types which are important to be understood. For instance, not all traditional knowledge is part of indigenous knowledge, but indigenous knowledge is a subset within TK. This is because TK is created by any individual within a group whether indigenous or not, but indigenous knowledge is not flexible and is only generated by indigenous people. Thus, indigenous knowledge is a type of TK that is held by indigenous communities. To summarize, indigenous knowledge is TK but not all TK is indigenous. However, oral transmission, being customary, holistic, and experiential are some of the common qualities of both knowledge types (Kudngaongarm 2009).

Traditional knowledge is a cumulative body of knowledge, practice and belief that is evolved by adaptive processes and is handed down from generation to generation through oral cultural transmission (Alexander *et al*. 2011). Traditional knowledge is transmitted through generations through stories, paintings, performances, dance, songs, and everyday practices. This transmission is important because it harnesses the potential of women and young people to face complex challenges such as climate change (United Nations 2019).

Local knowledge is also developed over time in a community based on people's experiences and adaptation in local culture and environment. However, local knowledge is not confined to the tribal groups or the original inhabitants of a place. Rather, all communities possess local knowledge. Traditional knowledge however is more static in a community deeply enrooted in its culture and its people do not interact with other knowledge systems on a larger scale (FAO 2004). Thus, it is extremely hard to clearly differentiate between traditional and local strategies and their origin and this lack of clarity might cause misinterpretation of examples of both knowledge types. Also, although Ghanche was an isolated area from a long time but considering the intensity with which globalization is hitting it hard, it might not be wrong to say that other knowledge systems have already influenced the already existing knowledge

systems in Ghanche. Thus, it was considered wise to keep the broader category of knowledge for this research by considering both traditional and local knowledge systems.

Traditional and local knowledge and climate change

According to Berkes and Jolly (2001), there is a gap between global and local level on knowledge generation about climate change, its impacts, and responses. Therefore, in order to comprehend climate change impacts on communities, this gap needs to be filled by making TK compliment western science-based understanding of CC and enhance adaptive capacity of communities to CC. It must be noted that although 'adaptive' is any response that enhances probability of survival. However, this concept includes two different concepts including 'coping mechanisms' and 'adaptive strategies'. Coping mechanisms are short-term responses to shocks or perturbations that threaten livelihoods. These are often the emergency responses to stresses. Adaptive strategies on the other hand are solid long-term modifications in the norms, local rules, activities, and institutions of communities to secure their livelihoods (Berkes and Jolly 2001).

Alford *et al*. (2012) give a major recommendation of integrating indigenous and local community efforts to reduce vulnerability to glacier-related disasters in the Hindukush-Himalayan region as these regions are vulnerable due to some of the following reasons:

- Glacial recession: The high Himalayan, Karakorum and Hindukush regions lie within an active zone of glacier hazards and GLOF events have been severe and deadly in these regions due to a rapid increase of glacial retreat. Water resources upon which local communities largely reply on are also affected.
- Demographics: The population in the HKH region mainly consists youth (21.7 years of median age in Pakistan) and because this large portion of population lacks experience and skills to deal with CC disasters, this has influenced the level of preparedness, planning, response, and recovery capacity of these regions. Therefore, it has become fundamental for these regions to document and integrate indigenous and traditional knowledge of elders and community leaders before it disappears.
- Gaps in knowledge and awareness of mountain hazards: Due to power and informational disconnect of HKH communities with their governments but also with the external world such as scientists, there is a large gap between community members and their knowledge on CC hazards. This lack of scientific knowledge on

mountain hazards and geophysical processes, awareness on disaster preparedness and planning is minimum.

- Male outmigration: Female members in some of these regions are burdened with greater responsibilities of taking care of their families and household chores. This restricts them from attending trainings and awareness programs on CC hazards and usually, male members of the households are observed to be active not only in participation but also in attaining major information regarding CC risks. However, a large percentage of male population has migrated out to pursue employment opportunities which has left the remaining household members without the required information of disaster preparedness.

(Alford *et al*. 2012)

Therefore, integration of TK and its exercise on regional and global level is necessary to enhance disaster preparedness and comprehension of CC risks in HKH region.

With traditional knowledge getting an increasing attention, its role in understanding climate change impacts and formulating responses to overcome them by local communities is investigated by several researchers. For instance, Joshi *et al*. (2013) conducted research on herders' perception of and their response to climate change in Gilgit-Baltistan Pakistan. The results state that herders were aware of the changing climatic conditions and therefore considered several coping mechanisms such as water trapping from glaciers, construction of new irrigation channels to irrigate pastures and changing grazing patterns. Long-term adaptive strategies included herd diversification. Evolution of socio-hydrological system based on traditional knowledge in Ladakh is another successful example of which involves construction of artificial glaciers to overcome seasonal water scarcity (Nusser and Baghel 2016). Climate change adaptation based on coping mechanisms and adaptive strategies formulated by Inuvialuit people in Canada's western Arctic was studied by Berkes and Jolly (2001). Short-term responses included switching species and "adjusting the where, when and how of hunting" while long-term culturally embedded techniques included flexibility in seasonal hunting patterns, diverse hunting activities based on traditional knowledge, food-sharing networks, and intercommunity trade.

3. Methodology and conceptual framework

3.1. Research methodology

The research design was developed in a way that all the research objectives could be fulfilled using appropriate methods.

Research methodology predominantly included qualitative research methods as this type of research can provide descriptions of how people experience a given issue. It provides information about the "human" side of an issue. It answers questions about experiences, meaning and perspectives from the point of view of the participants (Hammarberg *et al*. 2016) and therefore, was the most appropriate research method for this research work. After in-depth literature review and conceptual framework formulation (figure 12), climate data (temperature and precipitation) was collected from Earth Engine Data Catalog for the study area for around past 30 years and trendlines were obtained to understand average trends in the past temperature and precipitation patterns. As this was not a major objective of this research work, in-depth analysis of climate data using a highly professional software was not performed. In order to understand seasonal temperature patterns, winter and summer temperature data was extracted from the annual temperature data that was obtained from Earth Engine Data Catalog and related graphs were prepared to show seasonal temperature trends. This data extraction was done using R-programming. Secondary data collection was followed by the primary data collection. Interviews were conducted from 30 diverse stakeholders (farmers, teachers, community leaders) of the study area (Ghanche). These were structured and semi-structured interviews with open and close-ended questions which were delivered via a questionnaire (appendix A) by a local translator. The questionnaires were then translated from the local language (Balti) to English.

Once the interview data was collected and translated, data analysis was performed by validating scientific climate data with the participant's observations of changes in the climate parameters. Moreover, remaining research objectives were fulfilled by discussing the results from the relevant data gathered and the data was discussed using the conceptual framework on how traditional knowledge can overcome vulnerability to climate change and enhance climate change adaptation.

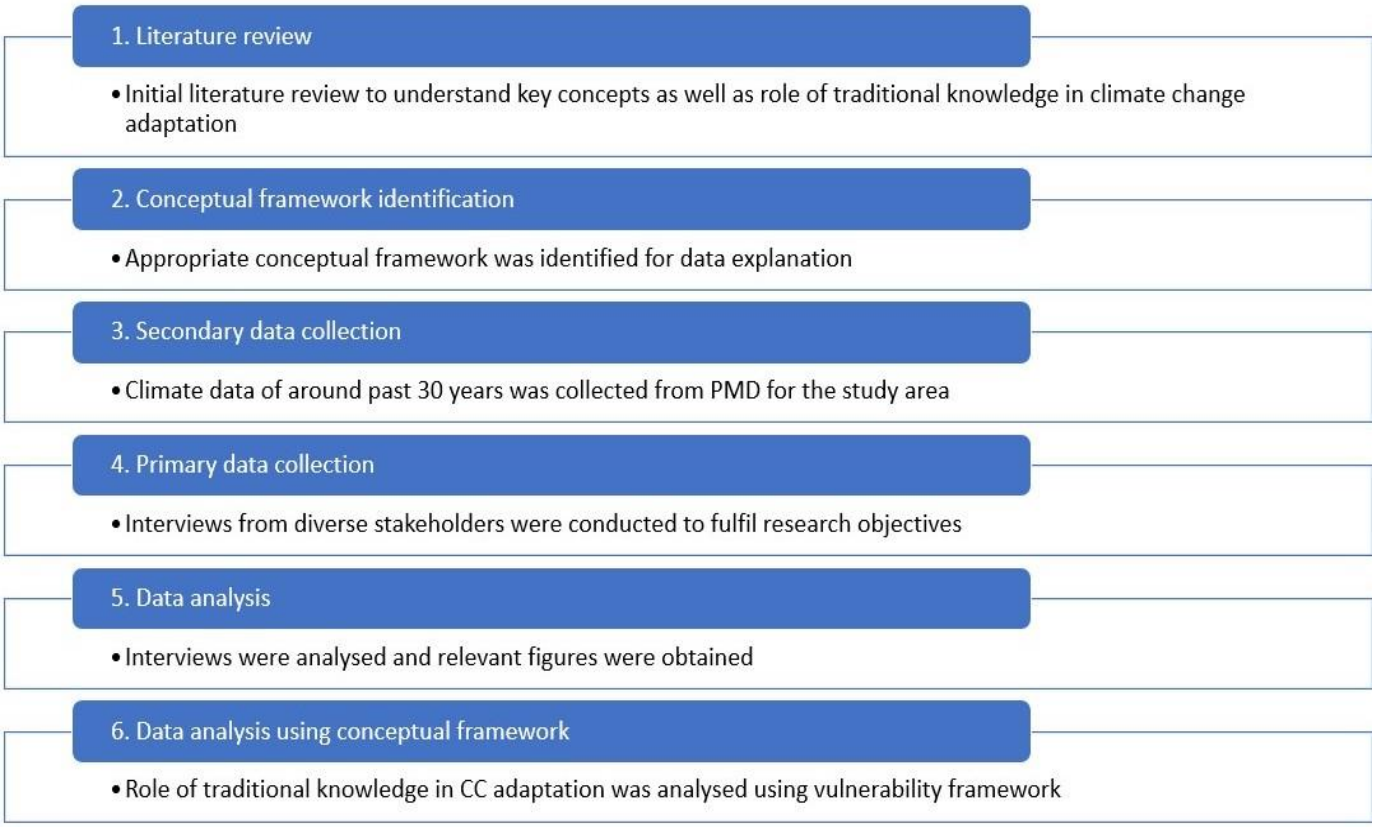


Figure 12. Research design (Akhtar 2020).

3.1.1. Site selection

Ghanche district in Baltistan division of Gilgit-Baltistan province was selected as a study area because of the following reasons: Firstly, Ghanche is one of the isolated mountain regions of Pakistan bordering with India and China. Such isolated mountain communities with lack of financial and technical assistance are considered "laboratories of adaptation". This kind of coupled systems of close interaction between humans and their environment possess valuable knowledge and experiences of past which is extremely helpful to understand future processes (Hemp and Hemp 2008). Secondly, like many other mountain regions, Ghanche is also facing impacts of climate change such as changes in the precipitation, temperature, flood, and avalanche patterns. Also, no climate change-related research has been done in this region. Therefore, it is interesting not only to know impacts of climate change in such isolated communities but also, it is tremendously significant to formulate climate-related policies for mountain communities which are inclusive which means they must include data from every community that is facing climate change. This is possible only if these communities are prioritized, not ignored and people are invited to talk and share their experiences and knowledge. Thirdly, northern regions with mighty mountain ranges and glaciers are and will

hit hard by climate change and therefore, it is important to understand how their resilience can be enhanced to secure their future. Thus, Ghanche can be taken as a case study to understand climate consequences and resilience building.

3.1.2. Data collection

Initially, secondary meteorological data of precipitation and temperature for the period of around 30 years was received from Earth Engine Data Catalog for the study area to fulfill the first research objective. In order to fulfill the remaining objectives, primary data was collected with the help of a local translator from multiple stakeholders via open and close-ended questionnaires and face to face interviews. These responses were recorded with a smart phone, translated to English, and analyzed.

3.1.3. Data analysis

Secondary data for precipitation and temperature was obtained in CSV (comma-separated values) format from Earth Engine Data Catalog. The annual temperature data was converted into seasonal data using R-programming and the trends were analyzed using graphic representation. Annual precipitation data was plotted and discussed via graphs. Primary data was analyzed depending upon the nature of each question. For instance, responses to close-ended questions were plotted in the form of figures using excel. Open-ended questions were analyzed based on common themes or common responses of the participants alongside fitting them into the conceptual framework while addressing relevant research objectives.

3.2. Conceptual framework

Vulnerability frameworks which account for the vulnerability of coupled human-environment systems with diverse and complex linkages are required to answer the questions such as: who is vulnerable to the environmental changes and where? How are those changes amplified by human and environmental conditions? What factors can reduce vulnerability and how can resilient communities be built? The vulnerability framework used here is developed by the author based on the survey data received from the participants. This framework (figure 13) aims to “make vulnerability analysis consistent with the concerns of sustainability and global environmental change science” (Turner *et al*. 2003). It shows how relevant, adequate, and useful Tk is and will be to overcome vulnerability to CC impacts in a mountain community in present and future.

According to Turner *et al*. (2003), the following are the important elements to be considered in any vulnerability analysis:

- Multiple perturbations and stresses that interact and their sequencing
- Exposure beyond perturbation and stress (a coupled system that experiences hazards)
- How sensitive a coupled system is to the exposure
- Resilience of the system to cope including consequences as well as risks of poor or slow recovery
- Adjustments and adaptations of the system after the response taken
- Multiple scales of the hazards, the system, and its responses

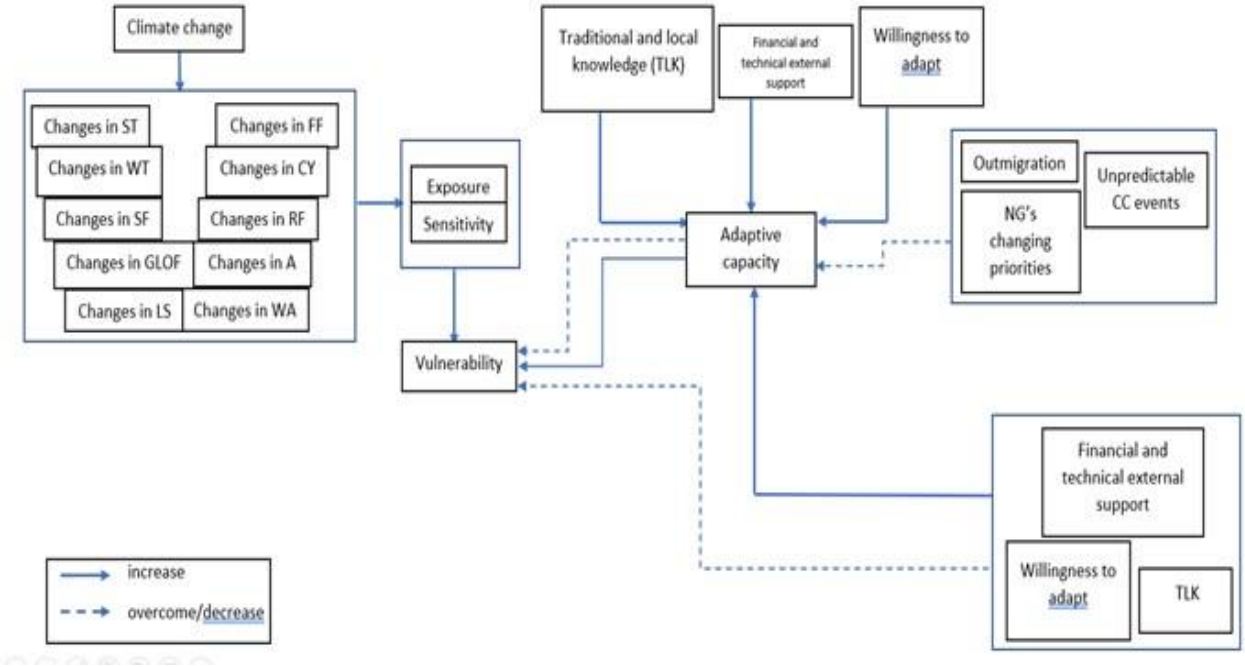


Figure 13. Vulnerability framework and its components operating in a particular region based on the survey data. ST: Summer Temperature, WT: Winter Temperature, FF: Flash Floods, CY: Crop Yield, SF: Snowfall, RF: Rainfall, A: Avalanche, LS: Landslide, WA: Water Availability, NGs: New Generations, CC: Climate Change, TLK: Traditional and Local Knowledge.

