MOUNTAIN DEVELOPMENT AND CLIMATE CHANGE IN NEPAL : A CASE STUDY OF THINI (GHARPAJHONG RURAL MUNICIPALITY)

A Thesis

Submitted to APF Command and Staff College,

Faculty of Humanities and Social Sciences, Tribhuvan University,

in Partial Fulfillment of the Requirements

for Master Degree in Security, Development and Peace Studies

Submitted by

SHANKAR KHANAL

Seventh Batch (2078-2080)

Roll No.: 28MSDPS40007

TU Regd. No.: 35006-94

APF Command and Staff College

Sanogaucharan, Kathmandu, Nepal

July, 2023

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DECLARATION

I hereby declare that this thesis entitled **"MOUNTAIN DEVELOPMENT AND CLIMATE CHANGE IN NEPAL: A CASE STUDY OF THINI (GHARPAJHONG RURAL MUNICIPALITY)"** submitted to APF Command and Staff College, is entirely my original work.

I have made due acknowledgments to all ideas and information cited and extracted from different sources in the course of preparing this research. The result of this research paper has not been presented or submitted anywhere else for the award of any degree or any other purpose. I assure you that no part of the content of this research paper has been published in any form before. I shall be solely responsible if any evidence is found against my research paper.

This thesis is being submitted to APF Command and Staff College, Faculty of Humanities and Social Sciences, Tribhuvan University in partial fulfillment of Master Degree in Security, Development and Peace Studies.

Signature:

Name: Shankar Khanal

Date: July 2023

LETTER OF RECOMMENDATION

I certify that this thesis entitled **"MOUNTAIN DEVELOPMENT AND CLIMATE CHANGE IN NEPAL: A CASE STUDY OF THINI (GHARPAJHONG RURAL MUNICIPALITY)"** was prepared by Mr. Shankar Khanal under my supervision. The researcher has fulfilled the criteria prescribed by Faculty of Humanities and social Sciences, Tribhuvan University. I hereby recommend the thesis for the final evaluation and approval.

……

Thesis Supervisor

Prof. Dr. Ramesh Raj Kunwar

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LETTER OF APPROVAL

This thesis entitles **"MOUNTAIN DEVELOPMENT AND CLIMATE CHANGE IN NEPAL: A CASE STUDY OF THINI (GHARPAJHONG RURAL MUNICIPALITY)"** submitted by Mr. Shankar Khanal to APF Command and Staff College, Faculty of Humanities and Social Sciences, Tribhuvan University in Partial Fulfillment of Master Degree in Security, Development and Peace Studies has been approved by the undersigned members of the Evaluation Committee.

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ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest gratitude to my research supervisor Prof. Dr. Ramesh Raj Kunwar for his relentless guidance, encouragement, and useful critiques in completion of this research. Similarly, I would also extend my sincere gratitude to my co-supervisor DSP Lava Kumar Sapkota for his guidance. Further, I would also like to express my sincere gratitude to Dr. Naresh Rimal for his valuable suggestions, guidance, and support during the research process.

I am grateful to the academic coordinator and directing staff of APF Command and Staff College for their support for the study and research work. I am indebted to all Faculty members, Senior and Junior officers, other ranks, library management and administration team of APF Command and Staff College for their assistance and providing a conducive environment for the study.

I extend my sincere thanks and respect to all the respondent and Key Informants who have rendered me their precious time in providing proper feedback. My sincere thanks also go to the members of different government and non-government organizations who provided me with valuable input through KII.

I would like to thank Mr. Mohan Singh Lalchan and Ms. Jamuna Adhikari (Chairperson and Vice Chairperson of Gharpajhong Rural Municipality) for their support during the data collection. I am also thankful to Mr. Anup K.C., CDO of Mustang District, Inspector Gopi Krishna Subedi of Nepal Police, Dr. Shiva Khanal Undersecretary at Climate Change Management Division, Ministry of Forest and Environment.

I acknowledge and appreciate the arrangement and worth environment made by APF Command and Staff College, Sanogaucharan, Kathmandu for providing needful time and resources. Finally, I would like to thank my friends and family members for their direct and indirect support while preparing this research paper.

Shankar Khanal

ABSTRACT

Climate change is a change in the state of the climate that can be identified by changes in the mean and / or the variability of its properties, and that persists for an extended period, typically decades or longer. Mountain development is the process of improving the lives and livelihoods of mountain people, while conserving mountain environments and cultures. This study investigates the impact of climate change and mountain development with a specific focus on the Thini village, Gharpajhong Rural Municipality, Mustang. The research methodology employed a concurrent triangulation approach, combining quantitative and qualitative methods through household surveys, Key Informant Interviews (KII), Focus Group Discussions (FGD), and observations in Thini Village, utilizing both primary and secondary data sources, and presenting the findings through a narrative approach. The findings reveal that climate change has resulted in habitat disruption, altered weather patterns, and changes in traditional ways of life in the Thini village. These environmental changes have far-reaching implications, including the depletion of decline in snow fall, reduced agricultural productivity, and increased vulnerability of human settlements to natural disasters. While at the same time mountain development has provided people with various opportunities for their livelihoods. To address these challenges, the study recommends the adoption of sustainable resource management practices, such as responsible land use planning, water management, and forestry practices. This study emphasizes the importance of collaborative efforts at local, national, and international levels to mitigate climate change impacts in mountainous regions. By implementing the recommended strategies, policymakers, communities, and stakeholders can work together to protect the environment, ensure the well-being of local communities, and promote sustainable development.

Keywords: climate change, mountainous regions, environmental impacts, mountain development

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LIST OF ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
APA	American Psychological Association
CH4	Methane
CO2	Carbon Dioxide
COVID	Corona Virus Disease
ECS	Equilibrium Climate Sensitivity
FGD	Focus Group Discussion
GHG	Greenhouse Gases
GLOFs	Glacial Lake Outburst Floods
HFCs	Hydrofluorocarbons
HKH	Hindu Kush Himalayan
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
KII	Key Informant Interview
MCA	Manaslu Conservation Area
mm	millimeter
N2O	Nitrous Oxide
NTFP	Non-Timber Forest Products
RCC	Reinforced Cement Concrete
SDGs	Sustainable Development Goals
UNFCCC	United Nations Framework Convention on Climate Change
VDC	Village Development Committee

CHAPTER I

INTRODUCTION

1.1 Background of the study

Climate change means the alteration of the world's climate that we humans are causing, through fossil fuel burning, clearing forests and other practices that increase the concentration of greenhouse gases (GHG) in the atmosphere. This is in line with the official definition by the United Nations Framework Convention on Climate Change (UNFCCC) that climate change is the change that can be attributed "directly or indirectly to human activity that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods" (UNFCCC, 1992). However, Intergovernmental Panel on Climate Change (IPCC) defines climate change as a change in the state of the climate that can be identified by changes in the mean and / or the variability of its properties, and that persists for an extended period, typically decades or longer" (IPCC, 2022).

Climate change poses a pressing and urgent challenge in mountainous regions, where the majestic mountains bear witness to and serve as visible reminders of this phenomenon. The water resources that originate from these mountainous areas are particularly susceptible to environmental transformations brought about by climate change. The melting of glaciers, along with fluctuations in temperature and precipitation, profoundly impacts the availability of water in these regions. Consequently, this leads to unpredictable variations in stream flow, resulting in either devastating floods or debilitating droughts. Moreover, the conversion of snow into glacier ice due to rising temperatures significantly disrupts the overall patterns of water runoff. As glaciers continue to shrink, the seasonal fluctuations in water flow become more pronounced, posing significant implications for vital sectors like irrigation and hydropower. Additionally, these alterations reshape the risks and hazards associated with water resources in mountainous regions (Singh, Khadka, Karky, & Sharma, 2011).

Moreover, in recent decades, the Hindu Kush Himalayan (HKH) region has experienced notable transformations in its cryosphere. These include temperatures surpassing the global average, the melting of glaciers, and a reduction in the volume of annual snowfall. These

alterations carry significant consequences for water availability and food production, leading to water scarcity and increased costs associated with water collection and storage. Furthermore, the rapid changes in the cryosphere escalate the risks of various disasters, including floods, avalanches of snow, ice, and rocks, as well as landslides. These disasters result in property damage, infrastructure destruction, and loss of life. The mountain communities endure the immediate and severe impacts of these changes, which impose economic burdens and can cause psychological trauma, mental stress, and other health problems, particularly among vulnerable groups (Tuladhar, Pasakhala, Maharjan, & Mishra, 2020)

One of the most significant impacts of climate change on mountain regions is the melting of glaciers, which can have a range of effects on water resources, biodiversity, and human livelihoods (Steiger, Knowles, Poll, & Rutty, 2022). Glaciers act as a natural water storage system, and their loss can lead to water scarcity in downstream areas. This can have significant impacts on agriculture, hydroelectric power generation, and other sectors that rely on water. Climate change can also lead to changes in vegetation patterns, with some species becoming more dominant and others disappearing altogether. This can affect wildlife populations and alter ecosystem functioning, with potential impacts on soil stability, water quality, and other important ecosystem services (Borunda, 2019). In addition to ecological impacts, climate change can also have significant social and economic impacts on mountain communities. These communities often rely heavily on natural resources for their livelihoods, such as agriculture, forestry, and tourism. Changes in climate patterns can lead to decreased productivity, increased risk of natural disasters, and other economic impacts (Merrey, Hussain, Tamang, Thapa, & Prakash, 2018).

Mountainous regions, particularly those inhabited by disadvantaged and marginalized groups, are experiencing a range of challenges including increasing poverty, natural hazards, deprivation, and socioeconomic conflicts. These difficulties have been further intensified by the impact of climate change. The intricate web of life and livelihoods that mountains sustain is under threat from climate change, natural hazards, and other factors. The consequences of poverty and environmental degradation extend well beyond mountain communities, as the highland areas face a rising number of landslides, mudslides, catastrophic floods, and other natural disasters that adversely affect the densely populated lowlands. Additionally, the rapid melting of mountain glaciers and degradation of watersheds are leading to reduced water

availability and escalating conflicts over dwindling natural resources and supplies. These changes will have the most immediate and severe impact on impoverished and isolated mountain communities, who possess limited capacity to cope with and adapt to these transformations. The consequences for the billions of people downstream of major mountain areas who depend on critical environmental resources provided by mountains, water, biodiversity, and hydrological processes, will be equally severe (Dhakal, et al., 2022).

The development of mountainous regions and the impacts of climate change are intricately connected, with mountain areas bearing a disproportionate burden of climate change effects compared to other parts of the world. These vulnerable mountain regions are home to approximately 1.1 billion people, which represents around 15 percent of the global population (Lama & Devkota, 2022). However, the capacity of these communities, particularly in developing nations, to adapt to climate change is constrained by financial limitations and a lack of opportunities to expand local livelihoods. Mountains play a critical role in global freshwater resources, acting as the "water towers" that sustain half of humanity. In the HKH region, mountain communities heavily rely on the melting cryosphere for agriculture, pastoralism, drinking water, hydropower generation, and recreational activities, while it also regulates micro-climates. Despite their rich resources, mountain areas have often been overlooked in terms of infrastructure development, with decisions made by distant centers of power that primarily benefit lowland regions. Widespread poverty and hunger persist in these communities, highlighting the urgent need for targeted support and sustainable development initiatives (Kohler, et al., 2015).

Nepal stands as a remarkable example with its majestic mountains, including Mount Everest, and diverse ecosystems that span from lush tropical forests to high-altitude alpine tundra. The livelihoods of indigenous communities in Nepal rely heavily on natural resources such as agriculture, forestry, and tourism. Achieving sustainable development in Nepal's mountainous regions requires a careful balance between economic growth, environmental preservation, and social progress. This entails the promotion of sustainable land use practices, the encouragement of renewable energy and sustainable tourism, as well as providing support for the growth of local businesses and industries. Considering Nepal's susceptibility to the consequences of climate change, it becomes imperative to prioritize efforts in climate change adaptation and mitigation (Baloch, et al., 2022).

To address the challenges of mountain development and climate change, a range of strategies and approaches are needed. These may include measures to reduce greenhouse gas emissions and adapt to the impacts of climate change, as well as efforts to promote sustainable land use practices and support local communities in building resilience to climate change.

1.1.1 Climate change and mountain

Mountain systems worldwide are presently experiencing swift and significant transformations that are anticipated to be enduring. These alterations have extensive implications for multiple facets of mountains, encompassing their climate, landforms, and ecological systems. A particularly noteworthy consequence is the unparalleled pace at which glaciers are receding, resulting in profound implications for the overall dynamics of mountain systems. This, in turn, leads to environmental risks and alterations in available resources and services. Additionally, human endeavors like agriculture, urban development, and tourism intensify the effects of climate change in mountainous regions (Jones et al., 2021).

Mountains possess importance not solely for their physical characteristics, but also for their picturesque allure, exceptional ecosystems, rare species, and indigenous communities. These components are intricately linked, forming interconnected biosystems that encompass climate, physical phenomena, ecosystems, and human existence. Nevertheless, these biosystems are presently functioning beyond their inherent capacities due to their susceptibility to climate change and human interventions (ICIMOD, 2022).

Climate sensitivity refers to how the Earth's atmospheric temperature responds to changes in carbon dioxide (CO2) levels. Equilibrium Climate Sensitivity (ECS) captures the overall response of the Earth system to human-induced influences. Different metrics have been employed to assess the sensitivity of various components within mountain systems, including the cryosphere (snow, glaciers, permafrost), hydrosphere (river runoff), and biosphere (plant ecosystems, species), to climate changes. However, the intricate nature of sensitivity and the intricate interactions within mountain systems present challenges in obtaining a comprehensive understanding of their overall sensitivity. The diverse and interrelated factors involved necessitate careful analysis and consideration to develop a holistic perspective on the sensitivity of mountain systems (Jhang & Wang, 2020).

Furthermore, the future trajectory of mountain components in response to climate change is marked by uncertainty, owing to their diverse sensitivities to external influences. Human actions within mountain regions, including agricultural practices, urban development, and the introduction of invasive species, already exert considerable influence on these elements. In some cases, these human activities may overshadow the impacts of climate forcing, further complicating the understanding of their dynamics. As a result, mountains represent intricate systems that might exhibit unpredictable responses to climate change, thereby posing challenges in the identification and management of risks related to hazards, water availability, and the preservation of ecosystem and cultural services (Tse-ring, Sharma, Chettri, & Shrestha, 2015). The Himalayan mountains are experiencing warming at a rate 0.3-0.7°C faster than the global average, resulting in the shrinkage of glaciers, the retreat of snowlines, and an elevated risk of floods caused by the rupture of expanding glacial lakes (Lama, 2021).

1.1.2 Mountain development in Nepal

ICIMOD defines mountain development as "the process of improving the lives and livelihoods of mountain people, while conserving mountain environments and cultures." Mountainous regions have frequently been overlooked by policymakers, major investors, and development practitioners primarily due to their geographical remoteness, marginal status, fragility, and vulnerability. These areas are often perceived as "remote" and encounter numerous challenges, including high illiteracy rates, insufficient transportation and communication infrastructure, and limited access to energy sources. Such circumstances have historically isolated mountain regions from other areas, impeding their development and giving rise to a complex development dilemma (Mahat, 2021).