The basic structure of this vulnerability framework consists of linkages to the human and environmental conditions and processes operating on the coupled system, perturbations and changes that emerge from these conditions and processes operating on the coupled system and the coupled system of concern in which vulnerability resides including exposure and sensitivity and adaptive capacity.

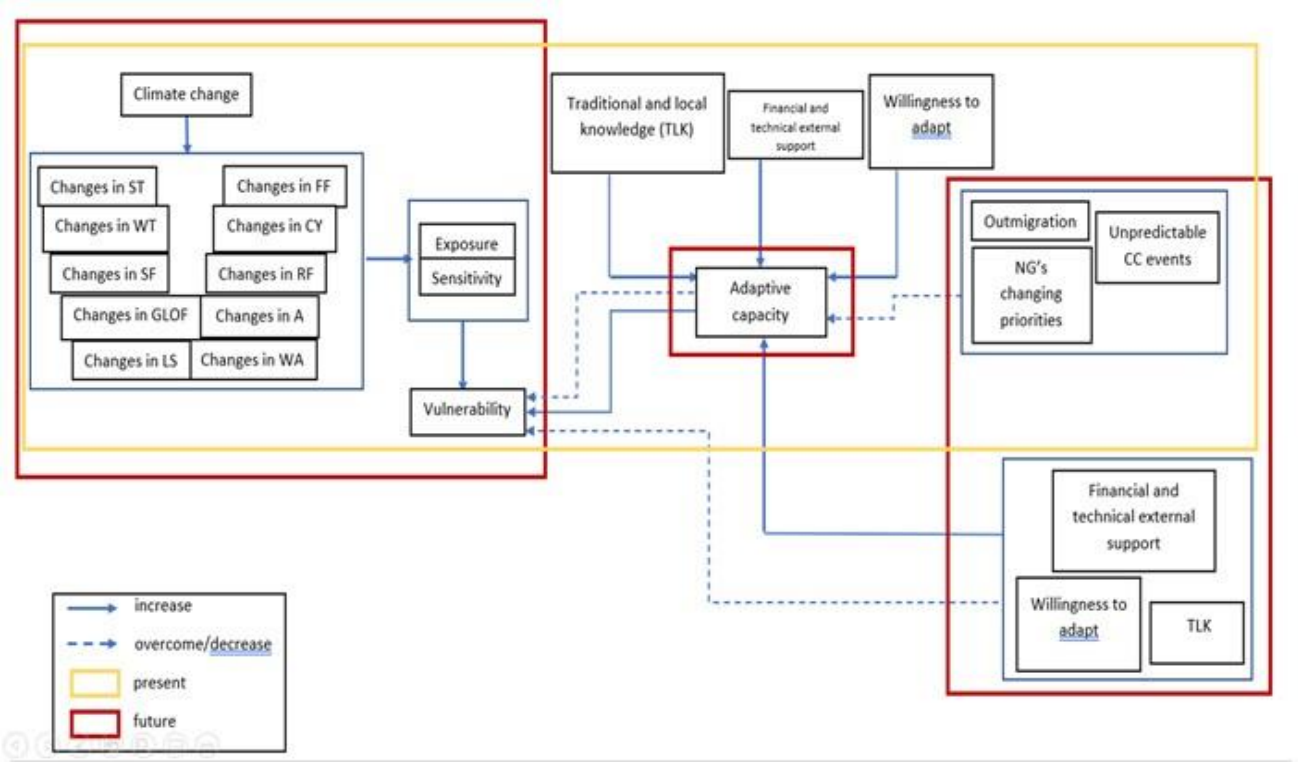


Figure 14. Elaboration of the vulnerability framework based on the temporal scale. ST: Summer Temperature, WT: Winter Temperature, FF: Flash Floods, CY: Crop Yield, SF: Snowfall, RF: Rainfall, A: Avalanche, LS: Landslide, WA: Water Availability, NGs: New Generations, CC: Climate Change. TLK: Traditional and Local Knowledge.

Figure 14 elaborates the vulnerability framework based on the temporal scales (present and future) it functions at. Detailed description of figure 13 and 14 is given in the results section 4.5.

3.3. Research limitations

This study has several limitations associated with its characteristics:

- Firstly, the total sample size taken was much smaller due to limited time and financial resources. Thus, the sample might not be the best representative of the entire population of Ghanche. This limitation was somehow combatted by selecting participants from different villages of Ghanche.
- Secondly, another issue arises concerning language. Interviews were conducted in Balti language (mother tongue) and were translated into Urdu and English. So, the problem of misinterpretation could be possible. Local languages such as Balti are extremely hard to translate into another language because the literal meaning of some original words cannot be found in other languages such as English. However, high

standard Urdu and English translation was ensured with the help of a local translator with command on both Balti and English.

- Thirdly, many people working in environmental organizations of the government or NGOs were not present during the fieldwork schedule. It was winter and most moved to cities on winter vacations. However, some of them were requested to fill the questionnaires online to ensure at least some representation from their behalf.
- Next, no previous studies or published research on similar topic was found for Ghanche. This would help compare the findings and make this research more credible. Most analysis was done based on the primary data collected from the respondents.
- Lastly, gender representation; most participants were men with few local women. This is because it was challenging to easily recruit women in most places of Ghanche compared to men. Respecting the local norms and regulations was a major 'thing to consider'.

4. Results and analysis

The following sub-sections discuss the results (in graphical, tabular, and descriptive form) directly discussing each research objective (RO). Relevant findings from the surveys are discussed too thus linking them to the vulnerability framework (figure 13 and 14).

4.1. The manifestation of climate change in Ghanche: Community observations and scientific evidence

The following RO will be discussed in two sections. First, participants' responses will be shown in the graphical form which will be followed by data validation for temperature and precipitation.

4.1.1. Climate change-induced variations in different variables based on community perceptions and observations

Participants were asked multiple open and close ended questions regarding their observations and understandings of changes in different climate change-related events.

Changes in summer and winter temperature trends

As it can be understood from figure 15 and 16, 100% of the participants mentioned that both summer and winter temperatures have increased in around past 25 years. Although these

seasonal temperatures are increasing, but the change is not very extreme. The temperature overall has become warmer though. Most participants mentioned that they never used fans or air coolers before, and tree shadows would be enough to spend summer days. However, a lot of families are now considering getting help of facilities such as fans and air coolers. One farmer commented while pointing towards a mountain top:

> "*You see that mountain top; I don't see it white anymore. Even if we get intense snow sometimes in winters, it doesn't stay longer because warmer summers now melt snow faster."*

Another participant shared a very interesting observation:

> "*I remember, winters used to be so extreme, even dry fruit oil would freeze sometimes and now, sometimes, even some waterbodies do not freeze properly."*

Majority of participants mentioned that although winter temperature has increased now compared to past, but locals still face extreme cold as commented by one local businessman:

> *"There are two conditions in winters. Firstly, winters overall have become warmer compared to past. This is obvious because it is not harsh", and we get less snow overall. However, they are still extreme enough and we sometimes get extreme snow which blocks roads and due to lack of proper heating system and electricity, people spend their entire winters in cold burning lots of wood."*

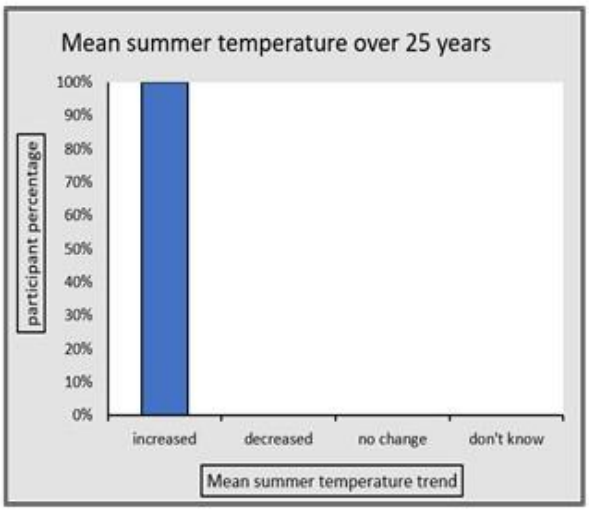


Figure 15. Mean summer temperature trends in around past 25 years according to participant's responses.

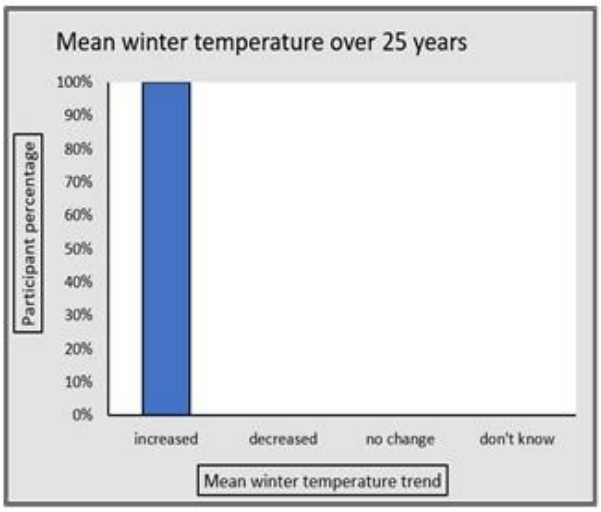


Figure 16. Mean winter temperature trends in around past 25 years according to participant's responses.

Changes in spatial distribution of summer and winter temperatures

Participants were asked questions regarding changes in the spatial distribution of summer and winter temperatures (spatial distribution here means observed changes in spatial patterns of temperature).

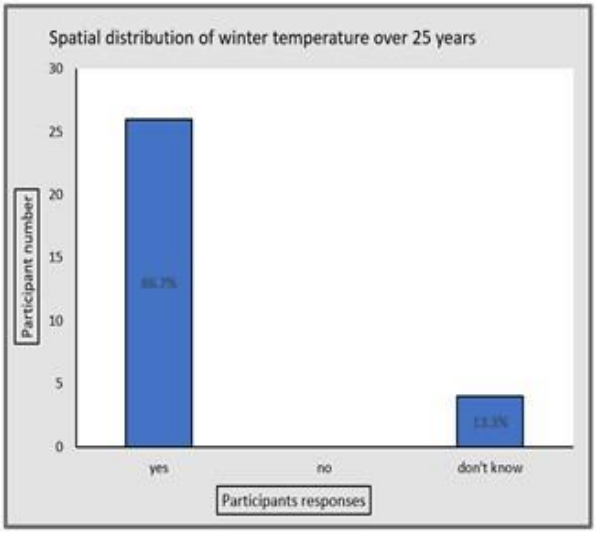


Figure 17. Participant's responses to changes in spatial distribution of summer temperature in around past 25 years.

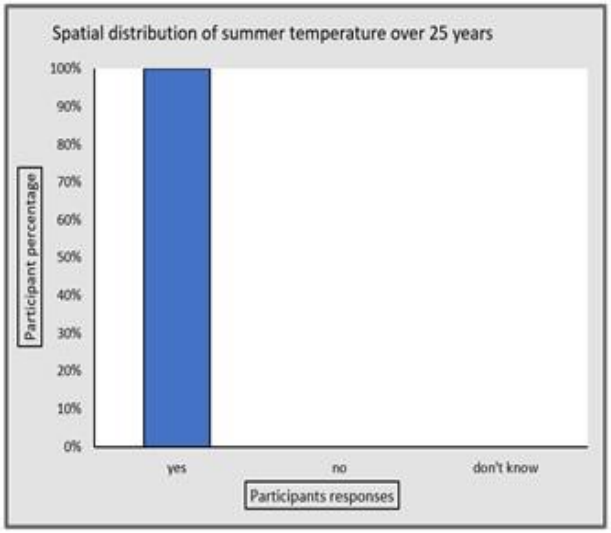


Figure 18. Participant's responses to changes in spatial distribution of winter temperature in around past 25 years.

100% agreed that summer temperature has changed spatially (figure 17). For instance, the study area Ghanche itself is an example which was not a warmer region before as it is now. Some participants mentioned that areas closer to mountain regions also have become warmer now. Regarding spatial distribution of winter temperatures, 13% participants were not sure but around 87% locals mentioned that winter temperatures have changed spatially to some extent (figure 18). For instance, areas closer to mountains have become a little warmer but those far sometimes get extreme cold events unlike before.

Changes in rainfall patterns and precipitation extremes

100% of the participants agreed that rainfall patterns have changed, and rainfall overall has increased in Ghanche (figure 19). They now experience very irregular rainfall events, but rainfall has increased overall compared to past. 93% of the participants agreed that precipitation extremes have changed and increased in around past 25 years (figure 20). One local mentioned:

> "*2015 rainfall was record breaking which flooded an entire village (Talis), killed some people and animals and destroyed a lot of agricultural land."*

Another participant who was a government employee shared similar observations about 2015's intense rainfall.

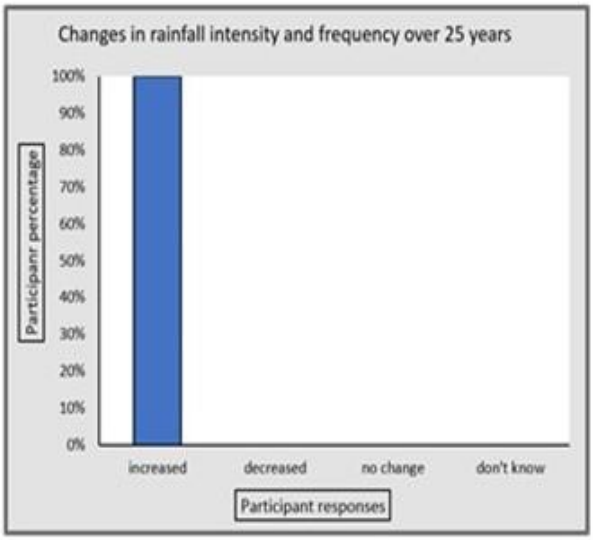


Figure 19. Participant's responses to changes in rainfall patterns in around past 25 years.

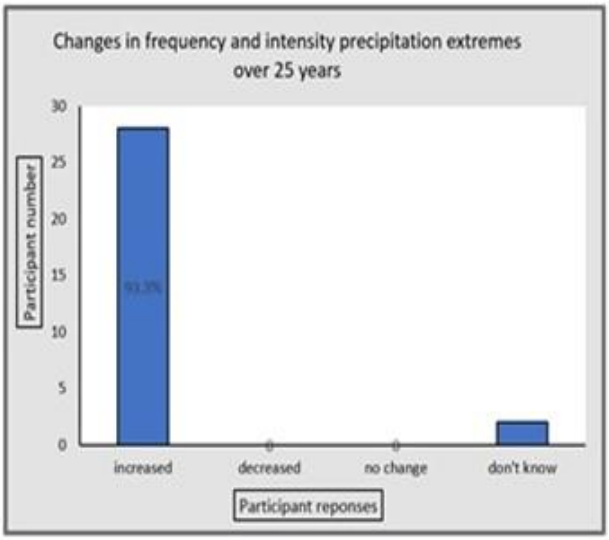


Figure 20. Participant's responses to changes in precipitation extremes in around past 25 years.

Changes in flashflood patterns

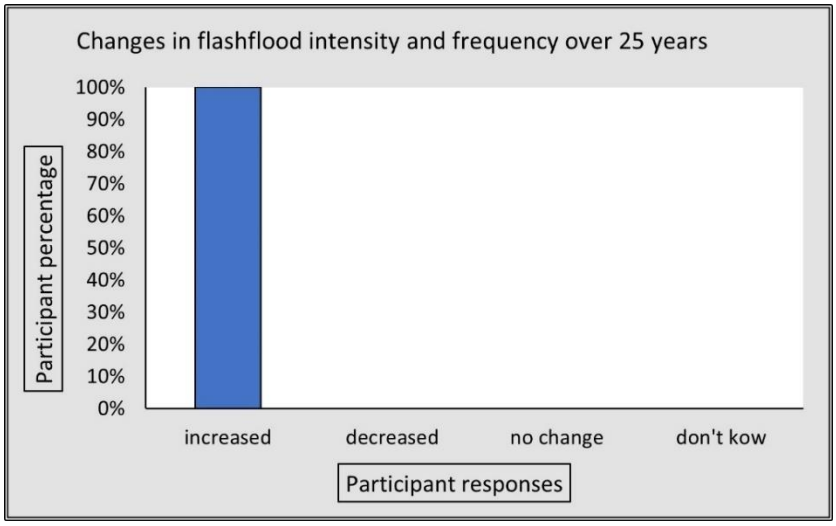


Figure 21. Participant's responses to changes in flashflood patterns in around past 25 years.

Interestingly, 100% of the participants mentioned that flashflood patterns have changed in Ghanche in around past 25 years (figure 21). These events have become extremely irregular but have increased overall in their intensity and frequency. One local said:

"Land erosion is a major concern. People spend a lot of time and energy managing their agricultural land but FFs erode them in once and their hard work goes into vain. Their crops are destroyed, and food availability is affected."

Another local commented:

"*Flashfloods bring down a lot of mud and rocks. They block and fill our major water channels with soil and mud, and we have to clear them on regular basis to get glacier water as well as for floodwater to pass easily."*

Changes in avalanche and landslide events

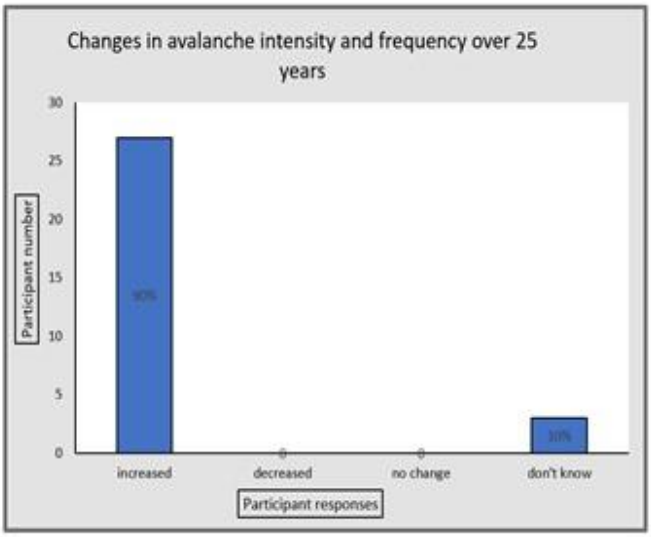


Figure 22. Participant's responses to changes in avalanche events in around past 25 years.

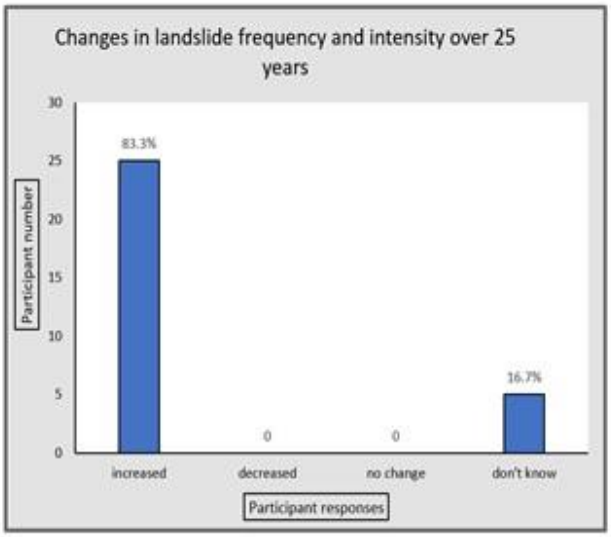


Figure 23. Participant's responses to changes in landslide events in around past 25 years.

Participants were asked questions regarding changes in avalanche events in around past 25 years in Ghanche and 90% of them agreed that avalanche events have changed (figure 22). They mentioned that these events have increased now compared to past in their frequency, intensity, and occurrence. 10% were not sure about the change in the avalanche events but some of them mentioned that these events do happen in winters thus blocking their link roads and affecting their daily commute to other regions. One local mentioned:

"Road obstruction and major complications in transport and communication are major challenges. Import export gets highly influenced because KKH (Karakoram Highway is the major road of transportation which usually remains blocked due to avalanches."

83% of the participants mentioned that landslide events have increased (figure 23). One local said:

> *"Whenever landslide happens, they cause road obstruction and erode our agricultural land. Our land is extremely sloppy, and landslides are very common. I think a landslide itself is a change."*

Changes in snowfall and GLOF events

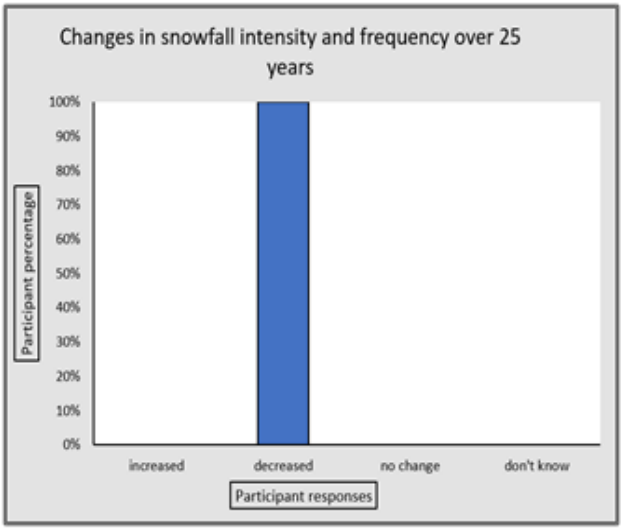


Figure 24. Participant's responses to changes in snowfall patterns in around past 25 years.

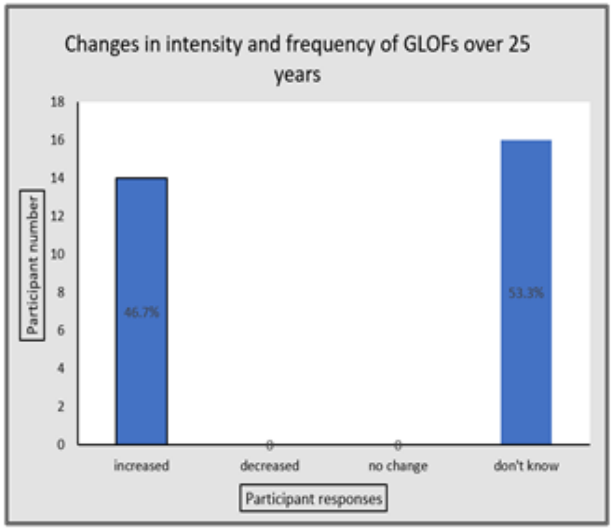


Figure 25. Participant's responses to changes in GLOF events in around past 25 years.

All the participants (100%) agreed that snowfall patterns have changed (figure 24). All of them mentioned that these patterns have become highly irregular now and have reduced overall. Upon asking follow-up questions, they mentioned that sometimes snowfall is extreme, and they face road blockades and other times, it is very less and makes water availability low in later seasons. One female farmer mentioned:

> *"Very irregular patterns of snowfall now. For instance, Dec-Jan are main winter months but sometimes snowfall happens intensely in March which is weird. Few years back it happened in April as well and destroyed our crops. Whatever snowfall we get, it melts early and affects water availability for our agriculture. However, we are still facing avalanche events and road obstruction when it snows extreme. We are cut off from rest of the world for days. We feel helpless in medical emergency. Who will live here in such winter conditions? A lot of people have started migrating to cities in winters."*

Another local commented:

"Very irregular snowfall patterns but have reduced overall. I remember snowfall used to be so extreme, it would reach the terrace of our mud house but now it is not extreme at all."

The responses regarding GLOF events were mixed. Around 47% participants agreed that GLOF events have changed and increased now (figure 25) but 53% were not sure about this change. One participant mentioned:

"GLOF events cause major flooding downstream and erode our crops and trees. In some places, they block the water that flows down thus affecting water availability to water our lands."

Changes in crop yield and water availability

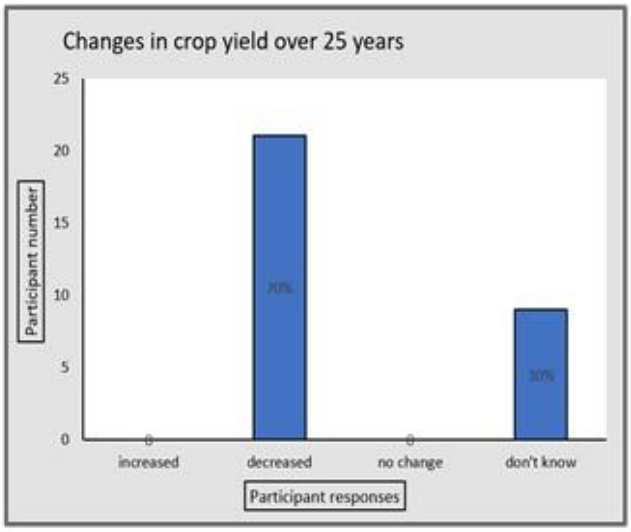


Figure 26. Participant's responses to changes in water availability in around past 25 years.

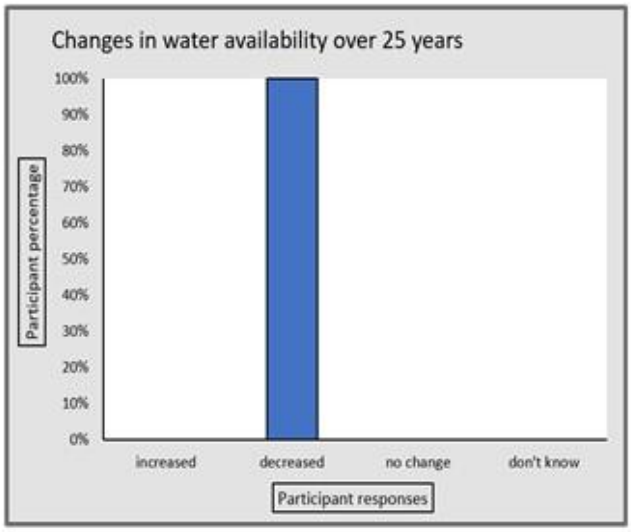


Figure 27. Participant's responses to changes in crop yield in around past 25 years.

Water availability was another important parameter to which 100% of the participants agreed that it has change and reduced over 25 years (figure 26). One local said:

"Water availability has reduced overall which has affected our crop growth. This I think is a reason grass quantity in meadows has reduced. Due to early melting of snow, we do not get enough glacier water when growing our crops. Thanks to natural spring water, a lot of people are adjusting now."

Moreover, 70% of the participants agreed that crop yield has reduced compared to past. Some locals mentioned that although less water availability is one reason, change in people's

priorities is another reason. People are now oriented more towards jobs and education and are not willing to work hard to grow crops. One local said:

> *"Food availability at home or family level has reduced and people have become dependent upon market products. This shift is dramatic and dangerous because our people are no more self-sufficient in terms of agriculture. Imaging if people around the globe rely on market and stop producing food. This makes me very sad."*

Another local teacher mentioned:

> "*One reason behind reduction in crop yield is an unbalanced water availability at time when we grow crops. but another major reason is social and change in people's priority. People now put less effort in growing crops because they want to earn money through education and jobs. Also, due to easy access to market products, people are highly relying on them instead of growing organic food by their own and thus, the concept of organic food is vanishing."*

4.1.2. Whether changes in temperature and precipitation patterns observed by the participants compliment the scientific data

Seasonal temperature (winter and summer temperature) and annual precipitation data for around 25-35 years was downloaded from Earth Engine Data Catalog was plotted for data validation.

Figure 28. Annual precipitation trends in Ghanche for the period of around 35 years (Data source: Earth Engine Data Catalog).

Annual precipitation over around 25-35 years (figure 28) is irregular but has increased as mentioned correctly by the participants (figure 19 and 20). For instance, after 1994 to 2008, most rainfall bars fall below 175mm but after 2008, extreme events have increased with most bars falling above 225mm thus enhancing the overall rainfall patterns as shown by the trendline. Moreover, one participant says that 2015 flood was devastating and in figure 28, 2015 bar shows one of the extreme rainfall events.

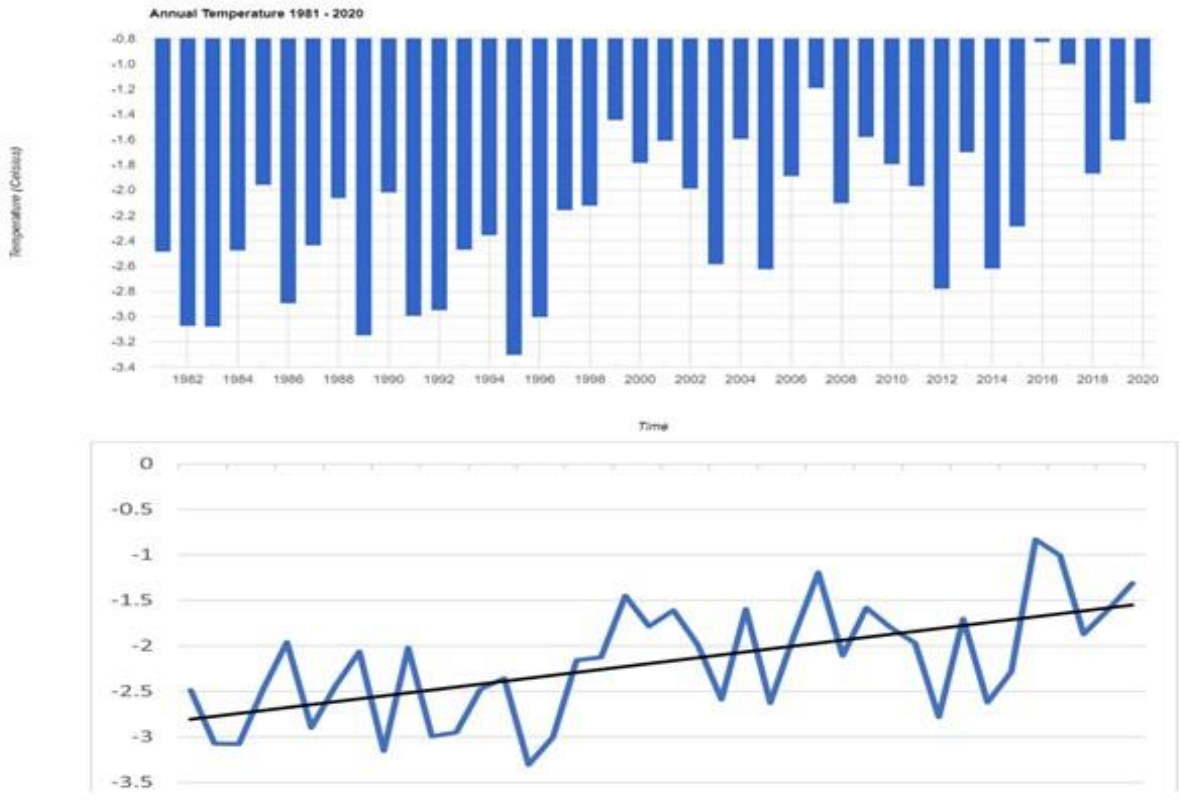


Figure 29. Ghanche's annual temperature for the period of around 35 years (Data source: Earth Engine Data Catalog).