Nepal stands out as a noteworthy example where mountain development has garnered substantial focus, owing to the country's distinctive geographical attributes and the pivotal role mountains play in various facets of Nepalese society. Renowned for housing eight of the world's fourteen highest peaks, including the iconic Mount Everest, Nepal has been proactive in implementing endeavors aimed at fostering sustainable mountain development.

1.1.2.1 Sustainable tourism

Nepal's mountains draw a multitude of tourists and climbers from across the globe. In recognition of the importance of preserving the natural environment while capitalizing on the

economic advantages, the government has been actively engaged in promoting sustainable tourism practices. These efforts encompass a range of initiatives, such as regulating trekking routes to ensure their sustainable use, advocating responsible mountaineering practices, and providing support to local communities residing in mountainous regions. By undertaking these measures, Nepal aims to strike a balance between promoting tourism and safeguarding the ecological integrity of its mountain areas.

1.1.2.2 Conservation and biodiversity

Nepal's mountainous regions boast abundant biodiversity, harboring rare and exceptional flora and fauna. To safeguard these valuable natural resources, conservation initiatives have centered around the establishment of protected areas and national parks. Examples of such conservation areas include Sagarmatha National Park and Langtang National Park. These protected areas play a crucial role in preserving the distinct ecosystems and wildlife that inhabit the mountains of Nepal. By designating these areas, the country aims to ensure the long-term conservation of its diverse mountain biodiversity.

1.1.2.3 Infrastructure development

The development of infrastructure in mountainous areas holds significant importance for the well-being of local communities and the promotion of tourism. In Nepal, efforts have been directed towards improving transportation networks, which involve constructing roads and bridges to enhance accessibility to mountain regions. These infrastructure developments play a vital role in facilitating various aspects of community life, including trade, education, healthcare, and overall economic growth (Kohler, et al., 2015). By enhancing connectivity, Nepal aims to foster sustainable development in its mountainous areas and improve the quality of life for the local population.

1.1.2.4 Disaster risk reduction

The mountainous terrain in Nepal is susceptible to natural disasters like landslides and avalanches. Recognizing the importance of disaster preparedness and risk reduction, initiatives have been undertaken to strengthen these measures in mountain regions. These efforts encompass the establishment of early warning systems to provide timely alerts, implementing slope stabilization techniques to mitigate the risks associated with unstable

slopes, and conducting training programs to educate local communities about disaster response and building resilience (Kohler, et al., 2015). By prioritizing these measures, Nepal aims to enhance the safety and well-being of its mountain communities in the face of natural disasters.

1.1.2.5 Renewable energy

Nepal possesses significant hydropower potential owing to its mountainous rivers. Recognizing this opportunity, the government has prioritized the development of hydropower projects to fulfill the energy requirements of the country and promote the utilization of clean and sustainable energy sources. By harnessing hydropower, Nepal not only aims to meet its energy demands but also creates economic prospects and contributes to the overall development of mountainous regions (Adhikari, et al., 2021). These projects serve as catalysts for job creation, infrastructure development, and improved living standards, thereby driving socio-economic progress in these areas.

1.1.2.6 Livelihood diversification

In Nepal, mountain communities have historically relied on agriculture and animal husbandry as the mainstay of their livelihoods. However, recognizing the need for diversification and enhanced resilience, efforts have been made to promote alternative income-generating activities in these communities. Initiatives such as ecotourism, handicraft production, and organic farming have been encouraged to provide additional sources of income and reduce dependency on traditional practices (Tiwari, et al., 2020). By diversifying livelihood options, mountain communities can better adapt to changing circumstances and enhance their resilience in the face of challenges. These initiatives also contribute to the preservation of local traditions, cultural heritage, and the sustainable development of mountain regions.

1.1.3 Climate change adaptation

Nepal's mountainous regions are exceptionally vulnerable to the consequences of climate change, such as the retreat of glaciers and alterations in water availability. Recognizing the urgency of addressing these challenges, the government, in collaboration with international partners, has undertaken climate change adaptation strategies specific to mountain regions. These strategies involve a range of measures, including community-based adaptation projects

aimed at enhancing the resilience of local communities, promoting sustainable land management practices to mitigate the impacts of climate change, and raising awareness about climate change issues among the population. By implementing these initiatives, Nepal strives to minimize the adverse effects of climate change on its mountainous areas and ensure the well-being of its communities (Karki et al., 2010).

1.2 Statement of the problem

The mountainous regions of Nepal face high vulnerability to the consequences of climate change, which are anticipated to bring significant ecological, social, and economic repercussions. The melting of glaciers shifts in precipitation patterns, and changes in vegetation distribution are expected to impact water resources, biodiversity, and the livelihoods of the local population. Concurrently, rapid pace of economic growth in Nepal, including infrastructure expansion, tourism, and resource extraction, adds further strain on mountain ecosystems, intensifying the effects of climate change. There is a need to devise and implement effective strategies for mountain development and climate change adaptation in Nepal, aiming to strike a balance between economic progress and ecological sustainability while enhancing resilience of mountain communities against climate change impacts.

1.3 Research questions

This research has been guided by the following research questions:

a. What are the impacts of climate change in the mountainous region of Nepal with specific focus in Thini village?

b. How climate change and mountain development impact the livelihoods of people in Thini village?

c. How can the effect of climate change be mitigated?

1.4 Objectives of the study

1.4.1 General Objective

The general objective of the study is to examine the climate change and mountain development tin Nepal.

1.4.2 Specific Studies

The specific objectives of the study are as follow:

a. To assess the impacts of climate change in the mountainous region of Nepal with specific focus on Thini village.

b. To analyze how climate change and mountain development impact the livelihoods of people in Thini village.

c. To examine the ways to mitigate the effects of climate change.

1.5 Significance of the study

The study can provide insights into the broader issue of sustainable development in mountainous regions, which are often marginalized and face unique challenges such as rugged terrain, limited infrastructure, and fragile ecosystems. Further, the study can contribute to the global understanding of climate change impacts and the need for adaptation and mitigation strategies. As a country highly vulnerable to climate change, Nepal's experiences and responses can provide valuable lessons for other developing countries facing similar challenges.

1.6 Limitations of the study

Some of the limitations of the study identified are as follow:

a. The study is focused specifically on Thini village, Ghaparjhong Rural Municipality, Mustang, Nepal. This allows for an in-depth analysis of the Thini village but it does not fully represent the broader context of climate change and mountain development in Nepal.

b. The study conducted a household survey with 63 respondents out of a total of 121 houses in Thini. A relatively small sample size has limited the statistical significance and generalizability of the results.

CHAPTER II

REVIEW OF LITERATURE

2.1 Review of theoretical literature

This section analyzes the concept of regarding mountains, climate change, mountain communities and infrastructure.

2.1.1 Mountains

The definition of mountains and highlands lacks a clear and universally accepted standard, likely due to the fact that mountains exist on every continent, ranging from the equator to the Polar Regions, and exhibit various altitudes and unique ecosystem patterns. Generally, they are structured higher than 600 meters and reach the extreme height of 8,848 mt (i.e. Mount Everest, highest mountain in earth). As three-dimensional entities, mountains encompass a diverse range of topography, climate, flora, fauna, and cultural differentiation, making them one of the most diverse and complex features on Earth. Instead of relying solely on a simplistic definition based on altitude above sea level, mountains can be characterized by their altitudinal succession of distinct climatic, geomorphic, and vegetational belts. Irrespective of their absolute altitudes, mountains encompass areas with pronounced relief, significant ecological variations, and slopes that are susceptible to both natural hazards and human activities. Notably, approximately 46.7 percent of the total land area across all continents is situated above 500 meters, with 26.9 percent above 1000 meters, and 11.1 percent exceeding 2000 meters. These figures highlight the substantial extent of mountains and highlands as a prominent ecosystem on our planet (Rahbek et al., 2019).

The Himalaya, known as the "abode of snow," extends for over 4000 kilometers from Afghanistan in the west to China and Myanmar in the east. This majestic mountain range acts as a magnet for moisture-laden clouds, which generously bless its slopes with precipitation, creating the source of great rivers in Asia. These rivers include the Indus, Ganges, Yarlung Tsangpo/Brahmaputra, Salween, Lancang Jiang, and Yangtze. The Himalaya is home to more than 150 million mountain dwellers who rely directly on its resources for their biophysical, socio-cultural, economic, recreational, and other essential needs. Moreover, the goods and services produced by the Himalaya benefit over 500 million people living downstream. It

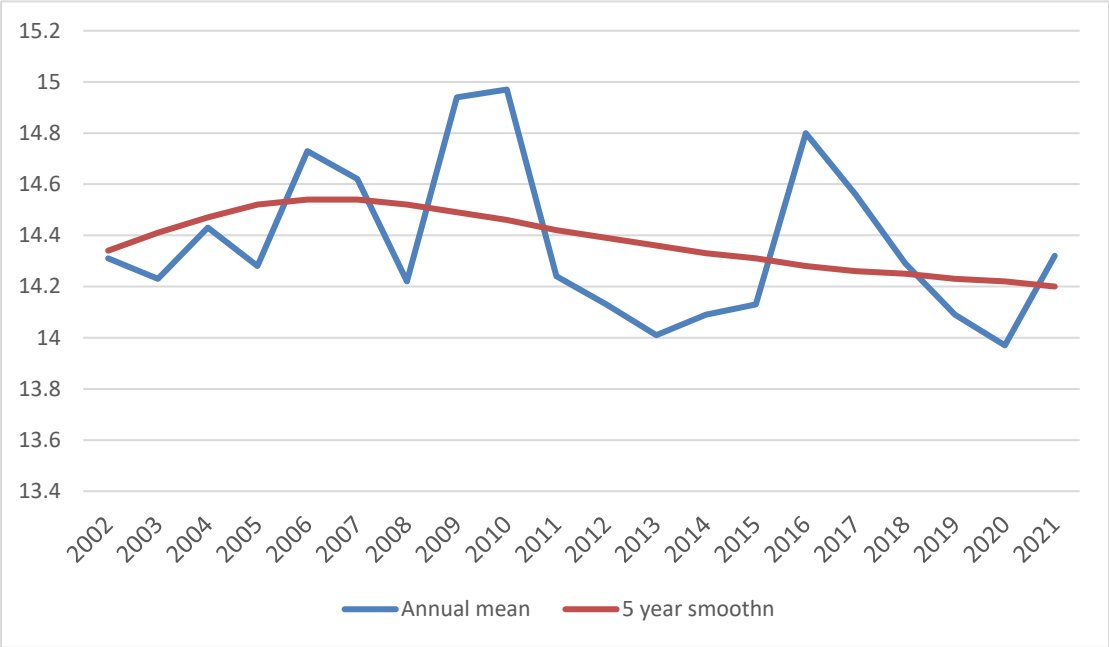
serves as the primary source of drinking water, industrial inputs, agricultural support, and various economic activities for downstream communities. However, the impact of climate change, with rising temperatures and altered precipitation patterns, disrupts water flows, affects ecosystems, exacerbates natural hazards, and poses threats to livelihoods worldwide. Mountain ecosystems are particularly sensitive to climate change compared to other terrestrial ecosystems, while mountain communities tend to have lower average incomes than those residing downstream. Consequently, the effects of climate change in mountainous regions disproportionately impact both the ecosystems and the people who depend on them (ADB, 2015).

2.1.2 Climate change

Nepal, due to its fragile mountainous topography and ecosystems, experiences high vulnerability to climate change and natural disasters, facing both sudden and gradual climate-related hazards. The country's susceptibility arises from its highly variable monsoon-driven hydrology, unplanned settlements, and inadequate resilient infrastructure. Recent events such as the Gorkha earthquake and fuel crisis in 2015, floods in 2017, landslides, and the COVID-19 pandemic in 2020 have underscored Nepal's exposure to shocks. In fact, Nepal ranks as the 10th most affected country in the world according to the Climate Risk Index. Around 80 percent of the population is at risk from natural and climate-induced hazards, including extreme heat stress, flooding, and air pollution. The highest-risk groups are vulnerable communities living in poverty, remote areas, and engaged in subsistence agriculture, with variations in exposure across different geographic locations. Earthquakes and floods have been the most devastating natural hazards thus far, while floods and landslides have been the most frequently occurring over the past four decades. The frequency of flood events has doubled in recent years, and storms, erosion, and landslides are also on the rise, resulting in loss of lives and livelihoods. The heavy monsoon floods and landslides in 2020 caused numerous fatalities, displaced thousands of people, and inflicted significant damage to infrastructure, particularly roads. Mountains in Nepal are warming at a faster rate than the plains, leading to ice and permafrost melting and an increased risk of landslides. Incidents of dry spells, droughts, forest fires, heatwaves, flash floods, and disease outbreaks are also escalating, highlighting the growing risk of slow-onset disasters (World Bank Group, 2022).

Figure 2.1

Observed average annual mean temperature of Nepal, 2002-2021



Source: (World Bank, 2022)

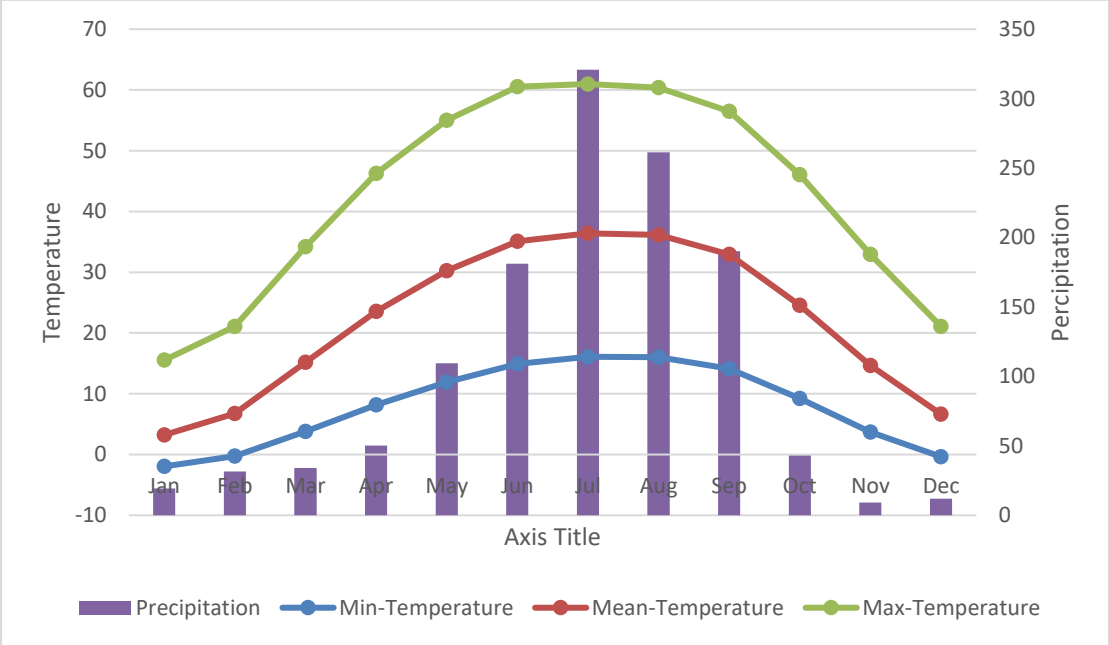
Nepal exhibits significant climate variations both seasonally and based on altitude. The country can be divided into distinct climate zones according to altitude, ranging from the Terai region in the south, which lies at an elevation of less than 500 meters above sea level, to the High Himalayan region in the north, reaching altitudes exceeding 5,000 meters. Average temperatures decrease from a peak of over 24°C in the southern regions to sub-zero temperatures in Nepal's highest mountains. Precipitation patterns also show spatial variability, with certain central and northern areas receiving more than 3,000 millimeters (mm) of rainfall, the central and southern plains typically receiving 1,500-2,000 mm, and some high-altitude regions in the north receiving less than 1,000 mm of precipitation.

These distinct climate zones play a crucial role in shaping Nepal's ecosystems and agricultural practices. The Terai's warm and fertile lands are suitable for rice cultivation and support a diverse range of flora and fauna. The Hill region's temperate climate makes it favorable for growing crops like wheat, corn, and millet. Meanwhile, the High Himalayan region's harsh conditions limit agricultural activities, and the main economic activities often revolve around animal husbandry and tourism, given the region's popularity for trekking and

mountaineering. Understanding these climate variations is essential for the country's sustainable development and effective adaptation to the impacts of climate change.

Figure 2.2

Monthly climatology of min-temperature-mean temperature, max temperature and precipitation 1921-2020



Source: (World Bank, 2022)

Some of the major causes of the climate changes are listed below:

2.1.2.1 Greenhouse gas emissions

The primary driver of climate change is the increase in greenhouse gas concentrations in the Earth's atmosphere. Human activities, particularly the burning of fossil fuels such as coal, oil, and natural gas for energy, release large amounts of CO2 and other greenhouse gases (e.g., methane and nitrous oxide) into the atmosphere. These gases trap heat and contribute to the warming of the planet, leading to the greenhouse effect (World Bank Group, 2022).

2.1.2.2 Deforestation

Deforestation, mainly for agriculture, logging, and urbanization, results in the loss of forests that play a crucial role in absorbing CO2 from the atmosphere. When forests are cleared or

burned, the stored carbon is released back into the atmosphere, contributing to increased greenhouse gas concentrations (ADB, 2015)

2.1.2.3 Industrial processes

Certain industrial activities, such as cement production, steel manufacturing, and chemical production, emit greenhouse gases as byproducts. Additionally, some industrial processes release potent synthetic greenhouse gases, like hydrofluorocarbons (HFCs), which have significantly higher warming potential than CO2 (ADB, 2015).

2.1.2.4 Agricultural practices

Agricultural activities contribute to climate change through various mechanisms. The use of synthetic fertilizers releases nitrous oxide (a potent greenhouse gas), while livestock farming, particularly cattle, produces significant amounts of methane. Rice cultivation in flooded paddies can also result in the emission of methane (World Bank Group, 2022).

2.1.2.5 Land use changes

Conversion of land for agriculture, urbanization, and infrastructure development can contribute to climate change. Altering land cover affects the balance of greenhouse gases, reduces the planet's capacity to absorb CO2, and can lead to changes in local and regional climate patterns (World Bank Group, 2022).

2.1.2.6 Waste management

Improper waste management practices, such as uncontrolled landfilling and organic waste decomposition, generate methane emissions. Methane is a potent greenhouse gas, and its release contributes to climate change (World Bank Group, 2022).

2.1.3 Mountain communities and infrastructure

Mountain environments and resources are considered a global common good that is utilized by both mountain communities and visitors. The close connection between people and mountain environments is evident using water and food resources, the functioning of ecosystems and ecosystem services, and the dependence of human livelihoods on these resources. In the past, mountain agricultural economies were viewed as isolated systems

based on pastoralism, but they are now recognized as part of complex spatial networks that encompass various mountain goods and services, cultural patterns, and long-term existence. Climate change plays a role in influencing human activities in mountains, such as agriculture, tourism, and industry, by impacting ecosystems and snow distributions. The concept of socioecological vulnerability and resilience is used to understand the interrelationships between mountain environments/resources and human activities. Environmental sensitivity and social resilience are terms used to describe these aspects. Studies conducted in the Himalayas emphasize the importance of integrated hazard risk management and adaptive planning at the community level, incorporating indigenous knowledge systems. However, similar approaches to mitigating climate change risks in mountains have not been widely developed for other mountain ranges. Some exceptions include a study on rural communities in the Swiss Alps that explores the feedbacks between socioeconomic and biophysical systems (Byers, 1995).

One of the most significant issues affecting people and communities in mountain regions, as well as downstream areas, is the changes in river discharge originating from glaciers and snow. These mountain "water towers" play a crucial role in regional water supply, such as providing water to approximately 60 million people in the Indus and Brahmaputra catchments and contribute to regional food security. Studies have shown that a significant percentage of mountain areas, around 43 percent, provide essential or supportive water resources for urban populations, particularly during dry seasons and in semiarid regions like central Asia. Glacier melt contributes to a considerable portion of seasonal river discharge in many catchments, impacting millions of people. The ongoing global warming intensifies glacier melt, leading to increased variability in river discharge. The complex interactions between mountain water sources and human activities have implications for various aspects, including the economy, culture, infrastructure, hydropower, food, and water security, geohazards, irrigation, ecosystems, and sustainable development. Climate models predict that glacier melt will continue in the coming decades, resulting in lower and more variable river discharges as glacier volume declines. This has consequences for sediment yield, geohazards, water supply, and water management strategies. The retreat of snow and glaciers in mountains already affects the development and sustainability of mountain tourism, conservation efforts, and the preservation of built heritage in these areas (Molden, et al., 2021).

2.1.4 Global warming

Global warming refers to the long-term increase in Earth's average surface temperature, primarily attributed to the buildup of greenhouse gases in the atmosphere. The burning of fossil fuels, deforestation, and various human activities contribute to the emission of greenhouse gases, such as CO2, methane (CH4), and nitrous oxide (N2O), which trap heat in the Earth's atmosphere and lead to a warming effect known as the greenhouse effect. This increase in temperature has far-reaching consequences, including rising sea levels, more frequent and severe heatwaves, changes in precipitation patterns, shifts in ecosystems, and impacts on human health and socio-economic systems. Mitigating global warming and its effects is a pressing global concern, with efforts focused on reducing greenhouse gas emissions, transitioning to renewable energy sources, promoting sustainable practices, and adapting to the changing climate (ADB, 2015).

2.2 Empirical review

The empirical review has been divided into two sections, international studies and national studies.

2.2.1 International studies

Steiger et al. (2022) emphasized that climate change poses a significant threat to mountain landscapes and communities, given their high sensitivity and vulnerability to its impacts. This is particularly crucial for the tourism sector in mountain regions, which heavily relies on natural resources and attractions that are susceptible to climatic changes. The study found that negative impacts on the snow season were predominant, while the impacts on summer season activities varied from positive to negative. The study identified seven key knowledge gaps: limited studies on South America and Africa, inadequate data and indicators, the need for a comprehensive all-season perspective, exploration of opportunities, consideration of economic and socio-political consequences for mountain communities, improved science communication, and insufficient studies on liability and regulatory risks. To mitigate the impact of climate change on mountain tourism, it is crucial to enhance multidisciplinary understanding, involve stakeholders, and prepare for projected changes by developing effective climate adaptation strategies for local populations in mountain communities. This

requires addressing the identified knowledge gaps, promoting further research, and fostering collaboration among researchers, policymakers, and local communities.

Baloch et al. (2022) explored the relationship between tourism development and environmental suitability, aiming to propose a framework for sustainable ecotourism. The framework suggests achieving a balance between business interests and environmental preservation through government support and policy interventions. The research involved various stakeholders in the tourism industry, including tourists, local community representatives, civil administration members, hoteliers, and tour operators. The findings indicated that a significant number of individuals perceived socio-economic benefits from tourism, such as employment opportunities, business growth, and infrastructure development. However, the state of natural and environmental resources was found to be deteriorating gradually. The study identified social vulnerability resulting from land overuse, the intrusion of external cultures, air and water pollution due to traffic congestion, solid waste accumulation, sewage, and carbon emissions. To promote sustained ecotourism, the study proposed a model framework that includes supportive government policies to ensure effective conservation of environmental and natural resources while preserving the economic viability and social well-being of local communities.

Knight (2022) argued that mountains are diverse in their extent, geology, climate, ecosystems, and human activities, making them highly vulnerable to anthropogenic climate change. This study identified four major properties of mountains impacted by climate change: the mountain cryosphere, hazards and risks, ecosystems and services, and communities and infrastructure. These properties exhibit varying sensitivities to climate change and are interconnected. The study presented a model of mountain socio-biophysical systems to understand climate impacts and found that effective management of climate change risks in mountains requires an integrated approach to monitoring and mitigation.

Anderson (2020) highlighted that Mountain ecosystems are currently facing the triple planetary crisis of climate change, nature and biodiversity loss, and pollution and waste. These ecosystems are crucial for hosting biodiversity hotspots and providing freshwater resources to a significant portion of the global population. They also offer important ecosystem services such as climate regulation and soil conservation. However, climate change disrupts micro-climates and poses a threat to endemic mountain species, while waste, including microplastics, exacerbates the challenges. To address these issues, the article

suggested four areas of action: increasing nature-positive investments to support the regeneration of mountain ecosystems, aligning the five-year action plan derived from the International Year of Sustainable Mountain Development with scientific guidance, enhancing regional coordination efforts, and integrating policy agendas and actions related to mountains. The article emphasized the importance of supporting international initiatives aimed at resolving the triple planetary crisis and protecting mountain ecosystems.

Eriksson et al. (2020) described the greater Himalayan region known as the "roof of the world" and comprises expansive high-altitude areas with vast glaciers and permafrost. The region's water resources flow through ten major rivers, providing livelihoods for over 1.3 billion people in Asia. These resources are crucial for global atmospheric circulation, biodiversity conservation, agriculture, hydropower, and global commodity production. However, the region's water resources face multiple threats. Global warming has a significant impact on snow and ice, affecting downstream water availability as a substantial portion of river flows come from melting snow and glaciers. The rate of warming in the greater Himalayas exceeds the global average, with observed increases of 0.6 degrees Celsius per decade in Nepal compared to the global average of 0.74 degrees Celsius over the past century. Precipitation patterns exhibit variability across the region, with some areas experiencing increasing trends while others see decreasing trends. Extreme weather events, including intense rainfall leading to flash floods, landslides, and debris flows, pose severe challenges. However, understanding the implications of climate change on water resources and hazards in the Himalayas and downstream river basins is limited due to the region's complex topography and insufficient data. Addressing this knowledge gap requires establishing monitoring systems for snow, ice, and water, downscaling climate models, using hydrological models for water availability predictions, and developing comprehensive scenarios considering water demand and socioeconomic development. Climate change-induced hazards like floods, landslides, and droughts will significantly impact the livelihoods of mountain and downstream populations, necessitating improved adaptation strategies and efforts to address structural inequalities that hinder adaptation for vulnerable communities. Strengthening local knowledge, innovations, and practices within social and ecological systems, as well as enhancing the functionality of relevant institutions, is crucial for effective adaptation. Sound science and credible knowledge should guide the development and implementation of policies to address these challenges.

Wester et al. (2019) emphasized that the HKH region holds immense value for millions of people, but it encounters various challenges including climate change, globalization, conflict, and environmental degradation. This report highlighted the significance of addressing mountain-specific priorities that align with the Sustainable Development Goals (SDGs). It emphasized the need for cooperation among communities, states, and countries to effectively manage the HKH region. The report provided a crucial foundation for achieving these goals and encourages collaboration among practitioners working together to tackle the challenges faced by the HKH region.

Borunda (2019) stated that the Himalayan region is undergoing accelerated warming, surpassing the global average, leading to glacier melting, changes in river flows, and an elevated risk of natural disasters like floods and landslides. The article emphasized the vulnerability of communities in the region to the impacts of climate change and emphasizes the urgency for action. The study recommends crucial mitigation efforts, such as reducing greenhouse gas emissions, and adaptation measures like enhancing infrastructure and water management. These actions are necessary for securing the long-term sustainability of the Himalayan region.

Kohler et al. (2015) underscored that Mountain regions play a crucial role in providing essential goods and services to a significant portion of the global population, including freshwater, hydropower, cultural and biological diversity, raw materials, and popular tourist destinations. However, these regions face various risks and hazards such as land degradation, inequitable land rights, resource exploitation, and severe poverty. The report emphasized that mountain regions are highly vulnerable to climate change and are already experiencing its impacts, which further exacerbates existing challenges. Global economic and social changes have also negatively affected traditional mountain livelihoods, resulting in the loss of local knowledge, land abandonment, and increased susceptibility to hazards. The report underscored the importance of tailored and integrated policies and governance structures to address the unique challenges posed by mountain environments.

Moon (2009) examined the challenges faced by mountain communities and emphasized the importance of integrating mountain-specific considerations into sustainable development policies and strategies. The report recognized the vital role of mountains in providing ecosystem services, particularly freshwater, and emphasized the need to protect these ecosystems for the well-being of both mountain communities and downstream populations.

Several recommendations are provided for policymakers and stakeholders, including prioritizing mountain-specific policies and investments, promoting sustainable livelihoods and climate resilience, and empowering mountain communities through participatory decision-making processes.

Ives (2006) explored the impact of environmental change on the well-being of communities in the Himalayan region. The authors argued that factors like climate change, deforestation, and tourism have led to environmental degradation, resulting in significant changes to the social, economic, and cultural aspects of Himalayan communities. Case studies and empirical evidence are presented to support this claim, highlighting the negative consequences of environmental change, such as reduced agricultural productivity, loss of biodiversity, and heightened vulnerability to natural disasters. The book also examined how local communities are responding to these challenges through the adoption of new agricultural practices, promotion of sustainable tourism, and the strengthening of community-based organizations.

2.2.2 National studies

Nyaupane and Timothy (2022) examined the unique characteristics of the Himalaya that distinguish it from other mountainous regions worldwide. It highlighted the Himalayan range as a significant global asset with ecological, climatic, cultural, spiritual, and economic importance. The diverse landscapes, climates, and biotic systems of the Himalaya make it an attractive destination for tourism. The book delved into the sociocultural, environmental, and economic dimensions of tourism and development in the Himalaya region. With sustainable development as a framework, the book presents interdisciplinary perspectives on nature, society, economic development, poverty, justice, health, social and environmental vulnerability, faith and culture, indigenous rights, women, conflict, heritage, and living culture.

Sharma et al. (2022) stated that vulnerability of mountain ecosystems to climate change is not well understood in detail. However, it is plausible that these regions, characterized by fragile landscapes, limited accessibility, and rapid changes in climatic zones, will experience significant impacts on biodiversity, water availability, agriculture, and hazards, thereby affecting human well-being.

Hamal et al. (2022) underscored that climate change has emerged as a prominent global issue with adverse effects on livelihoods, creating vulnerability in various communities. This presents a significant challenge for policymakers, governments, and organizations to develop effective strategies. However, prior to formulating coping, adaptation, or mitigation strategies, it is crucial to understand the reality and perceptions of local communities. The researchers found that the farmers' responses aligned with the actual temperature and precipitation data recorded between 1973 and 2018 from meteorological stations near the region. The findings suggested that the farmers in Lower Mustang have recognized and experienced the changes in temperature and precipitation patterns.