Figure 29 shows that annual temperature patterns have highly increased in Ghanche in around past 25 years. For instance, from 1982 to 1996, most bars fall beyond -2.8°C but after 1998, most fall below -2.2 thus showing an increasing annual temperature pattern. This increasing trend of annual temperature matches the responses of the participants in which they mentioned that temperature overall has become warmer compared to past.

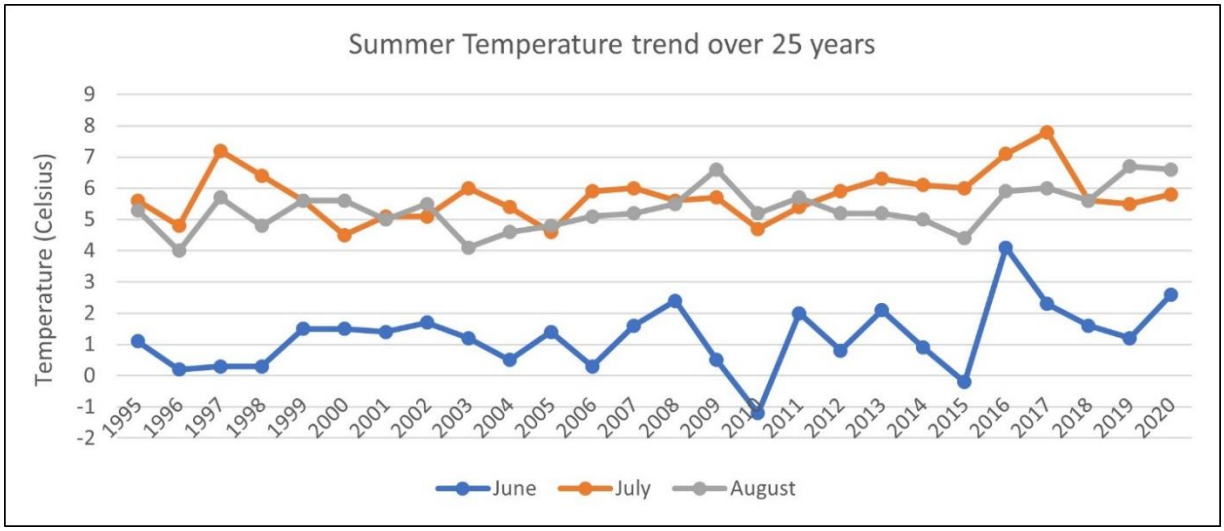


Figure 30. Summer temperature trends for Ghanche for the period of past 25 years (Data source: Earth Engine Data Catalog).

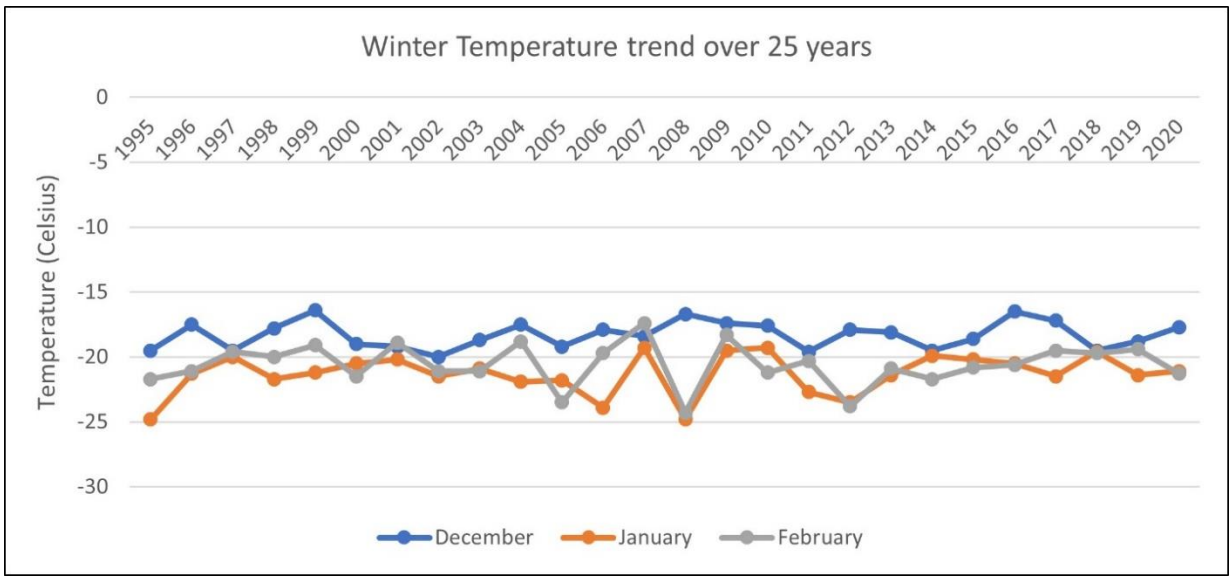


Figure 31. Winter temperature trends for Ghanche for the period of past 25 years (Data source: Earth Engine Data Catalog).

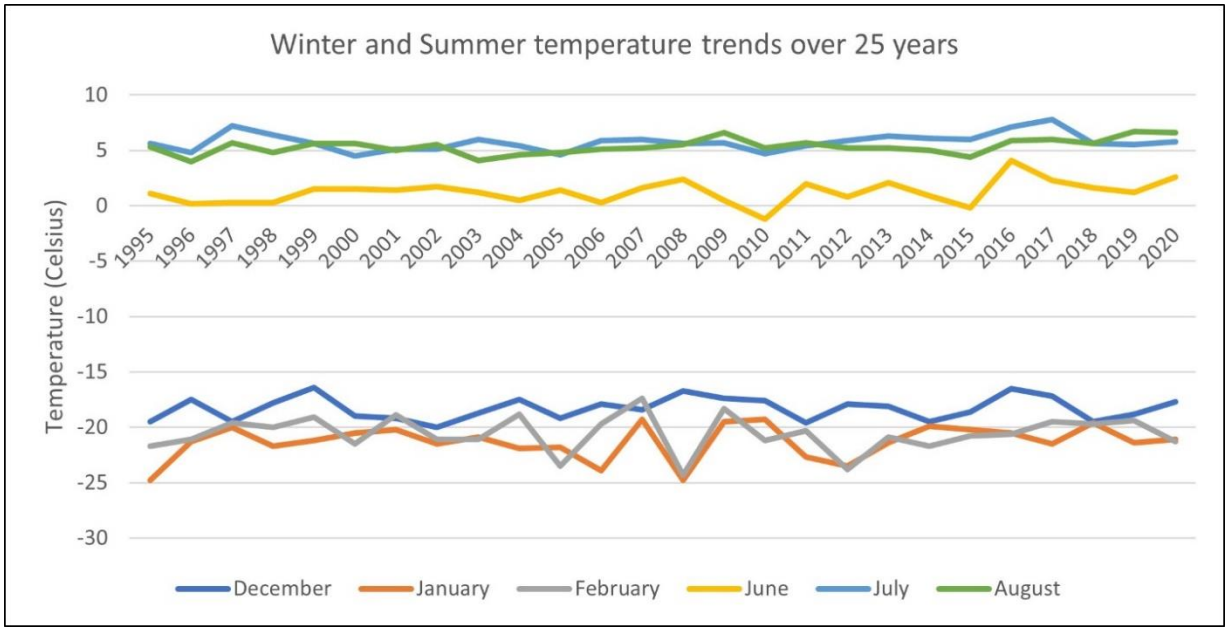


Figure 32. Winter and summer temperature trends for Ghanche for the period of 25 years shown together (Data source: Earth Engine Data Catalog).

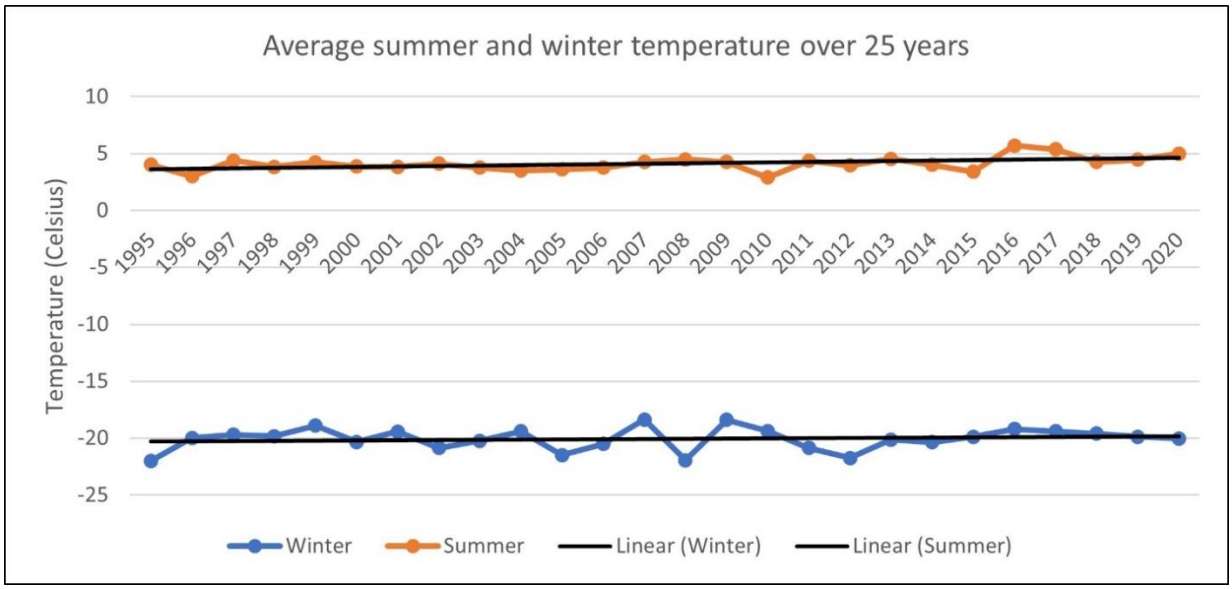


Figure 33. Average summer and winter temperature trends for Ghanche for the period of 25 years (Data source: Earth Engine Data Catalog).

It can be seen from figures 30-33, the average summer temperature patterns are showing an increasing trend. This matches the participant's responses in figure 15 in which they mentioned that summer temperatures in around last 25 years have increased. Average interannual winter temperatures however do not show an obvious trend in figure 33 but intra-annual trends of winter months in figure 31 do show an increasing trend to some extent thus

validating participant's responses in figure 16 in which they mentioned that winter temperature has increased.

4.2. Climate change impacts shared by the participants

This section discusses first section of RO2. The impacts of changes in the above-discussed climate change related parameters are discussed in tabular form which is followed by the adaptation strategies locals have implemented to overcome these impacts.

Table 1. Changes in summer and winter temperatures, rainfall and snowfall, avalanche events, crop yield, water availability, flashfloods, landslides and GLOF events and their impacts shared by the participants in Ghanche.

Change in parameter	Impacts
Changes in summer temperature (increased overall)	• Intense and frequent floods which destroy property such as land and households. Floods also erode agricultural land • Glaciers are retreating faster thus reducing water availability and crop yield • Floods sometimes and very less water available other times • Increase in river water due to intense and frequent floods which erodes the surrounding land • Floods damage and clog main water channels in the mountains with rocks and mud • People closer to flood prone areas have to be evacuated and given shelter
Changes in winter temperature (irregular but warmer overall)	• Irregular winter temperature (sometimes very extreme but has become warmer overall) • Less snowfall which affects water availability in later seasons • Snow melts earlier and makes water less available later • When snowfall is extreme, road obstruction and daily commute for jobs, business, schools, and hospitals is hampered
Changes in rainfall (extremely irregular but increased overall)	• Irregular rainfall but increased overall which causes floods thus destroying crops and eroding land • Sometimes, it rains in summer when fruits are ripening thus destroying them • Intense rainfall-caused floods destroy and fill major water channels with mud and rocks • Most people have mud houses, and they face regular water leakages • Intense rains cause landslides. This region is sloppy, so landslides become common • Floods damage main link roads, bridges and affect quality of waterbodies
Changes in snowfall (extremely irregular but reduced overall)	• Snowfall has reduced which has affected farmers because it makes water less available for agriculture • Whatever less snow falls, it melts earlier thus affecting water availability in later seasons • Quantity of grass in pastures and meadows has reduced maybe because they do not get water on regular basis now • However, when snowfall is extreme, avalanche events become common and intense snow blocks roads thus affecting daily commute for jobs, business and import and export as well as transport during health emergencies

Changes in flashfloods (increased overall)	• Killed some people few years back • Erodes agrarian land and crops are destroyed • Has affected people psychologically • Main water channels in the mountains are destroyed and filled with mud and sediments • Flashfloods destroy trees, link roads and bridges • Talis and Hanjour were highly affected
Changes in crop yield (reduced overall)	• The concept of organic food is vanishing and food production in homes has highly reduced • Some farmer's economic loss is caused by reduction in crop yield • People have become highly dependent upon market products • People relying on chemicals to grow more crops • People selling vegetables sell less vegetables now
Changes in avalanche events (increased overall)	• Road obstruction, land erosion and damage to personal and public property (KKH is the main road of transport which remains blocked) • Daily transport and communication get affected • Some avalanches are huge, they kill people
Changes in landslide events (increased overall)	• Road obstruction and damage to property including agricultural land • Animals are killed and trees are damaged • Roadblocks isolate this region from rest of the world thus limiting their daily commute and travel in need • Rock falling especially around main roads • Sometimes, landslides hit households
Changes in GLOF events	• Unpredictable floods which erode land • Road blockade • Damage to trees • Glacier lakes when formed block water that otherwise flows downstream for people to use especially for watering agricultural land
Changes in water availability (reduced overall)	• Very unpredictable but reduced thus affecting crop yield and agriculture • Due to unpredictable water availability, some people have stopped farming and rely on market products • Grass quantity in meadows and pastures has reduced • Economic loss due to less crop yield • Pastureland is destroyed

4.3. Adaptation approaches implemented by the locals to overcome climate change impacts

This section discusses the second half of RO2. Adaptation strategies adopted by individuals/families and community to overcome climate change-induced impacts in Ghanche are listed in table 2.

Table 2. Strategies adopted as individuals/family and as a community to changes in different climate change-related parameters in Ghanche.