Adhikari et al. (2021) stated that Nepal is recognized as one of the highly climate vulnerable nations globally. The analysis of temperature data from 1985 to 2016 revealed a consistent increase in mean annual maximum, minimum, and average temperatures over time. Agriculture, water resources, Non-Timber Forest Products, and human health were significantly affected by the changing climate. Additionally, the region experienced various natural hazards such as landslides, avalanches, spread of invasive species, and increased pest and fly populations. To adapt to these changes, the local community adopted several practices, including the construction of artificial ponds, pest and weed control, adjustment of plantation and harvesting time, and changes in cropping patterns. However, limited technical and financial resources posed significant constraints to effective adaptation. Based on the findings, it is recommended that local and provincial governments prioritize the development of policies at the local level to support mountain livelihoods and landscapes. These policies should address the specific challenges faced by communities in the Mustang region and provide the necessary resources for successful adaptation practices.

Adhikari (2021) asserted that Nepal, despite contributing minimally to global warming, experiences significant impacts from climate change. The mountain and freshwater ecosystems are particularly affected. Terrestrial ecosystem effects include land cover changes, species extinction due to habitat loss, and disruptions in carbon sequestration. In aquatic ecosystems, water bodies experience eutrophication and the extinction of endemic fish species. Climate change also leads to natural disasters and health impacts, especially in tropical areas. Microbes play a crucial role in maintaining ecological balance in all types of ecosystems, including their impact on biogeochemical cycles such as carbon, nitrogen, phosphorus, and sulfur.

Tuladhar et al. (2020) examined the relationship between the cryosphere (frozen water) and high-mountain livelihoods in Langtang Valley, Nepal, using a social-ecological system approach. The local communities in the area have observed significant changes in the cryosphere, including glacier retreat, altered snowfall patterns, and variations in temperature and precipitation. These changes have increased cryosphere-related hazards such as avalanches and landslides. Simultaneously, the communities are experiencing socioeconomic changes that have resulted in shifting aspirations, particularly among the youth. The disconnection between society and the cryosphere has led to a decline in local knowledge systems. As a result, livelihood sources have become more homogenized, with tourism becoming the dominant income source. However, this reliance on tourism has led to a dependence on imported food, posing long-term risks to local lives and livelihoods. The study recommends interventions to address these challenges, including diversifying livelihoods, strengthening social capital, and conducting hazard risk assessments. These interventions aim to strengthen the linkages between the cryosphere and the socioeconomic system, ensuring the resilience and sustainability of high-mountain livelihoods in the Langtang Valley.

Shrestha and Devkota (2019) assessed the impact of climate change on the livelihoods of a mountain community that relies on tourism. The study examined the effects of major climatic variables and climate change extremes on the community's livelihood. The residents of the study area have observed fluctuations in climatic variables and extremes, which align with meteorological data indicating increasing mean annual temperatures and decreasing average annual precipitation. The findings revealed that climate change, climate change extremes, and induced disasters have significantly affected all types of livelihood assets related to tourism in the mountain region. These impacts include biodiversity loss, depletion of local resources, and increased climatic hazards, resulting in infrastructure damage. Climatic hazards have disrupted off-farm livelihoods, including tourism activities, local businesses, supply chains, employment opportunities, and handicraft industries. Both off-farm and farm-based livelihood assets, crucial for the community's well-being, have been negatively affected by climate change in the area.

K.C. (2016) focused on impact of climate change on tourism and livelihoods in the Manaslu Conservation Area (MCA) of Nepal. The findings indicate that local communities have observed an increase in temperature and rainfall, which aligns with scientific data.

Socioeconomic factors such as marital status, household size, education, and landholding status were found to positively influence tourism participation, while livestock-holding status and occupation had a negative effect. The number of visitors to the MCA has been increasing, and tourism has provided local communities with opportunities to improve their living standards. However, the study highlights potential adverse effects of climate change on the tourism sector, including unfavorable weather conditions, intense rainfall and snowfall, melting snow, and the occurrence of hydrological and climatic hazards. Similar impacts have already been observed in other regions, such as Annapurna and Mt. Everest. Based on these findings, the research suggests several recommendations. These include tourism promotion activities in the MCA, awareness and education programs, initiatives for gender empowerment, advertisement and publicity for tourism promotion, subsidies and training for ecotourism, and skill development training for handicrafts.

Shrestha (2015) stated that the impact of climate change on agriculture in the Prok Village Development Committee (VDC) in the western mountain region of Nepal. The findings reveal that the socio-economic status of farmers in the Prok VDC is poor, making them vulnerable to climate change. The region has stony and sandy loam soil, leading to lower crop yields compared to the national average. Trend analysis of temperature and precipitation over a 30-year period shows various weather variability in the region. Farmers' perceptions align with the trends observed at the weather stations, with erratic changes in rainfall patterns, temperature variations, and reduced snowfall affecting farming activities. Drought, delayed monsoons, and unseasonal heavy rains are major challenges in agriculture. Farmers attribute crop failures, crop damage, degradation of pasture, and poor-quality fodder to increasing temperatures, erratic precipitation patterns, and windstorms. In response to these changes, local communities have adopted various strategies to secure their livelihoods, such as re-sowing, cultivating short-seasoned crops, shifting animal sheds to safer areas, planting fodder trees and practicing agroforestry, diversifying land use, engaging in off-farm activities, and accessing credit. However, the study concludes that existing local and institutional strategies are insufficient and unsustainable in coping with climate variability. It emphasizes the need for institutional support and long-term policy perspectives to address the challenges faced by communities in the region.

Rijal and Rijal (2014) focused on the impacts of climate change on agriculture and livelihoods in Sirdibas village, Gorkha district. The analysis indicates a gradual increase in

mean annual temperature at a rate of 0.05°C/year. The annual mean rainfall has also been increasing at a rate of 0.995 mm/year, although there has been a decrease in winter rainfall. The longer dry spells and rising temperatures have resulted in a reduction in the cropping period for both summer and winter crops. Maize, wheat, and millet productivity have shown a declining trend due to intense off-season rainfall and subsequent waterlogging. Moreover, shifts in livelihood options and out-migration of farming communities have further contributed to decreased crop yields. The impacts of climate change, combined with changes in government policies and shifts in livelihood options, have had significant effects on agriculture in the area. These findings highlight the vulnerability of farming communities in Sirdibas village to climate change and emphasize the need for adaptation strategies. Enhancing agricultural resilience, promoting alternative livelihood options, and addressing the broader socioeconomic factors are crucial for sustaining the well-being and livelihoods of the local community.

Gaire et al. (2014) focused on the impact of climate change on treeline dynamics in the high mountain slope of Kalchuman Lake in the Manaslu Conservation Area of central Nepal. Two transect plots were established to analyze the tree line and the limit of tree species. The dominant tree species, Abies spectabilis and Betula utilis, were mapped, and tree cores were collected for analysis. The findings reveal that Betula utilis has a higher maximum age (198 years) compared to Abies spectabilis (160 years). Abies spectabilis exhibits a high population of younger plants (< 50 years), indicating a high recruitment rate. The age structure of the population indicates an upward shifting of Abies spectabilis at a rate of 2.61 meters per year since AD 1850, while the upper distribution limit of Betula utilis has remained relatively stable in recent decades. The study also observed an increase in plant density and upward shifting in the studied treeline ecotones. The regeneration of Abies spectabilis is positively correlated with August precipitation and the monthly maximum temperature of the current year, with sensitivity to maximum and minimum temperature rather than average temperature. Moisture stress during the pre-monsoon season limits the growth of Betula utilis. Based on these findings, the study suggested that as climate change continues, Abies spectabilis and Betula utilis are expected to exhibit differential responses, leading to wider differences in their population status throughout the century. This research provides valuable insights into the dynamics of treeline ecosystems and their response to climate change in the study area.

Nepal (2011) stated that the lack of acknowledgment of climate change's threat to the tourism industry and highlighted the vulnerability of the industry to climate change. It focused specifically on tourism destinations in mountainous regions, with a particular emphasis on the Nepal Himalaya and developing countries. In high mountain regions, climate change can have specific effects, including increased rates and intensity of natural hazards such as landslides, avalanches, and flooding, which can have severe consequences for tourism destinations. Adaptation strategies need to consider the level of risk and weigh it against the costs and benefits of adaptation. If the benefits outweigh the costs, there is a higher likelihood of local responses to adaptation. However, if the level of risk and associated costs is deemed too high, local communities may adopt a fatalistic attitude towards climate change impacts. The paper suggests adaptation strategies for different stakeholders in the tourism sector, including tourism stakeholders, resident communities, and governments. It emphasizes that climate change strategies in the tourism sector should be approached collaboratively, considering institutional development, diversification of opportunities, equity, and sustainable economic growth. Overall, the paper highlights the importance of recognizing and addressing the challenges posed by climate change in the tourism industry, particularly in mountainous regions, and calls for collaborative efforts in developing adaptation strategies.

2.3 Summary of the literature review

Author	Objective	Findings
Steiger et al. (2022)	To analyze the scientific literature on the effects of climate change on mountain tourism	Negative impacts on the snow season were predominant, while impacts on summer season activities varied. Overall impact remains uncertain. Identified seven key knowledge gaps.
Hamal et al. (2022)	To investigate the awareness of climate change among local farmers in Lower Mustang	Farmers in Lower Mustang have recognized and experienced changes in temperature and precipitation patterns. Findings provide a foundation for context-specific strategies to address climate change challenges in the region.
Baloch et al. (2022)	To explore the relationship between tourism development and environmental suitability for sustainable ecotourism	Perception of socio-economic benefits from tourism, but natural and environmental resources are deteriorating gradually. Proposed a model framework for sustainable ecotourism.

Knight (2022)	To identify the properties of mountains impacted by climate change and propose an integrated approach to monitoring and mitigation	Mountains are vulnerable to anthropogenic climate change. Effective management requires an integrated approach to monitoring and mitigation.
Anderson (2020)	To highlight the triple planetary crisis faced by mountain ecosystems and suggest areas of action	Mountain ecosystems are facing the triple crisis of climate change, nature and biodiversity loss, and pollution and waste. Suggested areas of action to address these challenges.
Eriksson et al. (2020)	To describe the implications of climate change on water resources and hazards in the greater Himalayan region	Water resources in the greater Himalayas are facing threats from global warming, including snow and glacier melt and extreme weather events. Need for improved monitoring, downscaling climate models, and comprehensive scenarios. Strengthening adaptation strategies and addressing structural inequalities are crucial.
Wester et al. (2019)	To highlight the challenges faced by the HKH region and emphasize the need for cooperation	HKH region facing various challenges including climate change, globalization, conflict, and environmental degradation. Emphasizes the need for cooperation to effectively manage the region and achieve sustainable development goals.
Borunda (2019)	To examine the accelerated warming in the Himalayan region and recommend mitigation and adaptation measures	Himalayan region experiencing accelerated warming and associated impacts. Urgency for mitigation efforts and adaptation measures to ensure sustainability.
Kohler et al. (2015)	To highlight the importance of tailored policies and governance structures to address the challenges faced by mountain regions	Mountain regions provide essential goods and services but face various risks and challenges. Tailored policies and governance structures are crucial to address these challenges.
Moon (2009)	To emphasize the need for integrating mountain-specific considerations into sustainable development policies and strategies	Mountains play a vital role in providing ecosystem services, and their protection is important for the well-being of communities. Recommendations for policymakers to prioritize mountain-specific policies and investments.

Ives (2006)	To explore the impact of environmental change on the well-being of communities in the Himalayan region Case studies, empirical evidence	Environmental change in the Himalayan region leads to social, economic, and cultural changes. Communities are responding through new agricultural practices, sustainable tourism, and community-based organizations.
Nyaupane and Timothy (2022)	To examine the unique characteristics of the Himalaya and its tourism and development dimensions	The Himalaya has ecological, climatic, cultural, spiritual, and economic importance. The book explores various dimensions of tourism and development in the Himalaya, aiming to broaden understanding and promote sustainable development in mountainous regions.
Sharma et al. (2022)	To assess the vulnerability of the Eastern Himalayas to climate change and inform conservation policies	The Eastern Himalayas are vulnerable to climate change due to ecological fragility and economic marginality. Research activities conducted by ICIMOD provide valuable information and assessments to support conservation policies and coordinated research efforts in the region.
Adhikari et al. (2021)	To examine the impacts of climate change and adaptation practices in the Mustang region of Nepal	Climate change affects agriculture, water resources, Non-Timber Forest Products, and human health in the Mustang region. The local community has adopted adaptation practices, but limited resources pose constraints. Recommendations include the development of local policies, addressing specific challenges, and providing necessary resources for successful adaptation practices.
Adhikari (2021)	To highlight the need to consider the impact of climate change on microbes and ecological modeling	Microbes play a crucial role in maintaining ecological balance and should be considered in climate change studies. Ecological modeling can provide valuable insights into the future impacts of climate change in Nepal. Recommendations include emphasizing ecological modeling-based research to understand the effects of climate change and support sustainable measures.
Tuladhar et al. (2020)	To examine the relationship between the cryosphere and high-mountain livelihoods in Langtang Valley	Changes in the cryosphere and socioeconomic factors have led to a decline in local knowledge systems. Tourism has become the dominant income source, but dependence on imported food poses risks. Interventions recommended to strengthen the linkages between the cryosphere and the socioeconomic system for resilient and sustainable livelihoods.

Tuladhar (2020)	To explore the relationship between the cryosphere and high-mountain livelihoods in Langtang Valley	Changes in the cryosphere and socioeconomic factors have led to a decline in local knowledge systems. Tourism has become the dominant income source, but dependence on imported food poses risks. Interventions recommended to strengthen the linkages between the cryosphere and the socioeconomic system for resilient and sustainable livelihoods.
Shrestha and Devkota (2019)	To assess the impact of climate change on tourism and livelihoods in a mountain community	Climate change, climate change extremes, and induced disasters have significantly affected tourism and livelihood assets in the mountain region. Challenges include biodiversity loss, depletion of local resources, and increased climatic hazards. The study emphasizes the need for adaptation strategies to ensure sustainable tourism development in the face of climate change impacts.
K.C. (2016)	To investigate the impact of climate change on tourism and livelihoods in the Manaslu Conservation Area	Climate change impacts the tourism sector in the Manaslu Conservation Area. Recommendations include tourism promotion activities, awareness and education programs, gender empowerment, and sustainable measures to address the challenges and ensure sustainable tourism development.
Shrestha (2015)	To assess the impact of climate change on agriculture in the Prok Village Development Committee	Climate change affects agriculture in the Prok VDC, including changes in temperature, precipitation, and erratic rainfall patterns. Drought, delayed monsoons, and unseasonal heavy rains are major challenges. Local communities have adopted various strategies, but institutional support and long-term policies are needed to address climate variability effectively.
Rijal and Rijal (2014)	To examine the impacts of climate change on agriculture and livelihoods in Sirdibas village	Climate change has resulted in changes in temperature, precipitation, and cropping periods, affecting crop yields. Shifts in livelihood options and government policies have contributed to decreased crop productivity. Recommendations include enhancing agricultural resilience, promoting alternative livelihood options, and addressing socioeconomic factors for sustaining well-being and livelihoods in the local community.
Gaire et al. (2014)	To study the impact of climate change on treeline dynamics in the Manaslu Conservation Area	Abies spectabilis and Betula utilis exhibit differential responses to climate change. Upward shifting of Abies spectabilis and stable distribution of Betula utilis are observed. Climate change is expected to have long-term impacts on treeline dynamics in the study area.

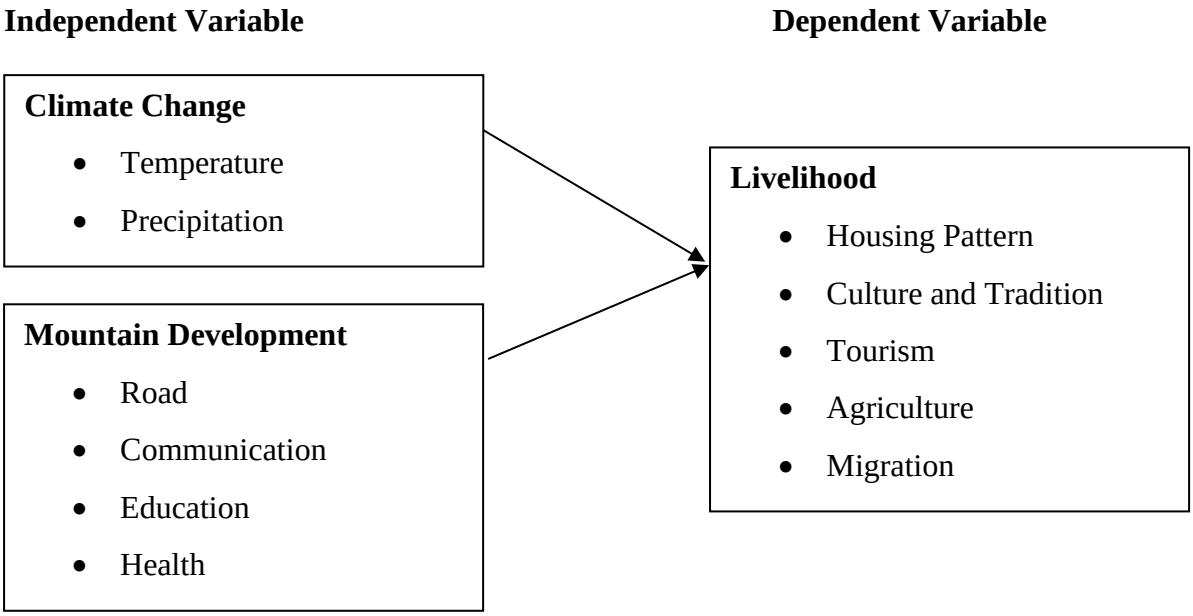
Nepal (2011)	To assess the vulnerability of the tourism industry in mountainous regions and propose adaptation strategies	Climate change poses risks to tourism in mountainous regions. The paper suggests adaptation strategies for tourism stakeholders, resident communities, and governments, emphasizing collaborative efforts, institutional development, and sustainable economic growth.

2.4 Conceptual framework

Based on the existing literature the following conceptual framework has been developed and based on it the thesis has been guided.

Figure 2.3

Conceptual framework



Source: Adapted from different literature

2.4 Research gap

Various authors have identified the impact of climate change in mountains, such as Steiger et al. (2022) examined the impacts of climate change on mountain tourism, emphasizing the importance of multidisciplinary understanding and adaptation strategies. Similarly, the author, Nyaupane and Timothy (2022) drew attention to the Himalaya's unique characteristics and its significance for tourism and development. They stress the need for a holistic approach to sustainable development. The majority of the author are focused on the vulnerability of the climate change and its impact on the livelihood of the people in the Mountain region.

However, there has been few focuses on the impact of mountain development on the livelihood of the people in the mountain area.

These studies underscore the importance of addressing climate change, sustainable development, and adaptation measures in mountain regions such as the Himalaya. This study has been conducted with the objective to analyze the impact of both climate change and mountain development in the mountain community of Nepal, which has not been studied at the same time. Similarly, this study has been done within the study area, i.e., Thini village, where such study has not been conducted.

CHAPTER III

RESEARCH METHODOLOGY

This chapter presents the research methodology adopted for the purpose of the study. This thesis paper was designed for the in-depth study of identified problems.

3.1 Research approach

Based on the nature of the study, this research has treated qualitative and quantitative methods as a prime method of the study. The qualitative method was used to collect the data through interviews, observations, and Key Informant Interview (KII) and Focus Group Discussion (FGD). While quantitative method was used to were collected from household survey.

3.2 Research design

A concurrent triangulation design was utilized by collecting data from qualitative and quantitative method at the same time and comparing the data from qualitative method to results from quantitative method to provide develop the final interpretation on climate change and mountain development in Thini village.

To carry out this research, data were collected through various methods such as interviews, questionnaires, and observations. The researcher engaged with local communities, policymakers, and experts in the field of mountain development and climate change to gather information and insights on the topic.

The data collected was analyzed using mixed methods, the statistical analysis combined with content analysis method for qualitative study. The results provided a comprehensive understanding of the current state of mountain development in Nepal, the impact of climate change on the region.

3.3 Study area and site selection

To conduct the study on the impact of climate change and mountain development, researcher has selected Thini of Ghaparjhong Rural Municipality, Mustang due to its historical, cultural

and geographical significance. The researcher visited the area for data and collected primary data using household surveys, unstructured interviews and focused group discussions with the KII of the Municipality. Field work for the research project began on May 25, 2023, and concluded on June 2, 2023. The researcher carefully chose a well-informed individual to participate in the study.

Thini was particularly selected for the study due to its location and its cultural and historical significance. It is located at the altitude of 2793.54 m and is located in longitude 83.72 and latitude 28.77. Thini village, one of the oldest Thakali villages in Thak Khola region does not categorize itself within Panchgaule (people from Pachgaun), instead they categorize themselves within Tingaule Thakali (lit. Thakali from three villages) which includes Thini, Syang and Chimang. According to the informants from Thini, they do not categorize those people who are originated from Marpha and Chhairo as original Thakali. They even do not have socio-religious relationships such as marriage and other local religious activities with Marpha and Chhairo.

Figure 3.1

Map of Thini

Source: Google Map, 2023

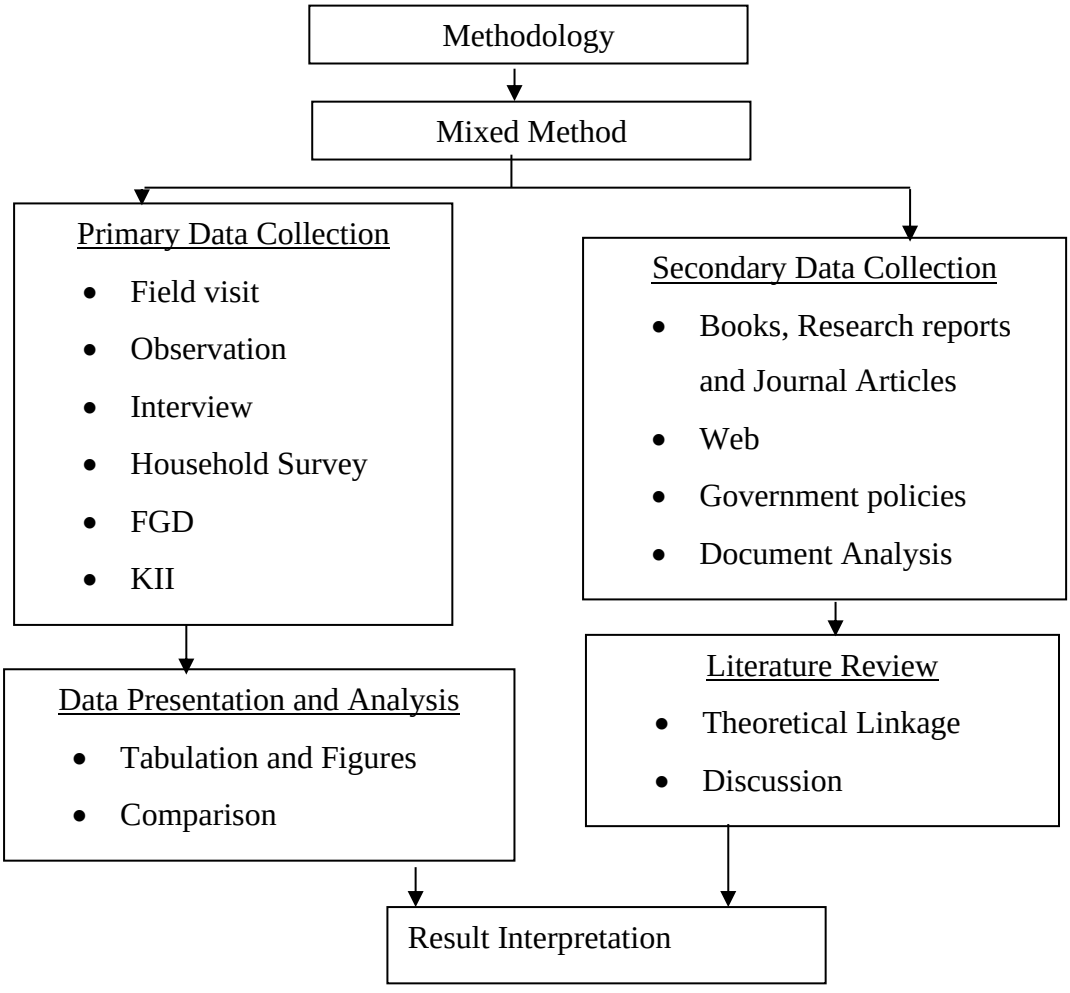
3.4 Nature and sources of data

The research collected data using both qualitative and quantitative method. For the qualitative method, this research explored the experience and perception of local communities and

policy makers on mountain development and climate change in Nepal. Similarly for the quantitative metho, a social survey was conducted among the local people of the study area. The data used in this study thus cover both primary and secondary. Primary data was collected through interviews conducted with community members, local leaders, and other stakeholders involved in mountain development and climate change activities. Secondary data was collected from published and unpublished reports, books, and academic journals on mountain development and climate change in Nepal.

Figure 3.2

Research flow



Source: Author's own work, 2023

3.5 Population and sample

For this research, researchers conducted household surveys. In the Thini area there were 121 houses. 50 percent of the total population were taken for the purpose of study with margin of

error 10 percent among them 63 houses were selected purposively selected for the purpose of survey. To collect the data and information, researchers visited the study areas, met the people of Thini to collect data from quantitative method and for data collection from qualitative method, FGD and KII were conducted to analyze the findings of the study.

3.6 Techniques and tools of data collection

The main source of primary data collection in this study was household survey and interviews. Structure questionnaire for household survey and unstructured questionnaire for interviews were conducted. In addition, observation and document analysis were used as complementary techniques to enhance the validity of the data.

3.6.1 Surveys

This research used household survey which included structured questionnaire and distributed among 63 respondents to analyze their view regarding the climate change and mountain development in the Thini village.

3.6.2 Interviews

For the interview an unstructured questionnaire was developed, and interview was conducted among KII in a more open-ended and flexible manner. Interviews were conducted in person, and to analyze the perspectives, experiences, and opinions of key stakeholders, including policymakers, experts, and local communities. A total of 10 interviews were conducted.

3.6.3 Focus group Discussion

A group of 10 participants was developed into a cluster and Focus Group Discussion was conducted in the topics to understand their general perception regarding the mountain development and climate change. A total of 10 members participated during the FGD conducted on 28th May 2023 in the Rural Municipality of Office.

3.6.4 Document analysis

The content analysis method for qualitative study involved reviewing and analyzing relevant documents, such as reports, policy documents, and academic literature, to gather information

on mountain development and climate change in Nepal. This method helped provide the context of the study via a comprehensive overview of the current state of knowledge and policy on the topic.

3.7 Data analysis and presentation

Data collected through both primary and secondary data were then tabulated in different figures and tables to develop the comprehensive understanding about the people's perception with an aim to identify patterns, relationships, and trends in the data, providing insights into the complex interactions between mountain development and climate change in Nepal. The triangulation method was used for this purpose.

3.8 Ethical consideration

In this study, the ethical guidelines outlined in the 7th edition of the American Psychological Association (APA) code of ethics were strictly followed. The research conducted was purely for academic purposes and did not receive any sponsorship. The study made a commitment to safeguard the confidentiality of individuals and organizations involved. Throughout the research process, there were no instances of dishonest practices. The sources and data used were treated with confidentiality, aligning with the fundamental ethical principles of research. In cases where necessary, identities were kept anonymous, and pseudonyms were used in qualitative sections to protect individuals' identities.

CHAPTER IV

FINDINGS AND DISCUSSION

4.1 Introduction of the study area

This study has three major objectives, i.e. To assess the impacts of climate change in the mountainous region of Nepal, to analyze how climate change and mountain development impact the livelihoods of people in Thini area and to examine the ways to mitigate the impacts of climate change. The study was conducted among the 63 respondents of Thini village. Similarly, the study conducted an interview among 10 respondents to analyze the impact of climate change. The respondents were selected based on their knowledge about the Thini village or have the knowledge regarding climate change and mountain development.

Thini village is one of the oldest villages in the Mustang district. In terms of infrastructure, Thini possesses a primary school, a primary health post, and a local private club catering specifically to the needs of the youth. Basic amenities like electricity and drinking water are available throughout Thini. All households have toilets and access to a drinking water tap within their own premises. However, a small proportion of households still rely on public drinking water taps, which are conveniently located within a 2–5-minute walking distance from their homes.

4.1.1 Tourism

Tourism has been one of the major income sources for the people of the Thini As Thini located near the Jomsoom area and is on the route to the Mustang, this area has been central for tourist for various reason. Thini holds cultural significance as one of the oldest settlements in the region and is part of the Panch Gaon or five villages, including Marpha, Syang, Chhairo, and Chimang. The village is known for its Bonpo Monastery and is also surrounded by attractions like Dhumba Lake and the impressive Kutsapterenga Monastery.

With construction of the road, the village has benefited from the mass tourism as well. As a result, people have established several hotels and restaurants and even have changed their houses as a homestay or hotels for the traveler. The major source of the livelihood for the people in the Thini village has been tourism.

4.1.2 Agriculture as a livelihoods

Agriculture also serves as the primary economic activity in Thini. All cultivable fields are categorized into two types based on the types of production. Fields cultivated for crops and vegetables such as *karu*, wheat, barley, buckwheat, potato, and various types of vegetables are categorized as "le" (known as "khet" in Nepali). Fields cultivated for apple trees are categorized as "*bhar*" (known as "*bari*" in Nepali). To protect the apple plants from wind, most villagers construct walls or fences around the *bhar* using materials like mud, stone, wood, or a mixture. The apple-planted fields are locally referred to as "*bikas*" (meaning "development").