Change in parameter	Strategies adopted as individuals/family	Strategies adopted as a community
Changes in summer temperature (increased overall)	• People have constructed their houses of concrete to avoid heat • Some families have installed fans, refrigerator, and air coolers for the first time • Planted trees around their homes to avoid heat • Most people have separate portions in home (upper portion usually for summers. This hut type portion made of mud and dry wood is with big doors and windows for proper ventilation) • In old ages, people would avoid wasting land on construction so would make houses very close to each other but now, people make houses in large open spaces to avoid congestion in summers	• Some people are organizing awareness sessions for the locals regarding impacts of changing summer temperatures • People gather and organize rallies against poor electricity management • People have made public water tanks (separate for men and women). They gather glacier or natural spring water and swim in summers • People gather to dig and maintain major water channels in the harsh mountain environments so that floodwater can pass easily but also, they could receive glacier water without interruption • People have made public water tanks to store glacier/spring water and water their lands turn by turn • Plantation drives
Changes in winter temperature (increased overall)	• Most people have separate portions in their homes made of mud and dry wood (lower portion usually for winters). These portions are with small doors and windows to avoid cold • Some people have put roofing sheets to avoid humidity from snow • People use traditional cookstoves and burn a lot of wood • People use local food such as oils and yak meat and animal skin clothes	• People have made public water tanks. They collect hot spring water and swim to avoid cold • People gather to eat local food and stay together around traditional cookstoves burning lots of wood • During intense snowfall, roads become slippery, and people gather to put soil to make them less slippery and clear snow from main public areas

	• People store food in special storerooms for winters	
Changes in rainfall (increased overall)	• People living in mud houses put special soil (shinjaq) on their terraces to avoid water leakage during intense rains • Some people have quit their mud houses and used cement/concrete now to get rid of water leakages • Some people have made sloppy terraces and put roofing sheets to avoid rain • People have made mini water channels around their houses to stop rainwater from reaching their home walls	• A strong civil society: People gather to dig water channels and clear them for rainwater and rain-caused floods to pass easily • People gather to help each other out soil on terraces and evacuate people in need and give them shelter for few days • People gather to clear landslides caused by intense rains in main public areas
Changes in snowfall (reduced overall)	• Some people have used concrete and roofing sheets on their terraces to avoid humidity from snow • Most people keep instruments in their houses such as spades to clear snow from their terraces and surrounding	• People gather to clear snow from the main roads to avoid road blockade • People gather and out soil on the roads to make them less slippery • If households are damaged from extreme snow, people help evacuate others and give them shelter
Changes in flashfloods (increased overall)	• People have planted in their land and surrounding to avoid erosion from flashfloods • Some people have made hard stone walls around their land especially that closer to river to avoid erosion from floods • Some people closer to flood prone areas have shifted their houses to safer places	• In a lot of public places, stone walls are constructed to divert/stop floodwater from reaching human settlements and agricultural land • People gather to clean major water channels so that floodwater can pass easily • People help evacuate those in danger from floods • Floodwater is stored in public water tanks for later uses

Changes in crop yield (reduced overall)	• Some people practice crop rotation • Most people use local fertilizers such as animal dung • People practice mixed cropping and intercropping • Plantation is not done randomly on the agricultural land because tree shadow reduced crop yield. Thus, people choose specific portions of land to plant trees • People have started relying on chemical fertilizers and pesticides • Some people have increased their cattle to gather more animal dung to use it as fertilizer	• People have installed tube wells in some places to extract water for agriculture • People share local fertilizers with others who do not rear animals • People gather to harvest crops for each other and store them for rest of the year
Changes in avalanches events (increased overall)	• One local farmer commented: *"In old ages, I remember our ancestors used to say that avalanches are caused by devil, so we should not try to suppress or deal with them. Therefore, we used to pray and throw little stones towards those places where avalanches would be predicted, and the avalanche would never reach human settings. With this belief in mind, we do not compete with avalanches."* • Some people have migrated to safer places due to fear of avalanches	• People gather to clear avalanche material from main public areas • Locals gather to help evacuate those who are affected by avalanche events
Changes in landslides (increased overall)	• Some people have made stone walls around their land to avoid landslides • People have planted more trees to avoid erosion and landslides One local made an interesting comment: *"We have planted more trees around our land especially that which is closer to the river to avoid landslide. Look the problem is, now we have to plant more trees to avoid landslide and erosion from frequent floods, but trees provide shadow and affect crop growth. So, this is one side effect of planting more trees."*	• If locals predict a devastating landslide, they gather to conduct mini blasts so that the land is brought down safely before it falls unpredictably • People actively inform high authorities to remove landslide material and road blockade as early as possible • People are always active and ready to evacuate those who are affected from landslides

Changes in GLOF events	• Some people have made separate water channels around their land for floodwater to pass easily without reaching mainland	• People have made stone and steel walls to divert floodwater towards the dead land • People are coordinating with UNDP for its GLOF projects and share their experiences and knowledge regarding GLOF events
Changes in water availability (reduced overall)	• Most people have made personal water tanks (zeing) to store glacier/spring water for future use • Glacier water has become unpredictable, so most people have started utilizing natural spring water because Ghanche is blessed with a lot of springs • Some people have fixed plastic pipes to bring spring water closer to their homes and lands • Some people closer to rivers pump river water with electric motors for their lands • Some people plough deeply so that they do not have to water their lands regularly once they water them • Some people share water from their personal water tanks with their neighbors	• Glacier grafting[1]: The most popular traditional strategy in which people grow/graft glaciers in places with less water availability • Locals have coordinated with NGOs such as AKRSP to graft more glaciers • Strict social norms: One local commented: *"In our community, our ancestors made some regulations to water our lands. We follow the same regulations. One of these regulations is to water our lands in our turn. Every household gets a turn, and everyone has to cooperate."* • People gather to collect spring water in the public water tanks • A complex network of water channels: One local commented: *"Our ancestors have made a very complex network of water channels and these channels reach every household. Through these channels, we use glacier water turn by turn and this strategy still works to manage whatever water we get from the glaciers."* ➢ Water sharing with neighbors

[1] "Glacier grafting is to "grow" the amount of ice at high altitudes during the winter months so that there will be increased water for crop irrigation from meltwater during the summer growing season. Typically, a dozen local men climb to shaded areas above the snow line in September and October with packs full of glacial ice (300kg) and pots of Indus River water (120kg), as well as other ingredients (saw dust, wheat husk, charcoal, and salt). These ingredients are placed in a cave or depression and then covered with soil" (AKDN 2021).

4.4. To differentiate between traditional and non-traditional adaptation strategies

Participants were asked further backup questions regarding whether the strategies adopted by individuals/families and community discussed in table 2 were based on traditional knowledge or non-traditional knowledge.

Strategies based on traditional knowledge are listed in figure 34. This sections thus fulfills RO3.

Traditional knowledge-based adaptation strategies to overcome the impacts of climate change-related events in Ghanche

1. Responses to changes in summer temperature
    - Tree plantation to avoid erosion from floods
    - Hut type portions made of dried wood and mud in households
    - Construction of public water tanks to collect water for swimming
    - Sitting in tree shadow
    - Construction of public water tanks to collect and store glacier/spring water for later uses
    - Water channels when filled with soil and mud are regularly maintained
2. Responses to changes in winter temperature
    - Separate portions in households made of mud and dried wood with small doors and windows to avoid cold
    - Use of traditional cookstoves and wood burning
    - Use of animal skin clothes and local food
    - Public water tanks constructed to collect hot spring water to swim in winters
    - People put soil on roads to make them less slippery during snow
    - Construction of public water tanks to collect spring water for daily use
3. Responses to changes in rainfall
    - Use of shinjaq (soil) on terraces to absorb rainwater
    - Use of plastic on terraces to avoid water leakage
    - Mini-water channels around households to stop rainwater from reaching mud walls
    - People gather to dig main water channels blocked and damaged by rainfall-caused flood
    - People gather to help evacuate those in need and give them shelter
4. Responses to changes in snowfall
    - Use of local equipment to clear snow
    - People gather to clear snow from terraces
    - People gather to clear snow from main public areas
    - People put soil to make roads less slippery
    - People always help evacuate those in need

5. Responses to changes in flash floods
- Tree plantation to avoid erosion caused by floods
- Hard structures such as stone walls to divert floodwater
- People gather to maintain main water channels destroyed by floodwater
- Stone walls around agricultural land to avoid flood-caused erosion
- Some people have gathered to make small dams to collect floodwater
- People gather to evacuate those affected from floods

6. Responses to changes in crop yield
- Crop rotation, mixed cropping and intercropping is practiced
- People harvest and store food in special storeroom for the entire year. These rooms are made in such a way that food should not be spoiled
- Trees are not grown randomly on agricultural land to avoid shadow because it affects crop growth
- Some people use local fertilizers such as animal dung and so rear many animals

7. Responses to changes in avalanche events
- People gather to help those affected from avalanches

8. Responses to changes in landslides
- Some people have made stone walls around their lands to avoid erosion
- Tree plantation to avoid erosion
- Once landslides are predicted, people in some areas arrange mini blasts to slide down the land safely
- People are always ready to rescues those affected from landslides
- People gather to clear landslide material from main public areas

9. Responses to changes in GLOF events
- People gather to dig the channels to release glacier water safely
- In some places, people have made walls of stone and steel to stop floodwater from reaching human settlements

10. Responses to changes in water availability
- People have constructed personal water tanks to store water
- People have shifted their focus to utilize natural spring water
- Water sharing among neighbors
- Glacier grafting
- Social norms for people to gather and maintain main water channels, store water in public tanks and use it turn by turn
- Public water tanks are constructed to store hot and cold spring water

Figure 34. List of traditional knowledge-based adaptation strategies to climate change-related events shared by the participants.

4.5. Limitations of vulnerability and adaptation in Ghnache today and gearing up for the future

Now comes the most interesting part which discusses RO4. To fulfill this objective, participants were asked if adaptation strategies based only upon traditional knowledge will be

enough to face climate change-induced risks in the future. Those who answered no/to some extent, they were asked backup questions on what else could be done to overcome CC impacts.

Traditional responses to changing summer temperatures

90% of the participants mentioned that traditional strategies alone cannot help facing increasing summer temperatures in the future and rest 10% were not sure. One local commented:

> *"Yes, they will work to some extent. For instance, they are enough for now but not for the future. For example, summer huts will not work if summer temperature increases further. We will have to install technology such as fans and air cooler."*

A farmer mentioned:

> *"Some traditional strategies will work such as tree plantation. Our elders did not know the science behind how they help avoid heat and reduce erosion, but they urged to plant trees. However, not every traditional strategy alone will be enough."*

Upon asking what else could be done, the following responses were received:

- Need modern technology and education to change mud infrastructure and use different materials such as concrete but also need to install air-cooling system
- Need to focus on afforestation and not deforestation
- Need technical and financial capacity to install flood infrastructure
- Need to enhance water storing capacity
- Technical assistance to dig and maintain major water channels

One local commented:

> *"Our ancestors were highly motivated to work for their survival and their priorities were different. Almost everything they did to face climate change related calamities, it required human power and hard work. These days, people prioritize jobs and education, they do not have time for this kind of work. How will traditional strategies be useful in future? Therefore, we need proper flood infrastructure and machinery to dig water channels. We need to change our houses from mud to cement/concrete to make them stronger to face floods or harsh rains."*

Traditional responses to changing winter temperatures

93% participants mentioned that traditional responses alone will not be enough to deal with changing and irregular winter temperature patterns in the future and rest of them were not sure. Upon asking what else could be done, the following responses were received:

- Need technical assistance to make household infrastructure suitable for all seasons. Need to install heating/insulation system in households
- Electricity management is poor which needs to be improved especially in winters
- Technical assistance to remove road blockades

One local commented:

> *"When there is a lot of snow, we go out to clean. We go out to clear blockades. Why can't we have machines doing that? A lot of people face leakage problems in mud houses during rains. Why can't we have an infrastructure scheme that helps people build strong houses? We need electricity to keep ourselves warm. We can't survive in mud houses in this time when rainfall has become intense and frequent."*

Traditional responses to changing rainfall patterns

29 out of 30 participants mentioned that traditional strategies alone will not be enough to face changing rainfall patterns in the future. The mentioned that they need external support and technical and financial capacity to enhance their resilience. Upon asking what else could be done, the following responses were received:

- Need to change mud infrastructure to concrete/cement
- Need to extend water channels and install flood infrastructure
- Digging and maintaining water channels is a big challenge and people need machines doing that
- Need detection systems to detect heavy floods

One participant mentioned:

> *"Social norms are important to keep people united as well as to give support in times of need. However, only social norms cannot help to overcome the impacts of intense rains. We need strong infrastructure to avoid water leakage. Our people are poor. They need financial support to build strong houses."*

Another local said:

> *"Traditional strategies take a lot of human effort but now, people are not willing or are not able enough to put a lot of effort to for instance dig water channels in the mountains on regular basis. Why do we have to put only human effort in every aspect? We need technology to do this. Our social norms have made us able to gather and dig channels to divert floodwater but why can't we have machines doing that? Why can't we get support to enhance our rain infrastructure?"*

One schoolteacher commented:

> *"Our future will be highly challenging as well as unpredictable and therefore, we need to think if traditional strategies will be useful for future and I think they alone cannot help until we do not get proper access to technology and infrastructure to avoid damage from floods but also, building strong houses to avoid water leakage."*

Traditional responses to changing snowfall patterns

43% of the participants were sure that traditional strategies alone cannot help cope with changing snowfall patterns but rest of them were not sure. The following alternative solutions were offered by the locals:

- Technical assistance to clear snow from the main public areas and link roads
- Household infrastructure to be changed and made suitable for all the seasons; making it stronger to avoid humidity, rains, summers, and winters

One local mentioned:

> *"Traditional strategies are developed in such a way that they require a lot of human effort. But in this era, when there are heavy machines around and engineering techniques around the globe, we do not have access to them. We need to make our infrastructure stronger; we need to protect our main roads from obstruction, we need our government and NGOs to invest in our place."*

Another said:

> *"You know that clearing snow with spades or putting soil is not a good solution. We face road obstruction on daily basis in winter. We need machines to clear that. We need to make our infrastructure stronger to avoid obstructions and landslides."*

Traditional responses to changing flashflood patterns

All the participants mentioned that traditional strategies alone will not be enough to face changing flashflood patterns in the future. It was mentioned that although people are highly dependent upon them now, future will be challenging and unpredictable and a life based only upon traditional strategies will not be resilient enough to cope with increasing flashflood impacts. One local mentioned:

> *"Although we are highly dependent upon some of these traditional strategies, but I think these alone cannot deal with CC related disasters in the future."*

The following alternative solutions were received from the participants:

- Damming floodwater for future use
- Installation of flood infrastructure and early warning systems
- Technical assistance to maintain main water channels
- Hard infrastructure to divert floodwater and reduce erosion
- Need to get equipped with facilities such as ambulances and first aid for emergency situations

The following were some interesting comments made by the locals:

> *"People are now not happy to put a lot of human effort in this regard. If this continues, who will clear water channels. Clearing channels is essential to get water from the glaciers and not to let it overflow otherwise floodwater will reach households. Thus, we need machinery to do this work. We also need to make water channels stronger. Most are not even made of cement or concrete."*

> *"Traditional strategies are useful for now, but I'm concerned about our future. For instance, stone walls are working for now, but floodwater will increase in future. Also, we gather to dig water channels in the harsh mountain and glacier environments but now, new generations do not prioritize this work so this strategy will fail in future. Thus, we need proper flood infrastructure to secure our future. We also need machines to dig water channels."*

> *"We cannot put so much human effort to clear water channels anymore. We need to focus on education and jobs. We need machines to do this work for us. We need support to make flood infrastructure. We need support to help people in flood prone areas to migrate to safer places."*