4.1.3 Livestock

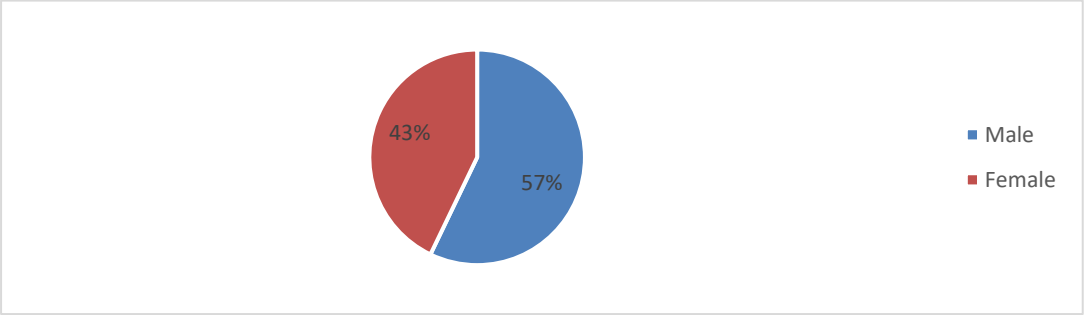
Livestock rearing is another important component of the agrarian lifestyle in Thini. villager's rear livestock for two purposes: to support agricultural cultivation (e.g., ploughing, manure, transportation) and to generate cash income (e.g., sale of meat, eggs, milk). Cattle such as cows, oxen, and *jhopa* are kept for agricultural activities, while sheep, goats, chickens, and mules are raised for cash income. Some households also keep horses for transportation. The study suggests that households with a sufficient number of livestock tend to have an easier time making a living compared to those with fewer livestock.

4.2 General characteristics of the respondent

A household survey was conducted among 20 respondents of Thini village. The general characteristics of the respondents are analyzed in the figure 4.1.

Figure 4.1

Gender of the respondents

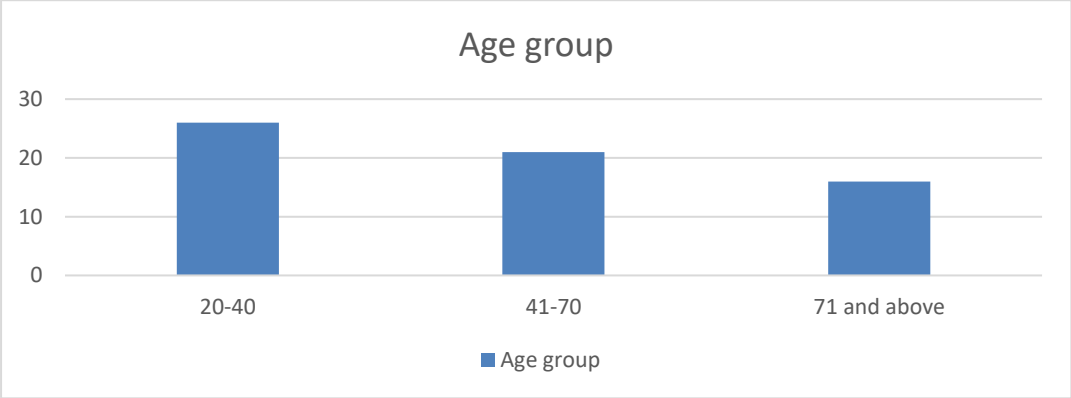


Source: Field Survey, 2023

Figure 4.1 shows the gender of the respondent. It was found that the respondents were evenly distributed between males and females, with 33 respondents (57 percent) identifying as male and 30 respondents (43 percent) identifying as female.

Figure 4.2

Age group of the respondent

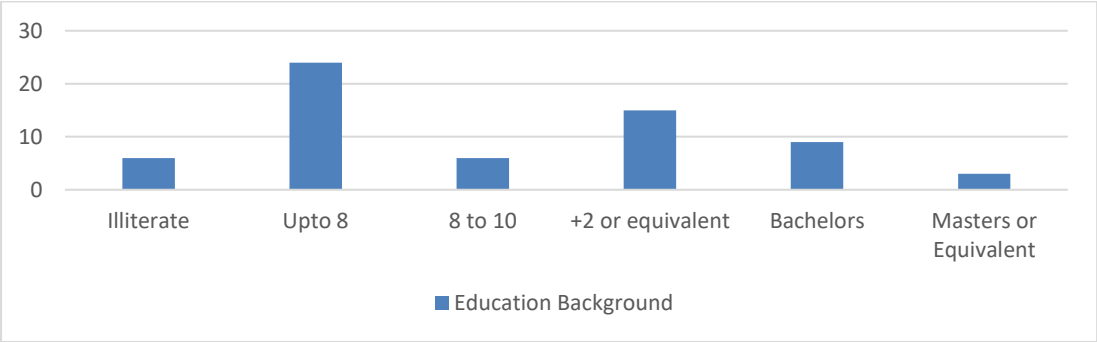


Source: Field Survey, 2023

Figure 4.2 shows the age group of the respondents. The respondents were categorized into three age groups. The largest proportion of respondents, comprising 26 individuals (41.27 percent), fell within the age range of 20-40 years. Another 21 respondents (33.33 percent) belonged to the age range of 41-70 years. The remaining 16 respondents (25.40 percent) were 71 years and above. This age distribution indicates a relatively balanced representation across different age groups.

Figure 4.3

Education background of the respondent



Source: Field Survey, 2023

Figure 4.3 illustrates the educational background of the student. Among the respondents, 6 individuals (9.42 percent) reported being illiterate, 24 individuals (38.10 percent) had completed education up to the 8th grade, 6 individuals (9.52 percent) had education between 8th and 10th grade, 15 individuals (23.81 percent) had completed education equivalent to the 12th grade (+2), 9 individuals (14.29 percent) held a bachelor's degree, and 3 individual (4.76 percent) had a master's degree or an equivalent qualification. This distribution showcases the educational diversity among the respondents, providing a range of perspectives based on their level of education.

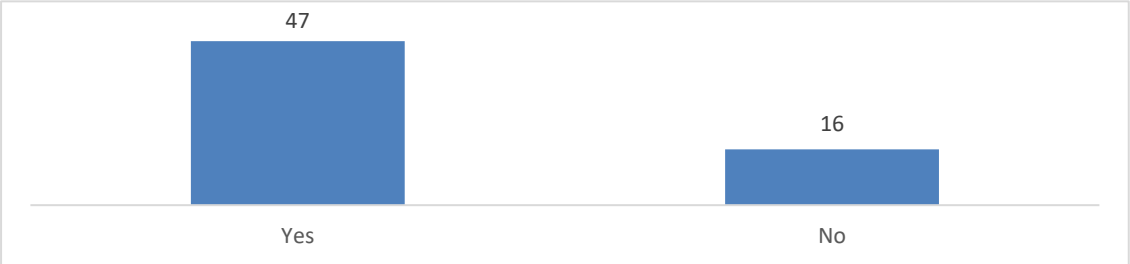
4.3 Impacts of climate change

The region's ecosystems are being impacted by the shifting patterns of temperature, precipitation, and wind. These modifications are resulting in altered population levels, altered migratory patterns, and a decline in biodiversity. Additionally, they have an impact on the abundance and distribution of both plants and animals. These alterations have the potential to affect both local communities and the tourism sector, stressing the need for action to mitigate the consequences of global warming and for the implementation of adaptation strategies to maintain the region's long-term viability.

The region's mountain ecosystems are also extremely susceptible to the effects of a changing climate. Water supplies are drying up, vegetation characteristics are changing, and landslides are becoming more severe and common because of rising temperatures and unstable rainfall patterns. Particularly susceptible to these consequences of climate change are overgrazed, unproductive grasslands, and abandoned lands, which render them unsuitable for producing crops of farmers' choosing and highly prone to invasive species.

Figure 4.4

Awareness about the Climate change

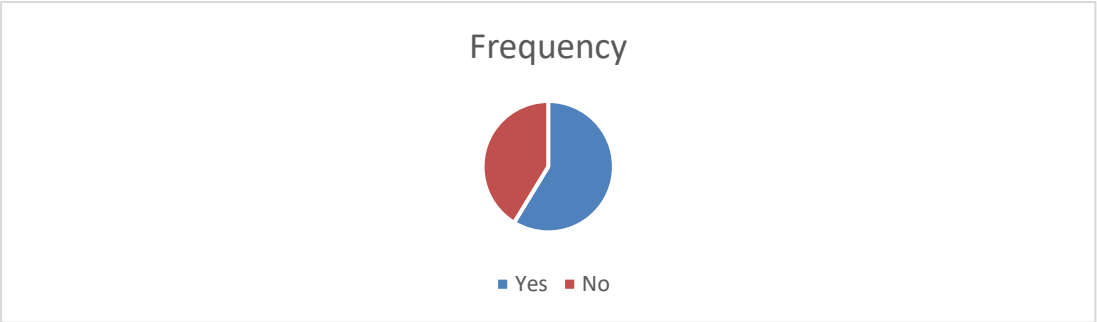


Source: Field Survey, 2023

Figure 4.4 illustrates whether the respondents were aware about climate change, a question was asked, and the data is tabulated in the figure. Out of the 63 respondents, 47 (74.60 percent) answered "Yes" indicating that they are aware of the impacts of climate change in the mountainous regions of Nepal. On the other hand, 16 respondents (25.40 percent) answered "No," suggesting that they are not aware of these impacts. This figure provides an overview of the distribution of responses and allows for a quick understanding of the respondents' awareness regarding the impacts of climate change in the specified region.

Figure 4.5

Noticed any changes



Source: Field Survey, 2023

Figure 4.5 shows the changes that the respondent has seen in the study area. Out of the 63 respondents, 37 (58.73 percent) answered "Yes" indicating that they have noticed changes in the climate patterns in Gharpajhong Rural Municipality over the past decade. On the other hand, 26 respondents (41.27 percent) answered "No," suggesting that they have not observed any significant changes. This figure provides an overview of the distribution of responses and allows for a quick understanding of the respondents' perceptions regarding climate pattern changes in the specified municipality.

One of the respondents stated that there has been a change in the snowfall pattern in the area. The snow fall pattern has changed, and the rain is not falling as used to fall. The change has impacted on the overall agriculture in the Thini village. Further one of the respondents stated that there has been frequent rainfall in the region, which is has been unusual as per the respondent.

4.3.1 Effect of climate change in mountainous region

Mountain communities and cultures are also affected by climate change">climate change. Transhumance - moving livestock from one grazing ground to another in a seasonal cycle - and traditional agriculture is dying out as grazing areas shrink and as water becomes scarcer. Tourism, mining, urbanization, and commercial forestry are also pushing out these traditional practices. Mountain heritage landscapes and indigenous cultures and knowledge are not adequately studied or valued.

Table 4.1

Challenges faced by people.

Response	Frequency	Percentage
Change in rainfall patterns	17	26.98
Increasing frequency of natural disasters	22	34.92
Changing temperature extremes	12	19.05
Water scarcity	9	14.29
Land degradation	3	4.76

Source: Field Survey, 2023

Table 4.1 shows that 26.98 percent of the respondents identified change in rainfall patterns as a major climate-related challenge, while 34.92 percent mentioned the increasing frequency of natural disasters. Changing temperature extremes were highlighted by 19.05 percent of the respondents, followed by water scarcity mentioned by 14.29 percent of the respondents. Finally, land degradation was identified as a major challenge by 4.76 percent of the respondents. This table provides an overview of the distribution of responses and highlights the main climate-related challenges perceived by the community in the specified municipality.

The mountain community of Thini has had major effects on daily life as a result of climate change. These include reduced water availability for agriculture, the spread of pests and diseases affecting crops and livestock, disruption of traditional farming practices, water scarcity due to reduced snowfall and glacial melting, infrastructure damage from extreme weather events, disruption of natural cycles and cultural practices, increased risks of natural

disasters, conflicts over limited resources, adaptation to alternative livelihoods, health challenges, and migration.

Table 4.2

Condition comparison to 30 years

Parameters of Impact of Climate Change	**Highly Increased (1)**	**Slightly Increased (2)**	**Same as before (3)**	**Slightly Decreased (4)**	**Highly Decreased (5)**	**Weighted Mean (6)**
Agricultural Production	0	0	7	16	40	4.75
NTFP's Production	0	0	16	37	10	4.10
Human Injury	3	13	31	16	0	3.10
Forest Fire	9	19	22	13	0	2.75
Mosquitos and other insects	9	34	16	4	0	2.35
Crop Disease	21	37	5	0	0	1.83
Invasive Species	0	19	25	19	0	3.15
Water Resources	0	0	13	22	28	4.45

Source: Field Survey, 2023

Table 4.2 shows that the weighted mean rating of 4.75 suggests that agricultural production has experienced a highly decreased condition compared to 30 years ago. This indicates that the impact of climate change has had a significant negative effect on agricultural output. Factors such as extreme weather events, changing precipitation patterns, and increased pest pressure might have contributed to this decline.

The weighted mean rating of 4.10 suggests a marginal decline in the production status of NTFP during the last 30 years. Forest resources like fruits, nuts, medicinal plants, and fibers are all considered non-timber forest products. The decline in their output may be related to altered ecological dynamics brought on by climate change, habitat degradation, and changes

in forest ecosystems. When compared to 30 years ago, the weighted mean rating of 3.10 shows that the state of human injury has remained largely stable. It implies that there hasn't been a discernible rise or fall in the overall effect of climate change on human injury throughout time. The condition of forest fires over the previous 30 years has marginally improved, with a weighted mean grade of 2.75. This may indicate a minor decline in the frequency or severity of forest fires. The overall trend is complicated, however, by the fact that regional variances and management strategies can have an impact on the frequency and severity of forest fires. The weighted mean rating of 2.35 suggests a slight increase in the condition of mosquitos and other insects compared to 30 years ago. This could indicate that climate change has created more favorable conditions for their proliferation. Factors such as temperature changes, altered precipitation patterns, and habitat modifications might have contributed to this increase.

The weighted mean rating of 1.83 implies a highly increased condition of crop diseases over the past 30 years. Climate change can influence the spread and severity of crop diseases through factors like altered temperature regimes, changing rainfall patterns, and shifts in pest populations. These factors may have collectively contributed to the observed increase in crop diseases.

The weighted mean rating of 3.15 suggests a slight increase in the condition of invasive species compared to 30 years ago. Invasive species can disrupt native ecosystems, outcompete local species, and pose challenges to biodiversity and ecosystem services. Climate change impacts, such as altered temperature and precipitation patterns, can create more favorable conditions for the establishment and spread of invasive species.

With a weighted mean rating of 4.45, the condition of water resources has highly decreased over the past 30 years. Climate change affects water availability and quality through altered precipitation patterns, accelerated glacial melting, and changes in hydrological cycles. These impacts can lead to water scarcity, reduced freshwater ecosystems, and increased competition for water resources.

4.3.1.1 Rainfall

In the region highest rainfall has been identified in the month of July and August, the trend of the rainfall pattern during these months over the years has been shown in the figure below:

Table 4.3

Rainfall pattern throughout the years in mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1993	14.4	8.2	45.3	8.1	8.4	13	21	52.3	121.7	0	0	0
1994	18.9	3	2.4	49	44	9	44.4	50	31.9	0	0	0
1995	24.3	7.4	63	11	8	63.6	36.4	60.6	65	1	38.6	
1996	8	39.6	9.8	29.7	9.2	4.3	22.8	75.9	19.5	145.6	0	0
1997	1.3	1.3	38.4	15.6	6.1	20.4	30.8	49	6.8	27.2	9	76.5
1998	0	4.4	47.1	2.4	4.2	15	52.2	33.1	6.1	30.8	6	0
1999	10.4	1.8	3	6.8	8.8	100	54.2	28	22.4	19.8	0	0
2000	1.6	5.4	33.8	8.3	15.2	45.1	23.8	21.6	22	0	0	11.8
2001	0	27.1	43.7	30.7	2.9	24.9	24.1	43.2	40.9	0	2.4	0
2002	20.2	52.1	35.3	18.1	14.7	9.6	24.8	41.2	62.7	9.7	19.8	0
2003	4	24	16.2	33.9	20.8	48.6	34.2	80.3	46.2	7	0	3.6
2004	19	1.4	0.5	30.4	24.8	15.2	49.4	51.8	18.8	19.4	12	0
2005	13.5											
2006	0	6	80.1	23.5	25	36	55	38.5	27	7.4	0	0
2007	0.5	45	37	8	5.9	15	81.4	45.6	68.5	25.5	3	0.1
2008	3	10	41.3	10	17.2	21.6	36.9	41.8	106.4	0	0	0
2009	0	0	27.3	28.8	53.5	9.6	32.8	55.3	22.8	84.8	6.6	0
2010	0	33	6.1	6	15.4	57.7	85.7	23.2	50.2	6.6	2.3	0
2011	16	28.5	1.8	21	2.9	44.2	37.2	44.8	24.8	0.9	0	0
2012	18.2	15.1	3.7	24.6	25.6	9.2	60.1	39.5	12.5	4.1	0	2
2013	15.9	62.8	3	25.7	20.8	118.4	61.5	48.8	17.7	18.7	0.7	0
2014	27.8	27.8	9.6	36.9	34.6	10.6	71.3	20	9.6	75.3	0	25.3
2015	83.8	15.2	98.1	45.4	6.8	74.9	32.2	28.9	8.1	8.4	6.2	0
2016	3.3	3.2	23.8	35.2	23.3	15.2	104	16.4	23.3	13.8	0	0.5
2017	34	5.1	15	30.9	35.1	16.7	76.8	27.1	29.2	2	0	3.3
2018	9.5	10.7	57.8	11.5	23	24.8	41.1	76.5	46.2	0	0	0
2019	15.5	75.9	15.8	20.6	10.4	25.5	52.9	51.6	40.2	5	3.5	19.4
2020	26.81	25.31	98.15	24.94	32.05	54.54	59.66	27.51	49.62	0	2.22	2.2
2021	0.01	5.72	23.16	30.3	88.8	199.9	88.2	91.4	50.8	45.2	0	42.3
2022	1.7	17.4	8.4	33.2	34.1	32.1	56.9	28.01	39.51	144.2	1	0
Average	13.11	19.66	29.72	22.28	21.44	37.82	49.47	44.99	36.65	23.92	4.11	6.44

Source: Department of Hydrology and Meteorology, 2023

Table 4.3 shows the trend of the rainfall during the last five years in the Thini area has been more than the average rainfall in the 30 years. Throughout the year, there is a clear pattern of precipitation deviation from the average in the recorded data.

January consistently shows lower or significantly lower precipitation in all years. In February, most years also experience lower precipitation compared to the average. Moving into March, all years, except 2019, exhibit lower precipitation than the average. As April approaches, 2018 and 2021 stand out with higher precipitation than the average, while the other years report lower values.

May portrays a remarkable contrast, as 2021 shows significantly higher precipitation than the average, while the rest of the years record lower values. Similarly, in June, all years, except 2020, witness lower precipitation compared to the average. As we enter the mid-year, July, August, and September continue to demonstrate a trend of drier conditions in 2017, 2018, 2020, and 2022, with lower precipitation than the average.

Heading into October, we observe an even more pronounced pattern, with 2017, 2018, 2020, and 2022 reporting significantly lower precipitation than the average. November follows suit, with the same years experiencing lower precipitation than the average. In December, all years, except 2019, show lower precipitation compared to the average.

Overall, a clear pattern emerges, indicating that 2017, 2018, 2020, and 2022 have consistently experienced drier conditions across most months compared to the average. Conversely, 2021 stands out with some exceptionally wet months, particularly May and June. On the other hand, 2019 generally saw precipitation levels closer to the average for the majority of the year. Notably, 2020 had an unusual spike in March, with significantly higher precipitation than the average.

4.3.1.2 Temperature

The temperature has risen to some extent in the last 30 years, which could be seen in the table 4.4.

Table 4.4

Maximum temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1992	12.59	9.44	16.52	19.78	19.24	22.26	23.04	22.57	21.37	17.58	14.49	12.22
1993	10.22	12.05	12.82	17.89	20.91	22.97	23.51	22.65	19.81	18.29	14.68	12.45
1994	11.25	10.36	16.11	0.00	22.59	23.94	24.13	22.12	20.73	17.42	12.86	10.47
1995	6.59	9.27	13.16	0.00	0.00	22.68	22.48	21.99	20.39	18.35	14.06	10.76
1996	9.90	9.97	15.60	17.88	20.98	21.68	22.77	21.76	20.85	15.70	14.39	13.30
1997	8.85	7.87	13.78	15.18	19.53	22.00	23.12	22.03	20.76	14.41	12.70	6.79
1998	9.99	10.26	12.70	18.48	22.11	23.93	22.40	22.52	22.05	19.07	16.23	13.14
1999	10.26	14.56	17.36	21.21	21.08	21.47	22.22	21.82	21.23	17.77	14.87	10.91
2000	9.80	8.42	12.06	19.21	21.13	21.62	22.52	22.34	20.12	19.00	14.04	12.90
2001	11.36	12.58	13.73	17.31	20.64	22.34	23.18	22.01	20.62	18.47	15.42	11.84
2002	9.59	11.89	15.14	18.71	20.35	22.32	22.94	22.66	20.28	17.52	14.51	11.35
2003	11.94	10.87	14.26	19.34	19.50	21.97	22.46	22.45	20.95	18.97	14.45	10.28
2004	9.54	12.59	18.15	18.72	20.81	22.05	22.40	22.89	21.46	16.52	12.94	12.98
2005	9.13	11.21	16.99	18.40	20.30	23.38	22.27	22.91	21.70	17.02	14.53	13.12
2006	13.59	15.86	14.45	17.39	20.81	21.94	22.88	22.53	21.72	17.98	14.29	13.69
2007	11.85	9.46	14.74	19.87	21.68	23.37	22.66	22.53	20.94	18.10	14.29	12.81
2008	9.50	11.20	14.88	18.12	20.41	22.76	22.76	22.31	20.66	17.87	16.88	14.11
2009	13.98	15.06	15.29	19.50	19.62	22.77	23.72	22.63	21.44	17.94	14.56	12.52
2010	13.30	12.02	17.79	20.88	20.96	22.60	22.25	22.55	20.86	18.81	15.62	13.65
2011	10.39	12.71	15.98	17.33	21.54	22.08	22.53	22.49	21.70	18.14	14.75	12.18
2012	7.92	11.90	15.70	17.34	20.60	23.50	22.78	22.62	21.81	18.18	14.40	14.14
2013	10.38	10.41	17.17	20.19	20.96	21.76	22.45	22.56	21.82	18.25	15.21	12.33
2014	10.35	11.80	15.10	17.99	20.68	23.82	22.99	23.17	21.89	17.45	15.41	12.56
2015	8.70	13.11	14.00	16.72	21.55	22.21	22.84	22.87	22.33	18.16	16.07	12.07
2016	10.29	14.22	16.42	19.95	20.40	23.11	22.30	23.24	22.05	18.90	16.68	16.22
2017	11.86	13.90	14.48	19.80	20.12	23.42	22.70	22.85	22.02	19.61	14.86	15.15
2018	12.33	13.06	15.71	18.17	20.52	23.01	23.31	22.58	21.54	17.29	14.92	10.80
2019	8.42	9.30	14.79	19.44	21.11	23.00	23.23	23.52	21.51	19.16	16.31	11.45
2020	8.74	11.96	14.16	17.01	19.54	21.44	22.37	23.50	21.93	20.37	15.00	12.82
2021	12.55	12.85	15.42	17.34	18.85	20.57	21.72	22.50	21.46	19.19	14.21	10.63
2022	9.00	9.65	18.29	20.25	20.20	23.17	23.15	23.41	21.17	16.70	15.63	15.04
Average	10.46	11.61	15.25	17.40	19.96	22.55	22.78	22.60	21.26	18.01	14.82	12.41

Source: Department of Hydrology and Meteorology, 2023

Table 4.4 indicates that during January, most years recorded maximum temperatures higher than the average, except for 2019, 2020, and 2022, which had temperatures on par with or

slightly below the average for the month. Moving into February, the year 2022 stood out with temperatures below the average, while all other years reported temperatures above the average for February.

As March arrived, cooler conditions prevailed for 2018, 2019, 2020, and 2022, as their maximum temperatures were lower than the average for the month. On the other hand, April displayed a more diverse pattern, with 2018, 2019, and 2022 experiencing cooler temperatures than the average, while 2020 and 2021 witnessed temperatures higher than the monthly average.

When May arrived, all years demonstrated temperatures exceeding the average, with 2021 displaying the most significant deviation with notably higher temperatures. June presented a mix of conditions, as 2018 and 2019 reported lower temperatures than the average, while 2020, 2021, and 2022 registered temperatures above the average for the month.

July showcased consistently higher temperatures than the average across all years. In August, 2018, 2019, and 2022 recorded temperatures lower than the average, whereas 2020 and 2021 exhibited temperatures higher than the monthly average.

As September approached, 2018, 2019, and 2022 experienced cooler temperatures than the average, while 2020 and 2021 saw temperatures surpassing the average. In October, a majority of the years reported temperatures above the average, except for 2018 and 2022. November followed a similar trend, with temperatures consistently higher than the average for all years. Finally, in December, all years displayed temperatures above the average, indicating warmer conditions during this month.

Its comparisons unveil a diverse mix of warmer and cooler temperature trends across different months and years. Certain months consistently exhibited higher temperatures than the average (e.g., May, July, November, and December), while others showcased lower temperatures (e.g., January, March, and September).

This comprehensive analysis provides valuable insights into the temperature variations throughout the year, aiding in understanding the seasonal patterns and climate changes experienced during these years.

Table 4.5

Minimum average

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1992	-2.98	-2.64	2.33	2.53	4.92	10.58	12.62	13.23	10.26	6.22	0.46	-0.72
1993	-1.03	-1.61	-1.03	3.04	6.24	11.71	13.87	13.86	10.34	4.98	1.62	-2.11
1994	-1.80	-2.78	1.49	2.38	6.10	11.92	13.97	13.99	11.82	5.53	0.65	-0.89
1995	-3.42	-0.15	2.30	3.95	9.07	14.15	14.16	13.98	11.65	6.83	2.45	-0.26
1996	-1.26	-0.28	3.53	4.49	7.85	12.15	14.57	13.66	11.57	6.13	2.47	-0.51
1997	-1.94		1.96	3.59	7.53	11.26	14.55	13.41	11.76	2.70	1.86	-2.87
1998	-1.53	1.04	1.97	5.76	9.84	12.48	14.50	14.79	12.46	7.93	3.52	0.25
1999	-1.91	2.15	3.46	6.42	10.15	11.99	14.39	13.72	12.29	6.63	2.52	-0.40
2000	-0.86	-2.60	0.42	5.86	10.38	13.34	14.15	14.10	11.07	6.35	3.17	-0.48
2001	-0.91	0.24	1.23	4.19	9.67	13.31	14.52	14.35	11.39	7.03	2.21	-1.00
2002	-1.35	0.00	2.95	5.61	9.25	13.13	14.92	13.76	10.82	5.44	2.44	-0.71
2003	-1.21	-1.21	1.93	3.78	7.08	12.55	14.44	14.62	12.83	5.41	2.37	-1.40
2004	-1.92	0.49	4.84	6.20	9.43	12.58	14.31	14.33	12.94	5.13	1.01	-0.10
2005	-0.80	0.20	3.09	4.44	7.09	11.60	14.55	14.37	11.99	5.84	0.89	-1.01
2006	-0.27	2.28	1.70	4.95	10.30	12.04	14.51	13.67	11.45	5.27	1.30	-0.38
2007	-1.33	-1.50	2.16	5.84	8.25	12.94	13.95	13.77	12.04	6.41	1.23	-1.55
2008	-0.53	-1.54	1.75	3.83	6.84	12.78	13.69	13.28	9.84	4.03	1.74	-0.38
2009	-0.60	-0.30	1.05	5.27	7.21	10.87	13.65	13.41	10.59	4.40	0.73	-1.57
2010	-1.80	-1.47	3.27	5.58	7.62	11.42	13.79	13.79	11.41	5.54	2.48	-2.97
2011	-3.21	-1.25	1.72	2.89	7.86	11.38	13.60	13.14	11.67	5.08	1.79	-3.12
2012	-3.93	-1.47	1.22	3.49	6.08	11.31	13.97	13.41	11.21	3.68	0.31	-0.84
2013	-2.31	-0.31	2.59	5.27	8.52	13.37	14.84	13.83	11.59	7.64	0.58	-0.94
2014	-2.34	-0.42	1.53	3.82	7.41	12.53	14.69	14.37	11.87	4.55	1.75	-0.63
2015	-1.14	0.33	2.64	4.09	8.11	11.42	13.45	14.03	11.71	5.63	2.19	-1.34
2016	-1.99	0.83	2.57	5.18	7.72	12.83	14.07	13.54	11.44	6.24	0.25	0.41
2017	-2.76	0.72	2.62	5.60	7.80	12.32	13.91	14.40	11.42	7.26	0.46	-0.49
2018	-2.10	0.13	2.19	4.84	8.32	12.60	14.63	13.87	11.94	3.47	0.35	-3.09
2019	-3.81	-2.15	0.77	4.61	5.38	10.27	12.61	12.41	10.89	4.78	1.73	-2.86
2020	-3.25	-1.55	0.30	2.40	6.14	10.75	12.48	12.20	11.16	4.72	0.25	-1.49
2021	-2.41	-0.88	0.82	1.71	6.94	10.54	12.69	12.73	10.91	5.92	-0.58	-2.60
2022	-2.94	-3.95	3.15	5.05	7.16	10.73	11.93	11.48	9.76	2.17	-2.03	-3.58
Average	-1.92	-0.65	2.02	4.41	7.81	12.03	13.93	13.66	11.42	5.45	1.36	-1.28

Source: Department of Hydrology and Meteorology, 2023

According to table 4.5, it is revealed that diverse temperature patterns across different months and years. In January, most years display temperatures slightly higher than the average, except for 2019, 2020, and 2021, which recorded temperatures that align closely with the average for the month. As February arrives, 2017, 2018, and 2021 stand out with

temperatures below the average, while the remaining years report temperatures slightly higher than the average.

March brings further distinctions, as 2022 experiences significantly higher temperatures compared to the average, while 2017, 2018, and 2019 encounter temperatures lower than the average. Similarly, April witnesses a noticeable contrast, with 2017, 2018, 2019, and 2022 all reporting temperatures below the average, while 2020 and 2021 depict temperatures slightly above the monthly average.

Moving into May, all years record temperatures higher than the average, and 2021 emerges with the most prominent deviation, showcasing notably higher temperatures. As June unfolds, 2017 and 2022 report temperatures lower than the average, while the other years display temperatures slightly higher than the average for the month.

July indicates uniformly higher temperatures across all years compared to the average, presenting a consistent trend. In August, 2017 and 2022 report temperatures are slightly lower than the average, whereas the other years exhibit temperatures slightly above the average.

September portrays a contrasting picture, with 2017, 2018, 2019, 2020, and 2022 experiencing temperatures lower than the average, while 2021 encounters temperatures slightly higher than the average. October follows suit, with all years, except 2022, showing temperatures below the average.