Traditional responses to changing crop yield patterns

70% of the participants mentioned that traditional responses to changing crop yield alone will not be enough in the future. Upon asking what else could be done, the following responses were received:

- Need scientific knowledge on the characteristics of soil this region has and the nutrients it requires
- Awareness and training programs for farmers on use of seeds and effective modern agricultural techniques
- Focusing on organic food production rather than relying only on the market products
- Should avoid use of chemical fertilizers for the sake of human health and environment and focus on producing local fertilizers

One local mentioned:

> *"I think chemical fertilizers and pesticides are not beneficial for crops and our environment because they are chemicals, so we need to come up with some different fertilizers, maybe local. In old ages, people used to use animal dung only but now, this is not enough maybe because we are pressurizing our land to grow more and more. We also need lab tests or scientific evidence on the type of our soil, the nutrients it needs and what exact crops can be grown."*

Traditional responses to changing avalanche patterns

There were not many traditional strategies discussed for avalanche events (figure 34) and that is why majority of the participants were not sure about this part. However, some alternative strategies came from some of them:

- Technical assistance to remove avalanche material and clear road blockade
- Early and efficient detection of major avalanches
- Efficient services in emergency situations

One local said:

> *"Avalanches cause road blockades, so we need machines to clear them. Link roads are the only way to connect us with other regions and their blockade is highly dangerous for us especially for medical emergency as well as import of food items."*

Traditional responses to changing landslide events

77% of the participants mentioned that traditional responses to changing landslide events will not be enough in the future. Some major alternatives suggested are:

- Technical support to clear landslide material
- Sensitive areas should be identified and hard structures such as stone and concrete walls should be built to avoid landslide
- Landslide areas need to be detected, and locals can be asked to involve in this matter
- Avoiding watering sensitive areas frequently
- Plantation drives to avoid erosion due to land sliding

Traditional responses to changing GLOF events

Most participants were not sure if traditional responses will help to overcome avalanche impacts in the future. However, some interesting alternatives were shared as follows:

- GLOF events need to be detected using modern early warning systems
- Installation of proper flood infrastructure to avoid damage
- Technical assistance to maintain and clean major water channels which get clogged by floodwater
- Those to be affected need to be identified and evacuated safely
- Land around the glacier flood passages need to be protected with stone walls to avoid erosion
- Those who lose their property need to be compensated

One local professor commented:

> *"For instance, hard walls that we learned to construct from our ancestors are working to stop floodwater for now, but I am concerned about our future. Floods will increase due to increase in temperature and these walls will not be enough anymore. So, we need proper flood infrastructure. We need detection systems to detect glacier lakes. We need to make channels to pass glacier water safely."*

Traditional responses to changing water availability

100% of the participants mentioned that traditional strategies alone will not help face changes (reduction) in water availability in future. To the question of what else could be done, the following interesting comments were shared:

- Spring water should be utilized as much as possible. Thus, people need external technical and financial support to make water infrastructure to bring spring water closer to their lands and residential areas
- Water storage capacity needs to be enhanced by damming water
- People need technical support to maintain and dig major water channels because if they are highly sedimented, they lose capacity to hold more water and water gets wasted
- Strict regulations against water misuse need to be implemented
- People should also focus on growing crops which require less water

One local female commented:

> *"Glacier grafting is the best example of combining both traditional knowledge and NGO work. But we need more external support to enhance our water storage capacity. Also, a lot of major natural springs are far from our households and lands, so we need to build a network of channels or pipes to bring this water closer and we should utilize spring water as much as we could and store glacier water."*

Another local farmer shared:

> *"What if we did not have natural springs? Glacier water availability has become highly unpredictable. Springs are natural, so what if they dry? We need to prepare ourselves for the future. We need to manage glacier water properly and should have strong infrastructure to store it for future uses."*

4.6. Role of traditional and local knowledge in overcoming vulnerability of mountain communities to climate change events based on the vulnerability framework

Traditional and local knowledge play an important role in enhancing resilience of mountain communities towards climate change risks. As this research explores as well as discussed by other authors including Leonard *et al*. (2013) and Granderson (2017), TLK plays a critical role in mediating traditional and local communities' understandings of environmental changes. However, TLK's retention in Ghanche is threatened by both climatic factors such as unpredictable climate change impacts in future and non-climatic factors such as out-migration, high reliance on western education and lifestyle and local norms not being practiced and given importance like before. Therefore, based on participant's responses, a framework (figure 35) has been formulated to understand the role of TK in enhancing

resilience to climate change in Ghanche but also, its applicability, usefulness, and survival possibilities in future.

In the schematic diagram, pink box shows the 'world' and green box shows a particular 'place' (Ghanche in this case). Moreover, dark blue arrows show an 'increase' or 'enhance' in something and light blue arrows and lines show an 'overcome' or 'reduction' of something.

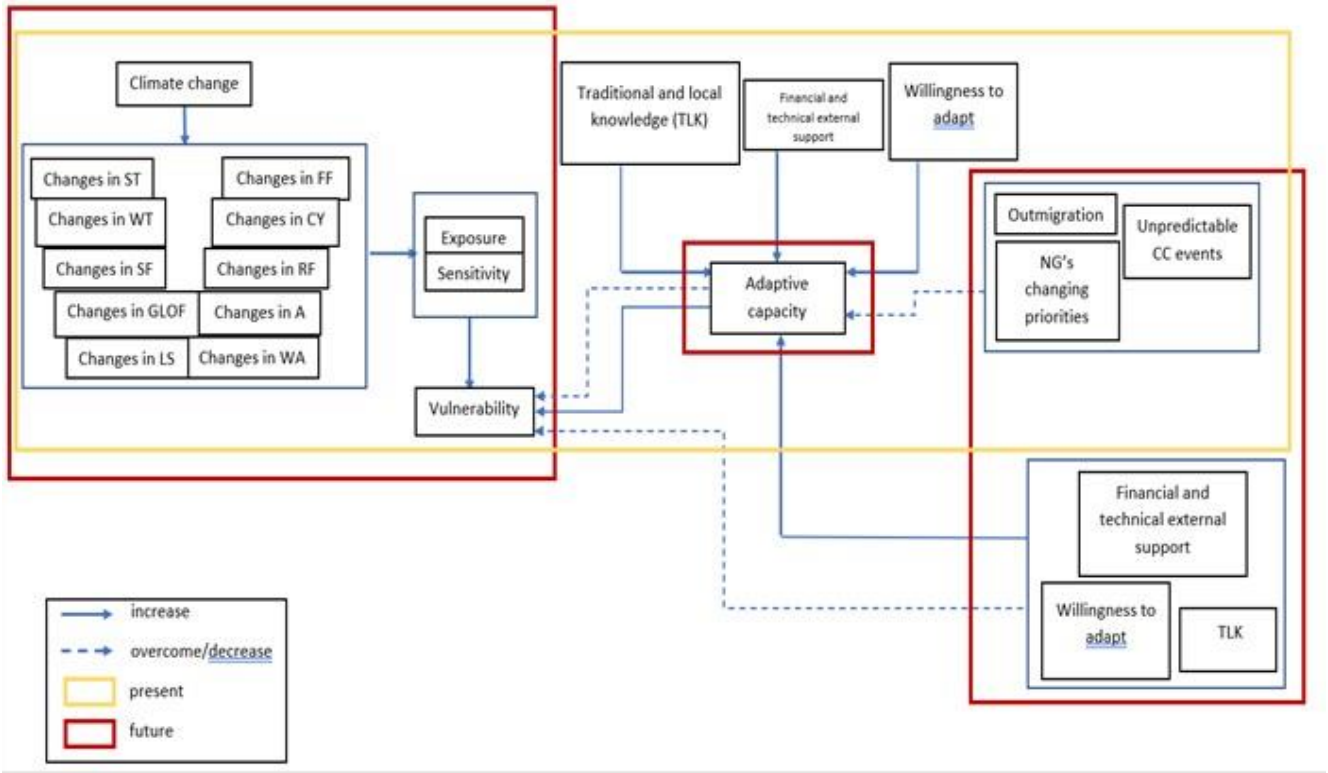


Figure 35. Schematic diagram/framework for the overall survey outcome based on participant's responses. ST: Summer Temperature, WT: Winter Temperature, FF: Flash Floods, CY: Crop Yield, SF: Snowfall, RF: Rainfall, A: Avalanche, LS: Landslide, WA: Water Availability, NGs: New Generations, CC: Climate Change, TLK: Traditional and Local Knowledge.

The dark blue lines show an 'increase', the dotted blue lines show a 'decrease' or an 'overcome'. Yellow box shows events happening in the present while red boxes show events that will happen in the future. Events in both boxes indicate their occurrence in both present and the future.

Starting from the top, climate change has induced changes in snowfall, rainfall, summer temperature, winter temperature, GLOFs, avalanche events, water availability, landslides, flashfloods, and crop yield in Ghanche. As exposure is the degree, duration and/or extent to which a system is subject to stress or perturbation (Adger 2006; Kasperson *et al.* 2005) and

sensitivity is the degree to which a system is affected (IPCC 2001), these CC-induced changes have thus increased the exposure and sensitivity of this system. Exposure and sensitivity greatly hold the concept of vulnerability in them; thus, increase in these two increases the overall vulnerability of the system. This vulnerability not only includes a system's exposure to the direct impacts of CC but also, to the indirect changes such as socio-economic alterations including loss of infrastructure, increasing conflicts over water rights, people's loss of personal property and psychological fear to the CC-induced disasters.

Coming towards the middle part of the framework, participants mentioned that they have enhanced their adaptive capacity over time due to three major factors: Traditional/local knowledge-based adaptation strategies, people highly willing to adapt to CC and some external support from the NGOs including AKRSP (Aga Khan Rural Support Program) and UNDP. This external support however is much smaller and recent compared to the other two factors; thus, it is written in a small box. The greater the adaptive capacity of a system is, the less sensitive and exposed it is to the stresses and perturbations thus reducing its overall vulnerability (Engle 2011) shown by the dotted blue line.

Participants however mentioned that starting from present to sometime in the future, events such as outmigration, people's changing priorities from focusing more on social norms and survival strategies to external jobs and education and unpredictable nature of CC have and will affect the resilience of the system (mostly that which has come from TK) thus reducing its adaptive capacity and making it more vulnerable. Therefore, traditional knowledge's survival, its applicability and usefulness in the future will reduce to a greater extent. Future is important and locals want a secure future. Thus, even if those traditional strategies which do not prove to be useful in the future vanish, getting greater external support including financial and technical support along with some of the useful traditional responses and local's and institution's willingness to adapt will once again make the system more resilient by overcoming the impacts of outmigration, people's changing priorities and unpredictable CC impacts. This will once again enhance system's adaptive capacity in future by making it less vulnerable.

Consideration of temporal aspect is crucial in this diagram. For instance, CC-induced changes are taking place in present and will take place in future as well. Therefore, these changes are assigned to both red and yellow boxes. Outmigration, CC's unpredictable impacts and new generation's changing priorities are also assigned to both boxes because these changes are

happening in present and will happen in future as well in Ghanche. Greater external support, greater willingness to adapt and less TLK in small box are assigned to the future box because these are the future scenarios locals need to overcome their overall vulnerability and secure their future. Moreover, need for adaptive capacity is in both present and past. Lastly, larger TLK, more willingness to adapt and smaller external support are assigned to the present box because these factors represent the current scenario of Ghanche.

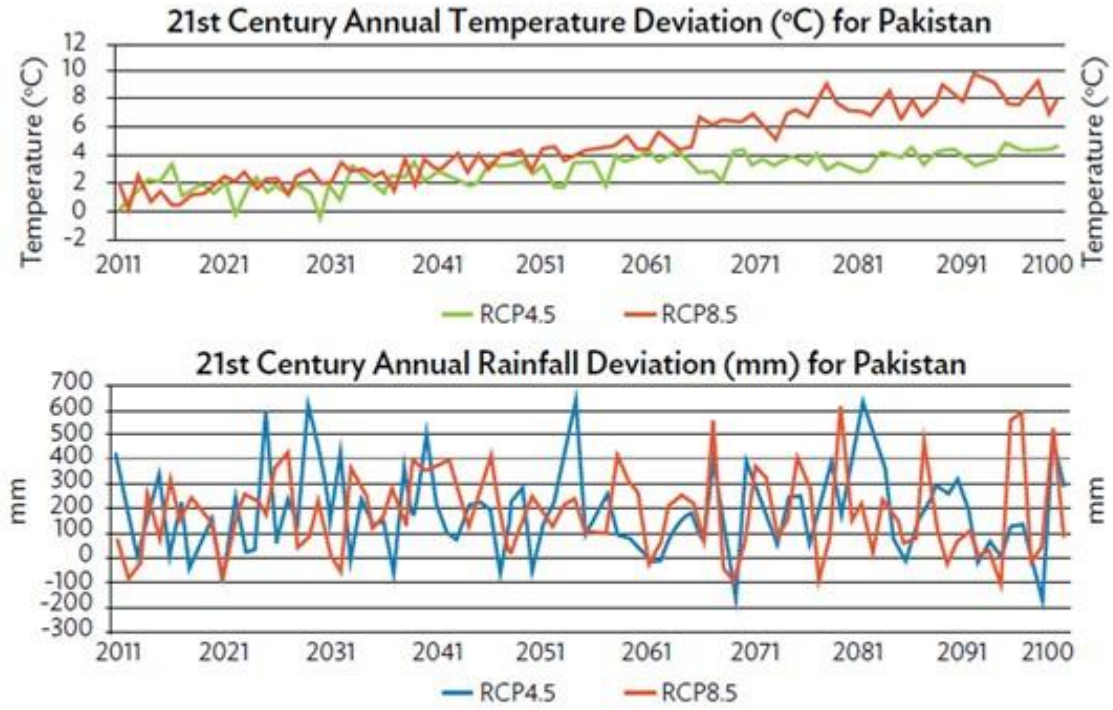
Based on the framework, traditional and local knowledge has highly contributed to enhance adaptive capacity of the region in present. However, CC has disrupted human relationships to their environment and its impacts will be unpredictable in future. Also, Ghance is experiencing large outmigration of people and new generations are focusing more on external jobs and education. Thus, TLK will not be transferred to new generations as much as it has till now, its high reliance on strong social norms and human hard work will fail to succeed in future but also, majority of TLK strategies will fail to face future CC. Thus, adaptation strategies based only upon TLK will not be useful and relevant to face future CC. It will require external financial and technical assistance to make Ghanche resilient towards future CC impacts.

5. Discussion

According to the climate change projections by the World Bank Group (2021), future projections for temperature and precipitation in Pakistan are higher than the global average. The global average temperature will increase by 3.7°C under Representative Concentration Pathway (RCP) 8.5 scenario from 2081-2100 while the model ensemble projects an average increase of 4.9C. Pakistan is in the same scenario. The projected rise in annual maximum temperature is estimated to be 5.24°C and that projected for the winter is higher than summer. Precipitation projections have a great uncertainty for simulating the South Asian monsoon and the dynamics of El Niño Southern Oscillation. However, research supports an increasing trend for annual precipitation (World Bank Group 2021).