November presents another consistent trend, as all years, except 2017 and 2022, report temperatures higher than the average. As December approaches, 2017, 2018, 2021, and 2022 record temperatures below the average, while 2019 and 2020 exhibit temperatures slightly above the average for the month.

This comprehensive analysis provides valuable insights into the temperature variations throughout the year, showcasing a mix of temperatures above and below the average across different months and years. Certain months consistently display temperatures higher than the average (e.g., May, July, and November), while others depict temperatures lower than the average (e.g., March, April, September, October, and December). These comparisons offer a deeper understanding of the seasonal patterns and climate changes experienced during these years.

According to a report the global temperature has increased at an average rate of 0.14 degrees Fahrenheit (0.08 degrees Celsius) per decade since 1880; however, the average rate of increase since 1981 has been more than twice as fast: 0.32 °F (0.18 °C) per decade. In the case of the Thini, the average temperature change observed was 0.48^0 C within the period of three decades, which approximately closer to the global temperature change i.e. 0.54^0 C in the last three decades.

According to respondents' observations, climate change causes more frequent and intense extreme weather occurrences such as heavy rainfall, storms, and droughts. These changes increase the risk of flooding, crop damage, and mountain communities' vulnerability to natural disasters. Weather patterns that are erratic make it difficult to plan agricultural activities and adapt to changing conditions. Field observations in the Thini region show that climate change has had a substantial impact on how people live. People used to live in buildings with mud roofs, which gave protection against leaks even during snowfall. Recent strong rains, however, have destabilized these roofs, leading residents to replace them with Galvanized Tin roofs in order to adapt and limit the risk of leaking caused by the rain. One of the respondents regarding the housing pattern, stated that

> *Now the villagers are actively changing the roof. The traditional roof made up of mud no longer withstand the rain, which were not common in the area. They have even began the construction of the RCC building and traditional roofs are no being replaced by Galvanized tin.*

This shows how climate change has made people adapt to a new livelihood style by completely switching from the traditional livelihoods pattern to more modern one.

4.3.1.2 Land coverage

Forest land, which was formerly abundant in the study area, has declined dramatically as a result of a variety of circumstances. Increased human pressure, road access, and tourism have all contributed to forest degradation. Deforestation has been exacerbated by the demand for timber production, notably in the study region. Grasslands in the study area have also declined, owing mostly to rising temperatures and decreased snowfall. Rising temperatures and a lack of snowfall have resulted in less moisture in the rangelands. Many studies have documented shifting tree lines and vegetation in diverse regions, but the Trans-Himalayan

region presents a unique scenario due to its specific biogeography, site characteristics (cold desert), and human effects.

The presence of younger tree species such as Betula utilis and Abies spp. showed that the tree line had migrated to higher elevations than its existing range in the research area. Several research have found that species distributions are shifting as a result of climate change. However, the ability of species to relocate to higher elevations in the Himalayas is limited due to factors such as soil types and water resources. Several species may suffer extinction if such activities persist in the Trans-Himalaya region.

4.3.1.3 Changing biodiversity

Mountain habitats have a distinct biodiversity, but climate change threatens these delicate ecosystems. Temperature and precipitation patterns can cause habitat disruption, resulting in changes in the distribution and composition of plant and animal species. Certain species may become extinct, affecting ecosystem dynamics and traditional livelihoods. When asked about the biodiversity one of the respondents stated that:

> *There has been a change in the overall pattern of agriculture. As Thini was considered one of the highest places to grow apples, now people in higher altitudes can grow apples. This has resulted in a decrease in the demand for the apples grown in the Thini Region. Similarly, there has been incident where the trees had been infected by insects, which were not seen few years back.*

Table 4.6

Impact of climate change on agriculture

Response	Frequency	Percentage
Reduced crop yields	27	42.86
Shift in planting and harvesting seasons	18	28.57
Increased pest and disease infestations	12	19.05
Water scarcity and irrigation challenges	6	9.52

Source: Field Survey, 2023

According to Table 4.6, 42.86 percent of respondents indicated decreasing crop yields because of climate change. A shift in planting and harvesting seasons was mentioned by

28.57 percent of respondents, while increasing insect and disease infestations were mentioned by 19.05 percent. Also, 9.52 percent of respondents reported water constraint and irrigation issues. This table summarizes the distribution of replies and sheds information on the effects of climate change on agriculture and farming practices in the region, as reported by those polled.

4.3.1.4 Habitat disruption

According to field observations and responses from respondents, changing climate conditions, such as rising temperatures and shifting precipitation patterns, disturb habitats in mountainous locations. Species that have adapted to specific temperature or moisture levels confront difficulties as their environments alter or decline. Temperature and moisture availability changes influence vegetation patterns, resulting in changes in forest composition and the expansion or contraction of habitat ranges. Even the housing pattern of the people in the Thini region has been changed. There are a number of houses who had now built the roof of Galvanized tin and even concrete houses are being built. The figure illustrates an example of such activity.

Figure 4.6

Showing the galvanized tin in the Thini village

Source: Field Survey, 2023

The figure 4.6 illustrates the change in pattern of the housing in the study area. People of the Thini are now adapting to the climate change by changing the housing pattern and its structure. People are building concrete houses and roofs of galvanized tins as seen in the photographs above.

4.3.1.5 Species distribution

Climate change causes adjustments in the geographic ranges of plant and animal species. Species tend to migrate to higher elevations in search of suitable habitat as temperature and moisture conditions change. As a result, the composition and organization of ecosystems changes. Certain species may become extinct locally in some places if they are unable to adapt or disperse to new habitats, whilst new species may occupy previously unsuitable areas. Based on one respondent, there has been an incident of sighting of Mosquitos in the Thini village, which were not found before.

4.3.1.6 Impact on livelihoods

Nepal's mountainous areas rely largely on agriculture, forestry, and tourism. Climate change has an impact on several industries, affecting traditional livelihoods. Changes in water availability, crop yields, and natural resources can lead to lower agricultural production, biodiversity loss, and diminished tourism prospects, all of which have an influence on local economy. The Himalayas and their inhabitants are particularly vulnerable to climate change owing to a number of causes. For starters, rising temperatures in the high peaks have already increased Glacial Lake Outburst Floods (GLOFs), causing landslides, soil erosion, and flash floods downstream. Second, mountain people are strongly reliant on rain-fed agriculture as their primary source of income, with little chances for non-farm work or diversification, which is more viable in the Terai area. Third, residents of the mid-hills and mountains rely heavily on livestock rearing, even more so than those in the Terai, and livestock are particularly vulnerable to rising temperatures, decreased fodder production, and worsening extreme weather events such as landslides, droughts, and increased rainfall. These modifications can result in decreased animal weight, poorer feed conversion, decreased milk output, and impaired reproduction. Fourth, when temperatures increase, the storage of animal goods such as meat and milk become more difficult, owing to insufficient cold chain infrastructure. Moreover, impoverished small-scale farmers and Agro-business owners have

restricted access to current cold chain facilities. The construction of the road had a negative impact on the livelihood of the people in the aera. One of the respondents stated that:

> *Prior to the development of roads, people used to walk from the Jomsom to the Mustang and would prefer to stay in the Thini region. However, as the construction of the road is seen, people could easily travel to their desired destination and return back to Jomsom. This has led to a decrease in the flow of tourism in the area.*

In most cases, the construction of the roads is a major reason for the economic opportunities. However, in the case of Thini the construction of the road has reduced their economic opportunities, i.e., tourism.

In contrast, one of the respondents claimed that, rather than having a negative impact, climate change has created possibilities for the people in the region. Climate change has resulted in shorter cold seasons, while rising temperatures have permitted people to travel during formerly inaccessible seasons. This has resulted in a decline in seasonal migration in the Thini region. Additionally, this has resulted in the growth of tourism to meet the needs of tourists all year.

Table 4.7

Impact on the livelihood

Response	**Frequency**	**Percentage**
Decreased agricultural productivity	27	42.86
Loss of traditional livelihood sources	18	28.57
Increased reliance on off-farm income sources	13	20.63
Limited opportunities for income diversification	5	7.94

Source: Field Survey, 2023

According to table 4.7, 42.86 percent of respondents indicated lower agricultural production as a result of climate change. 28.57 percent of respondents mentioned the loss of traditional livelihood sources, while 20.63 percent mentioned an increased reliance on off-farm income sources. Also, 7.94 percent of respondents reported a lack of chances for income diversification. This table summarizes the distribution of responses and gives insight on the effects of climate change on the livelihoods and income-generating activities of the local people as reported by the respondents polled.

4.3.1.7 Treeline shifting

The movement of the treeline to a higher elevation than its current range in the research region. Yet, soil types and water supplies are limiting variables in the process of moving the species upward. If such a process persists, linked species are at risk of extinction, and the previous location must be replaced by new species. This could be seen the photograph below:

Figure 4.7

Tree line shifting

Source: Field Survey, 2023

The figure 4.7 shows the shifting in the treeline. As stated by one of the respondent the trees were not able to grow in the past, however now the trees are growing at such altitude as well.

4.3.1.8 Warmer winters

Warmer winters have been the most widespread climatic change perceived by the tourism stakeholders of lower Mustang. The stakeholders‟ general perception is that it has become warm in winter, as well as dry. As one interviewee stated:

> *In earlier days winter used to be very cold while summer, just warm. But now a days the place has become very warm in winter. This has impacted on the seasonal migration and people are able to stay within the village. Similarly, people from various part of the country are also able to stay in the village and contribute to educational and health development in the area.*

From the stakeholder's perspective, the decrease in snowfall resulted in both positive and negative impacts. The positive impact is that winter is no longer a barrier for trekking tourism in lower Mustang. The negative impacts of warmer winters are the loss of the

natural/aesthetic beauty of the place and reduced water availability. Decreased snowfall in winter meant mountains left with patchy thin cover of snow that the stakeholders fear would lose the natural and aesthetic beauty of the mountains. Sharing the concern one of the respondents stated that, tourists arrive at the Thini to see the snowy mountain however depletion of the snow will negatively impact the arrival of tourist as major attraction of the village will be lost.

4.4 Development in the Thini area

Thini is the nearest town to Jomsom Airport, although there hasn't been much growth in the area for a long time. The development of a road connecting Jomssom to Mustang via the Thini region has created several chances for the locals. Visitors from all around the country were able to get to Thini with relative ease. Similarly, because of the area's proximity to road infrastructure, additional development initiatives such as communication, education, and health infrastructure were built. The impact of the development activities in the Thini village has been analyzed through the survey questionnaire in the table 4.8.

Table 4.8

Impacts of the development activities

Response	Frequency	Percentage
Improved infrastructure and access to services	37	58.73
Environmental degradation	16	25.40
Socioeconomic development	10	15.87

Source: Field Survey, 2023

According to table 4.8, 58.73 percent of respondents highlighted increased infrastructure and access to services because of development operations in the Thini region. This shows that the implementation of development projects has likely led to the construction or improvement of roads, bridges, schools, healthcare facilities, and other essential services that have positively affected the quality of life for the local population. Improved infrastructure can enhance mobility, connectivity, and access to education and healthcare, contributing to the overall development and well-being of the community. Environmental damage was mentioned as a potential impact of these actions by 25.40 percent of respondents. Also, 15.87 percent of respondents named socioeconomic growth as one of the consequences.

4.4.1 Roads development

The advantages of the road are emphasized, including improved mobility, lower prices for commodities, and simpler access to healthcare and educational services. The locals, who are happy to have the road, can especially see these advantages.

Development, though, might sometimes have unfavorable effects. The effects on the environment include increased plastic waste owing to the consumption of packaged items rather than locally produced goods and air pollution brought on by automobile emissions. Additionally, due to more convenient transportation, illegal logging has increased, causing wasteful shipping and deforestation, which adds to pollution.

Development faces difficulties on the social front as well. The changes brought on by urbanization are challenging for the younger generation. Families can afford to send their kids to schools outside the area, but when they return there aren't enough jobs available for them.

Another issue with development is the loss of cultural assets. Traditional ways of life frequently change as a result of development's increased connectivity to the modern world, which can also cause cultural practices to disappear Outsiders and trekkers who have seen similar development in other locations claim that culture is bound to change, despite the fact that some locals may not instantly notice the impact on their way of life.

4.4.2 Tourism and agricultural development

Because it is now simpler for people to get to the area, improved road access may have drawn more tourists to the Thini region. The local community has benefited from the increased tourism in terms of development and economic prospects. For the people of Thini, tourism-related businesses including homestays, hotels, and cultural exchanges offer new sources of income. During the visit, it was discovered that most of the residences had been renovated to serve as hotels or homestays.

However, the tourism practices are adapting towards the need of the tourist rather than adopting their traditional culture.

One of the respondents regarding the culture and tradition of the Thini stated

> *when the tourist used to visit the area, they were greeted with the traditional tea of the Thini area, however due to more commercialization tourists can easily get coffee or tea in the Thini area, sitting in modern themed restaurant and hotel, which could be seen as a decline of the traditional culture.*

This is similar to the character identified by as Kunwar's definition of the acculturation process (2017). He continues by saying that tourists not only bring in money to the area, but they also bring with them a strong and obvious way of life. Their attire, eating habits, and social behavior all provide something fresh and distinctive to the region where they are visiting. By nature, people adopt new behaviors or ways of doing things that they find pleasant (Kunwar, 2017). The people of the Thini have experienced this identical situation. The Thini people have been given a fresh opportunity as a result, but at the same time, acculturation has taken place, slowly eroding the importance of tradition.

Additionally, it was discovered that Dhumba lake, which Guru Rinpoche blessed while traveling, is today a popular tourist destination. Animals were kept out of the holy lake by a barrier covered in prayer flags. The lake was not a popular destination for the tourist, but as it has become more well-known, they are coming in greater numbers every year.

The development of agrotourism is comparable. For instance, the opening of Uman Agriculture and Livestock Farm in the study area has given the region a chance to draw in agro-tourists. As a result of the widespread conversion of residences into hotels, homestays, and restaurants, tourism is now a viable alternative source of income.

As Mustang falls within the high Himalayan Mountain system [the world's 7th and 10th highest mountains, Dhaulagiri (8,137 m.) and Annapurna (8,161 m.)], the interplay of climate change with the multiple stressors above, poses both opportunities and risks to the tourism. For instance, climate change has extended summer season and warmer winter which means extended season and tourism business in the Thini region. Higher levels of visitation brought about by the extended warm weather tourism season may have several implications on tourism management in this region. There are other imminent risks associated with climate change impact which could affect the destination's appeal, transportation infrastructure and operations, the resource base (natural and human), the sustainability of tourist facilities and the destinations.

4.4.3 Education

In the past, elder generations were proud to send their kids to study abroad in places like Pokhara, Kathmandu, and even India. The elder generations, who have not shared the same experiences, are opposed to the current generation of adolescents because they are the first to leave the area. The local area of Thini benefits from the establishment of The Mukti Namuna Secondary School. As teachers from other regions of the nation travel to teach the students, the standard of education has also increased. This shift in interest to the location is the result of the expansion of transportation infrastructure in the region and the warmer weather.

4.4.4 Health

There is a single health post in the Thini area. It has now facilitated people with various health services which people did not get few years back. Further climate change has resulted in warmer temperatures resulting people from different parts of the country to come and easily adapt in the region. Similarly, the seasonal migration has now reduced, and health post officers