Pakistan Meteorological Department (PMD) in 2015 published a time series for precipitation and temperature patterns from 2010 to 2090 under different climate change scenarios for Pakistan. These series show a 3°C-5°C rise in mean temperature under RCP4.5 and a rise of 4C-6C under RCP8.5 by the end of the century with a sharp increase after 2050. The series also showed highly irregular rainfall patterns with sharp inter-annual variability. However,

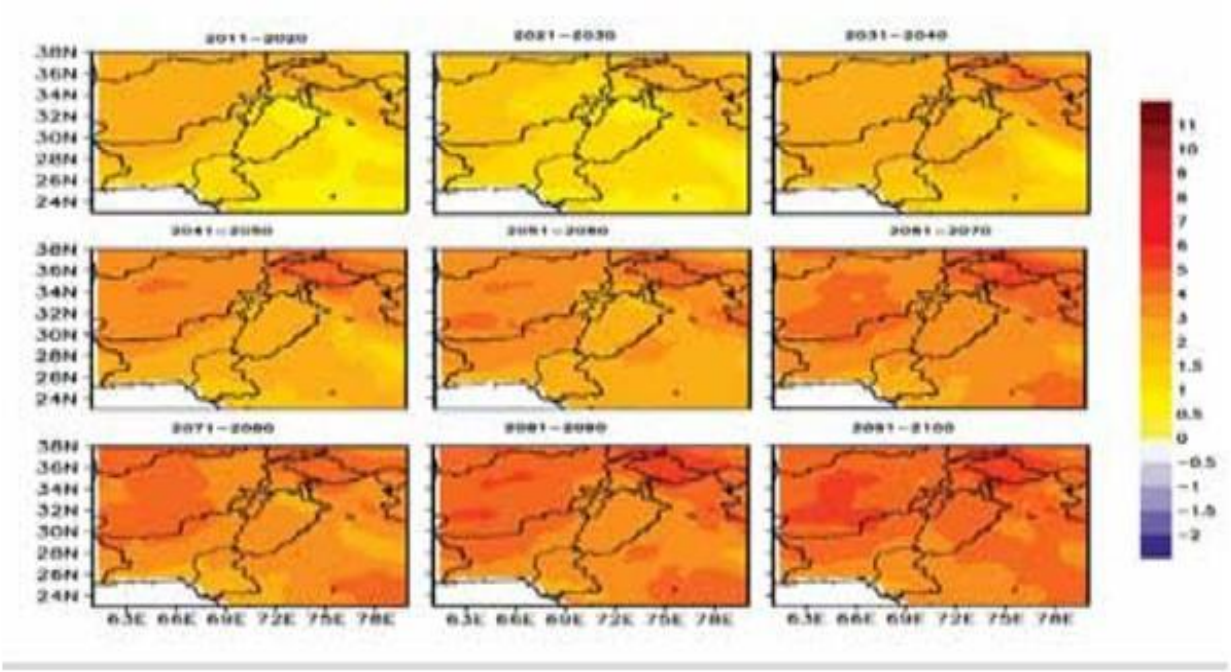
sharp rising peaks give an indication of extreme precipitation events with negative peaks indicating the possibility of droughts (figure 36) (Chaudhry 2017).



mm = millimeter, RCP4.5 and RCP8.5= Representative Concentration Pathways (RCPs) are emission IPCC AR5 scenarios. RCP4.5 is a stabilization scenario where greenhouse gas emissions stabilize by 2100. In RCP8.5 radiative forcing does not peak by year 2100.

Figure 36. Pakistan's mean annual temperature and precipitation deviation projection during the 21st century using RCPs 4.5 and 8.5 (Chaudhry 2017).

Snow cover will also be highly. Northern regions of Pakistan show a larger increase in the mean temperature compared to central and southern regions under RCP4.5 and 8.5 (figure 37) (Chaudhry 2017). This means that northern regions of Pakistan will lose significant snow cover, thus affecting agriculture, water availability and other socio-economic activities associated with water.



CMIP5 = Coupled Model Intercomparison Project Phase-5, RCP = Representative Concentration Pathways.

Notes: RCP4.5 is an emission IPCC AR5 scenario. RCP4.5 is a stabilization scenario where greenhouse gas emissions stabilize by 2100.

Figure 37. CMIP5 projections of annual temperature changes (°C) for 2011-2100 under RCP4.5, relative to 1975-2005 Aphrodite baseline (Chaudhry 2017).

5.1. Participant's responses and future climate change scenario in Pakistan

Participants' responses, confirm that Ghanche is already highly sensitive and exposed to the impacts of CC at present and its vulnerability will continue to be high in the future. Most participants agreed that climate change has induced changes in summer temperature, winter temperature, rainfall and snow fall patterns, avalanche and GLOF events, water availability, landslide patterns, flash floods and crop yields. These changes however are expected to increase in the future, thus potentially worsening socio-economic and environmental conditions in Ghanche. As some participants commented, this may require additional adaptation capacities and resources:

> *"Some traditional strategies are enough till now, but we should always consider our future which will be highly unpredictable and challenging. What if floods become more intense in future? What if rains become intense in future? Stone walls might not work permanently. We need external support, engineering ideas and machinery to make flood infrastructure."*

"Our future will be highly challenging as well as unpredictable and therefore, we need to think if traditional strategies will be useful for future, and I think they alone cannot help until we don't get proper access to technology and infrastructure to avoid damage from floods but also, building strong houses to avoid water leakage."

Interestingly, most participants had a clear sense that their future is highly vulnerable and unpredictable due to climate change. These observations and understandings match the observed and projected increase in precipitation and temperature (figure 28, 29; Chaudhry 2017) thus fulfilling the first research question: What changes are induced by climate change in Ghanche and whether some of these changes validate the scientific data. Some of the major climatic events mentioned by participants translate into impacts on agriculture, water availability and damage to personal and public infrastructure. Similar changes and challenges are mentioned in the 'Climate change profile of Pakistan' report by the Asian Development Bank (Chaudhry 2017). These findings fulfill the second research question: What impacts are induced by climate change in Ghanche.

Climate change trends and impacts mentioned by the participants in Ghanche are observed also in other northern regions around the globe. For instance, some regions in Northern Canada are experiencing warmer winters and springs compared to past with winters warming at higher latitudes (Ogden and Johnson 2002). Precipitation trends are shown to be variable similar to those in Ghanche but are shown to increase in winter, especially in high latitudes. Water, agriculture, infrastructure, and traditional lifestyles are among the most affected sectors (Ogden and Johnson 2002). Unfortunately, indigenous communities in Northern Canada are considered highly vulnerable to CC impacts despite having strong experiences of facing historic climate change events and traditional approaches to CC. The vulnerability of indigenous communities is determined by this relationship which is disrupted due to CC thus making them highly vulnerable. Locals in these communities, however, are in the best position to understand and assess their vulnerability to CC and adopt suitable adaptation practices based on their longstanding experiences with living off the lands (Ogden and Johnson 2002). This scenario also clearly applies to Ghanche.

Nepal is another important example of high vulnerability to climate change. Temperature and precipitation patterns are changing faster than the global average thus triggering snow and ice melt and frequent torrential rainfall events. Lower agricultural production, food insecurity, loss of forests, impacts on infrastructure and waterbodies are some of the CC-induced

impacts in Nepal (Climatelinks 2017). Similar observations were shared by the locals in Ghanche:

> *"Unpredictable and irregular rainfall has affected grass growth in the meadows. Sometimes, there is no water at all for their growth and in other times, they are flooded which is not a good condition for their growth."*

> *"Glacier water is largely dependent upon snow accumulation, and reduction in snowfall intensity and frequency has reduced water availability from the glaciers. Also, whatever less snow we get, it melts sooner due to increase in summer temperature. According to my observations, I feel like the quantity of grass in the mountain meadows (where we do our cattle rearing) has also reduced."*

Under fsuture climate change scenarios, life in Northern would be extremely challenging. These already present and projected changes are validated by the experiences and observations shared by locals. Humans' relationship to their environment is changing and their vulnerability is enhanced. Whether traditional and local strategies are useful and adequate in this will be discussed in next sections.

5.2. Assessing vulnerability of Ghanche

Vulnerability assessments evaluate a system's susceptibility to any known vulnerabilities, their severity levels and recommends mitigation measures to overcome their threats. It intends to identify these threats and the risks posed by them (Rosencrance 2020).

Ghanche is currently facing both socio-economic and environmental transformations. As mentioned by participants, people in the region are getting more access to external jobs and education which is making them economically more resilient. This however has caused outmigration on a large scale and external opportunities (globalization) have equipped people with modern facilities. At the same time, people are no longer able to focus on maintaining strong social norms and institutions. They are not willing to spend time on local adaptation strategies, such as digging water channels on a regular basis, volunteering building water tanks and channel networks to get water.

> *"Traditional strategies take a lot of human effort but now, people are not willing or are not able enough to out a lot of effort to for instance dig water channels in the mountains on regular basis. Why do we have to put only human effort in every aspect? We need technology to do this. Our social norms have made us able to gather and dig channels to divert*

floodwater but, why can't we have machines doing that? why can't we get support to enhance our rain infrastructure?"

Thanks to the existing traditional and local strategies as well as greater willingness of elder generations to adapt, and small scale external technical and financial support from NGOs such as AKRSP and UNDP, Ghanche still maintains high adaptive capacity (adaptive strategies listed in table 1 and 2) to face climate change impacts. These findings fulfill research question 3: What are the adaptation strategies of the locals to face climate change risks and whether these strategies are based on traditional and local knowledge. However, there are clear indications that many local and traditional strategies will prove to be irrelevant, insufficient, and ineffective in the face of future climate change, thus making the region more vulnerable. For instance, mud houses will not be able to withstand irregular rainfall events and precipitation extremes, water channel maintenance by people could fail if few people will be carrying the work, and stone and steel walls against floods will hardly help divert extreme and irregular floods. These observations and experiences shared by the participants answer research question 4: Whether strategies based only upon TLK will serve enough purpose to face CC impacts in the future.

"Our social norms related to traditional and local strategies are very important and useful. but they alone are not enough. Our future is very different and hard."

"Till now, social norms are followed and well implemented, but look, future will be different from ours. People are now focusing on their jobs and education. Who will gather and spend a lot of time on digging and clearing water channels high in the mountains? So, we need a proper and a permanent system for this. We need proper infrastructure and machinery because now we are putting human effort in almost everything. future will not be like that."

"Social norms are important to keep people united as well as to give support in times of need. However, only social norms cannot help overcoming the impacts of intense rains. We need strong infrastructure to avoid water leakage. Our people are poor. They need financial support to build strong houses."

Can Ghanche rely only upon TLK alone to overcome future CC impacts?

Based on the results obtained, if Ghanche keeps relying on TLK only and does not get external support from NGOs and from the Government of Pakistan, it will not be able to scale up its adaptive capacity to face future CC risks. Ghanche needs financial and technical assistance to enhance its flood infrastructure, maintain and clear major water channels, install

early warning systems to detect GLOFs and other major flood events, and build hard infrastructure to avoid landslides. The best scenario for Ghanche to enhance CC resilience as suggested by the locals is the combination of external support and TLK-based adaptation strategies.

One of the examples of this combination that frequently came from the respondents was glacier grafting.

> ***"****Glacier grafting. Our elders have grafted glaciers in places where there was not enough water especially for agriculture. Now, NGO's such as AKRSP are involving people to graft glaciers and get water."*
>
> *"Although glacier grafting is learned from our ancestors, but NGOs have helped to practice and implement it on a larger scale. NGOs have provided technical and financial assistance to help people take chunks of ice to graft glaciers, so both traditional and external support is needed to face CC."*

Glacier grafting is a technique which is used to grow ice patches in high altitudes of Gilgit-Baltistan and some regions in India. It is a conventional method of breeding male and female glaciers, and it has been practiced for centuries. Male and female glaciers are differentiated by the locals based on the color of ice/glacier, ability to provide water and surging activity. For instance, a female glacier is white or bluish, whereas a male glacier is blackish, covered with soil and rocks. Locals believe that a female glacier has high ability to provide water and move slowly, so should be added to the male glacier to grow. Around 100 hectares of the total area is required to graft a glacier. Glacier grafting has played a crucial role in improving the way people use freshwater but also to solve water conflicts. AKRSP has utilized this traditional knowledge and motivated locals to graft more glaciers to overcome unpredictable changes in water availability caused by climate change (Munir *et al*. 2021).

Traditional and local strategies such as glacier grafting can be highly successful if they receive external assistance from government or NGOs for their proper and regular implementation. However, external support should avoid making local communities fully dependent. It should not be in conflict with local and traditional norms and making them highly reliant on foreign aid. Foreign dependency should not aim for a temporary growth and development but sustainable development (Stanford 2015; Encyclopedia Britannica 2021). Locals should have jobs and opportunities to be independent as mentioned by an interviewee:

"Outmigration for jobs can be reduced if locals are hired to get involved in CC-related projects and schemes. This will make locals invest their educational experiences and talent in their own region."

"To create a good balance, new generation's changing priorities from local social norms to external jobs and education should be equilibrized by providing them jobs and other opportunities of earning."

Thus, traditional, and local knowledge alone cannot make Ghanche resilient towards climate change events in the future. It requires external financial and technical support in such a way that relevant and useful TLK-based strategies are combined to develop and implement CC-related policies. This combination should also provide jobs and other earning opportunities to secure local's future by making it sustainable for the present as well as future generations.

6. Conclusion

In conclusion, this study aimed at investigating and improving the understand of the role traditional and local knowledge play in enhancing climate change resilience and adaptive capacity in mountain communities in Northern Pakistan, thus making them less vulnerable. Thed Ghanche district was chosen as the study area to conduct this research. Ghanche's unique location of sharing borders with China and India, lack of previous research and data on climate change adaptation, presence and practice of traditional and local knowledge and growing events of climate change motivated the choice of the study area.

Due to time and resource constraints, 30 research subjects in total were recruited from different locations of Ghanche. The survey questions aimed at exploring climate change-induced impacts in Ghanche including changes in summer and winter temperatures, rainfall and snowfall, landslides, and avalanche events, GLOFs, crop yield, flashfloods, and water availability. These changes were validated through meteorological data obtained from the Earth Engine Data Catalog. Participants were also asked questions regarding impacts of changes in the above-mentioned parameters and adaptation strategies adopted by individuals/families and communities to overcome these shocks. Strategies based on TLK were listed separately based on responses and a vulnerability framework was designed by the author to analyze whether TLK-based strategies are enough for the locals of Ghanche to face future CC shocks and if not, what other alternatives can be applied.

Results indicated that most participants agreed with the following changes in the parameters: increase in summer and winter temperature, rainfall, and extreme precipitation events, GLOFs, flashfloods and avalanche events and a decrease in crop yield, water availability and snowfall. Changes in seasonal temperature patterns (summer and winter) and annual precipitation trends matched the general observations of participants. Some of the major impacts induced by changes in climate parameters in Ghanche included frequent and intense floods, damage to personal and public property, landslides, reduced water availability and impacts on agriculture, frequent road obstruction, damage to trees and cattle, low quality and quantity of meadow grass and influence on daily transportation and communication (full list in table 1). Strategies adopted to overcome the above-mentioned CC-induced impacts were mostly based on TLk and some of them on external knowledge such as from NGOs (list available in table 2).

TLk and willingness to adapt has played an extremely important role till now in Ghanche in overcoming CC impacts However, participants commented that most TLk-based strategies require human power, unity, and effort to succeed. Due to increasing outmigration for jobs, education and other facilities, new generations' changing priorities and unpredictable nature of CC events, strategies based only upon TLk cannot be sufficient to overcome future CC impacts. Thus, greater financial and technical external support, greater willingness to adapt and relevant TLk-based strategies can be the best combination to face future CC impacts. This means that mountain communities such as Ghanche require a combination of both traditional and local and external/scientific knowledge-based strategies to combat the impacts of future climate change in a more resilient manner.

This research holds a great potential to comprehend and overcome future climate change impacts in the mountain communities such as Ghanche. However, research projects with greater financial and technical support need to be implemented in such mountain communities with complex and important knowledge systems, community structures as well as complex climate systems, so that more data is recorded to understand climate change impacts on a deeper level. This research can be used as a baseline work in this regard.

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Appendix A – Research consent and questionnaire

Consent for Participation in Research Interview

Thesis title: Adaptive capacity in a transforming world: A case study of resilience to climate change via traditional knowledge in a northern region of Pakistan

Sponsored by: Erasmus Mundus Joint Master's Degree Program Scholarship

Program name: Master's in environmental science, Policy and Management (MESPOM)

Host institution: Central European University, Budapest, Hungary

I agree to participate in the research interview for the project 'Adaptive capacity in a transforming world: A case study of resilience to climate change via traditional knowledge in a northern region of Pakistan' conducted by Noreen Akhtar who is a current Erasmus Mundus Joint Master's Degree Program scholar funded by the European Union.

I accept the following terms and conditions of my participation for this research:

1. I have been given enough information about this research project. Also, the purpose of my participation as an interviewee has been clearly explained to me.
2. My participation in this interview is voluntary.
3. The interview will last around an hour. I allow the researcher to take notes and record the audio during interview. It is clearly mentioned to me that if I do not want to record any of my responses at any point, I can withdraw my participation.
4. No photos or videos will be made and shared on social media without my prior permission at any point during the interview.
5. I have the right not to answer any of the questions.
6. If I feel uncomfortable in any way during the interview, I have freedom to withdraw from my participation.
7. I am guaranteed that my privacy will be respected, and information obtained from this interview will be kept confidential.

Participant's signature: _____ Date: _____

Researcher's signature: _____ Date: _____

QUESTIONNAIRE

SECTION 1

1. Participant's name (optional)

2. What is your gender?
   a. Male
   b. Female

3. What is your age?
   a. 30 – 50
   b. Above 50 years

4. What is the highest level of education you have attained?
   a. No school
   b. Pre-school (for age of 3 to 5 years)
   c. Primary school (grade 1 to 5)
   d. Middle school (grade 6 to 8)
   e. High school (grade 9 and 10 leading to SSC)
   f. Intermediate (grade 11 and 12 leading to HSSC)
   g. University

5. What is your occupation?

6. What are the major sources of livelihood in your household?

SECTION 2 (climate change-related drivers)

Temperature

7. Over past 25 years, have you observed any noticeable changes in the mean summer temperature of Ghanche?
   a. Increased

b. Decreased

c. No change

d. Don’t know

8. Over past 25 years, have you observed any noticeable changes in the summer temperature extremes (min/max)? Please describe.

   a. Yes

   b. No

   c. Don’t know

_____

_____

9. Over past 25 years, have you observed any noticeable changes in the spatial distribution of summer temperature patterns? Please describe.

   a. Yes

   b. No

   c. Don’t know

_____

_____

10. Over past 25 years, have you observed any noticeable changes in the seasonality? Please describe.

    a. Yes

    b. No

    c. Don’t know

_____

_____

11. What impacts and challenges do you think these changes in the summer temperature and seasonality have caused?

_____

_____

_____

12. Over past 25 years, have you observed any noticeable changes in the mean winter temperature of Ghanche?
    a. Increased
    b. Decreased
    c. No change
    d. Don't know
13. Over past 25 years, have you observed any noticeable changes in the winter temperature extremes (min/max)? Please describe.
    a. Yes
    b. No
    c. Don't know

14. Over past 25 years, have you observed any noticeable changes in the spatial distribution of winter temperature patterns? Please describe.
    a. Yes
    b. No
    c. Don't know

15. What impacts and challenges do you think these changes in the winter temperature have caused?

Rainfall

16. Over past 25 years, have you observed any noticeable changes in the seasonal patterns, intensity, frequency, and place of occurrence of rainfall in Ghanche?
    a. Yes
    b. No
    c. Don't know

17. If yes, then describe the changes you observed.

18. Over past 25 years, have you observed any noticeable changes in the precipitation extremes (min/max)? Please describe.
    a. Yes
    b. No
    c. Don't know

19. Over past 25 years, have you observed any noticeable changes in the spatial distribution of precipitation patterns? Please describe.
    a. Yes
    b. No
    c. Don't know

20. What impacts and challenges do you think these changes in the rainfall patterns have caused?

Snowfall

21. Over past 25 years, have you observed any noticeable changes in the seasonal patterns, intensity, frequency, and place of occurrence of snowfall in Ghanche?
    a. Yes
    b. No
    c. Don't know

22. If yes, then describe the changes you observed.

23. Over past 25 years, have you observed any noticeable changes in the spatial distribution of snowfall? Please describe.

24. What impacts and challenges do you think these changes in the snowfall patterns have caused?

SECTION 3 (potential climate-related impacts)

Flash Floods

25. Over past 25 years, have you observed any noticeable changes in the frequency, intensity, and place of occurrence of flash floods in Ghanche?
    a. Yes
    b. No
    c. Don't know

26. If yes, then describe the changes you have observed.

_____

_____

_____

_____

27. Did these changes happen in the past?
    a. Yes
    b. No
    c. Don't know

28. What impacts and challenges do you think these changes in flash flood patterns have caused to human life, health, security etc.?

_____

_____

_____

_____

_____

Crop yield

29. Over past 25 years, have you observed any noticeable changes in the quality and quantity of crops as well as the types of crops you grow?
    a. Yes

b. No

c. Don’t know

30. If yes, then describe the changes you have observed.

_____

_____

_____

_____

31. Did these changes happen in the past?

a. Yes

b. No

c. Don’t know

32. What impacts and challenges do you think these changes in the crop quantity, quality or crop type have caused?

_____

_____

_____

_____

_____

Avalanche

33. Over past 25 years, have you observed any noticeable changes in the frequency, intensity, and place of occurrence of avalanche?

a. Yes

b. No

c. Don’t know

34. If yes, then describe the changes you have observed.

_____

_____

35. Did these changes happen in the past?

    a. Yes
    b. No
    c. Don’t know

36. What impacts and challenges do you think these changes in the avalanche intensity, frequency and place of occurrence have caused?

Landslide

37. Over past 25 years, have you observed any noticeable changes in the intensity, frequency, and place of occurrence of landslide?

    a. Yes
    b. No
    c. Don’t know

38. If yes, then describe the changes you have observed.

39. Did these changes happen in the past?

    a. Yes
    b. No

c. Don’t know

40. What impacts and challenges do you think these changes in the intensity, frequency, and place of occurrence of landslide have caused?

GLOF events

41. Over past 25 years, have you observed any noticeable changes in the frequency, intensity, and place of occurrence of GLOF events?

    a. Yes

    b. No

    c. Don’t know

42. If yes, then describe the changes you have observed.

43. Did these changes happen in the past?

    a. Yes

    b. No

    c. Don’t know

44. What impacts and challenges do you think these changes in the frequency, intensity, and place of occurrence of GLOF events have caused?

Availability of water (drought)

45. Over past 25 years, have you observed any noticeable changes in the frequency, intensity, and place of occurrence of drought (reduction in the water availability) for agriculture or household purposes?

    a. Yes

    b. No

    c. Don't know

46. If yes, then describe the changes you have observed.

47. Did these changes happen in the past?

    a. Yes

    b. No

    c. Don't know

48. What impacts and challenges do you think these changes in the frequency, intensity, or place of occurrence of drought have caused?

SECTION 4 (Responses to the potential climate change-related impacts)

Temperature

49. What strategies have you (as an/a individual/family) adopted to overcome the impacts of changing summer temperatures?

50. How and from where did these strategies emerge? In other words, where did these strategies come from?

51. What strategies have you (as a community) adopted to overcome the impacts of changing summer temperatures?

52. How and from where did these adaptation strategies emerge? In other words, where did these strategies come from?

53. Was anything you learnt from your ancestors (traditional strategies) useful to respond to these changing summer temperatures? Why or why not?

54. If yes, do you think your response to changing summer temperatures based only on the traditional knowledge from your ancestors will be enough? Why or why not?

55. If not, what else could be done to facilitate a more effective response to these changing summer temperatures?

56. What strategies have you (as an/a individual/family) adopted to overcome the impacts of changing winter temperatures?

57. How and from where did these strategies emerge? In other words, where did these strategies come from?

58. What strategies have you (as a community) adopted to overcome the impacts of changing winter temperatures?

59. How and from where did these strategies emerge? In other words, where did these strategies come from?

60. Was anything you learnt from your ancestors (traditional strategies) useful to respond to these changing winter temperatures? Why or why not?

61. If yes, do you think your response to these changing winter temperatures based only on the traditional knowledge from your ancestors will be enough? Why or why not?

62. If not, what else could be done to facilitate a more effective response to these changing winter temperatures?

Rainfall

63. What strategies have you (as an/a individual/family) adopted to overcome the impacts of changing patterns, intensity, frequency, and place of occurrence of rainfall?

64. How and from where did these strategies emerge? In other words, where did these strategies come from?

65. What strategies have you (as a community) adopted to overcome the impacts of changing patterns, intensity, frequency, and place of occurrence of rainfall?

66. How and from where did these strategies emerge? In other words, where did these strategies come from?

67. Was anything you learnt from your ancestors (traditional strategies) useful to respond to these changing rainfall patterns? Why or why not?

68. If yes, do you think your response to these changing rainfall patterns based only on the traditional knowledge from your ancestors will be enough? Why or why not?

69. If not, what else could be done to facilitate a more effective response to these changing rainfall patterns?

Snowfall

70. What strategies have you (as an/a individual/family) adopted to overcome the impacts of changing snowfall patterns, their frequency, intensity, and place of occurrence?

71. How and from where did these strategies emerge? In other words, where did these strategies come from?

72. What strategies have you (as a community) adopted to overcome the impacts of these changing snowfall patterns, their frequency, intensity, and place of occurrence?

73. How and from where did these strategies emerge? In other words, where did these strategies come from?

74. Was anything you learnt from your ancestors (traditional strategies) useful to respond to these changing snowfall patterns? Why or why not?

75. If yes, do you think your response based only on the traditional knowledge from your ancestors will be enough cope with these changing snowfall patterns? Why or why not?

76. If not, what else could be done to facilitate a more effective response to these changing snowfall patterns?

Flash Floods

77. What strategies have you (as an/a individual/family) adopted to overcome the impacts of changing flash flood frequency, intensity, or place of occurrence?

78. How and from where did these strategies emerge? In other words, where did these strategies come from?

79. What strategies have you (as a community) adopted to overcome the impacts of changing frequency, intensity, and place of occurrence of flash floods?

80. How and from where did these strategies emerge? In other words, where did these strategies come from?

81. Was anything you learnt from your ancestors (traditional strategies) useful to respond to these changes in the flash flood patterns? Why or why not?

82. If yes, do you think your response to these changes in the flash flood patterns based only on the traditional knowledge from your ancestors will be enough? Why or why not?

83. If not, what else could be done to facilitate a more effective response to these changes in the flash flood patterns?

Crop yield

84. What strategies have you (as an/a individual/family) adopted to overcome the impacts of change in the quality, quantity, and types of crops you grow?

85. How and from where did these strategies emerge? In other words, where did these strategies come from?

86. What strategies have you (as a community) adopted to overcome the impacts of change in the quality, quantity, or types of crops your grow?

87. How and from where did these strategies emerge? In other words, where did these strategies come from?

88. Was anything you learnt from your ancestors (traditional strategies) useful to respond to these changing crop yield and crop types? Why or why not?

89. If yes, do you think your response to these changes in the crop yield and type based only on the traditional knowledge from your ancestors will be enough? Why or why not?

90. If not, what else could be done to facilitate a more effective response to these changes in the crop yield and type?

Avalanche

91. What strategies have you (as an/a individual/family) adopted to overcome the impacts of changing frequency, intensity, and place of occurrence of avalanche?

92. How and from where did these strategies emerge? In other words, where did these strategies come from?

93. What strategies have you (as a community) adopted to overcome the impacts of these changes in the avalanche frequency, intensity, or place of occurrence?

94. How and from where did these strategies emerge? In other words, where did these strategies come from?

95. Was anything you learnt from your ancestors (traditional strategies) useful to respond to these changes in the avalanche intensity, frequency, or place of occurrence? Why or why not?

96. If yes, do you think your response to these changes in the avalanche patterns or intensity based only on the traditional knowledge from your ancestors will be enough? Why or why not?

97. If not, what else could be done to facilitate a more effective response to these changes in the patterns or intensity of avalanche?

Landslide

98. What strategies have you (as an/a individual/family) adopted to overcome the impacts of change in the frequency, intensity, and place of occurrence of landslide?

99. How and from where did these strategies emerge? In other words, where did these strategies come from?

100. What strategies have you (as a community) adopted to overcome the impacts of these changes in the landslide patterns?

101. How and from where did these strategies emerge? In other words, where did these strategies come from?

102. Was anything you learnt from your ancestors (traditional strategies) useful to respond to these changes in the landslide patterns? Why or why not?

103. If yes, do you think your response to these changes in the landslide patterns based only on the traditional knowledge from your ancestors will be enough? Why or why not?

104. If not, what else could be done to facilitate a more effective response to these changes in the landslide patterns?

GLOF events

105. What strategies have you (as an/a individual/family) adopted to overcome the impacts of change in intensity, frequency, and place of occurrence of GLOF events?

106. How and from where did these strategies emerge? In other words, where did these strategies come from?

107. What strategies have you (as a community) adopted to overcome the impacts of these changes in the GLOF event patterns?

108. How and from where did these strategies emerge? In other words, where did these strategies come from?

109. Was anything you learnt from your ancestors (traditional strategies) useful to respond to these changing GLOF patterns? Why or why not?

110. If yes, do you think your response to these changing GLOF patterns based only on the traditional knowledge form your ancestors will be enough? Why or why not?

111. If not, what else could be done to facilitate a more effective response to these changes in the GLOF patterns?

Water availability (drought)

112. What strategies have you (as an/a individual/family) adopted to overcome the impacts of changes in the frequency, intensity, and place of occurrence of drought?

113. How and from where did these strategies emerge? In other words, where did these strategies come from?

114. What strategies have you (as a community) adopted to overcome the impacts of these changing drought patterns?

115. How and from where did these strategies emerge? In other words, where did these strategies come from?

116. Was anything you learnt from your ancestors (traditional strategies) useful to respond to these changing drought patterns? Why or why not?

117. If yes, do you think your response to these changing drought patterns based only on the traditional knowledge from your ancestors will be enough? Why or why not?

118. If not, what else could be done to facilitate a more effective response to these changing drought patterns?

SECTION 5 (Traditional knowledge-based adaptation strategies)

If participants mention that their response to climate change-related impacts are also based on the traditional adaptation strategies passed from their ancestors

119. In your opinion, do you think these strategies from your elders are important and should be recorded and transferred to the new generations? Why?

120. Keeping in mind the out-migration and changing interests of people (globalization) in Ghanche, do you think these strategies which are passed to you from your elders will survive in future? Why or why not?

121. In your opinion, what should be done to keep the knowledge passed from your elders alive and transfer it to your new generations?

122. Is there any external support from the government of Pakistan/NGOs/foreign support to help you cope with the changing environment (such as changing temperatures, water availability, floods etc.)?

123. (If participant answers yes) what is the relationship between non-traditional external support and traditional adaptation strategies? In other words, are they supporting or conflicting each other? Why?

124. (If participant answers no) can you cope with the potential impacts of changes in the climate-related drivers (temperature, snowfall, rainfall) better in future if you get external technical or financial support from the government of Pakistan or any NGO? Why?

125. If you get external support, can it be combined with the traditional techniques passed from your elders to adapt to the changing environment (change in temperature, drought, floods etc.)?

Notes: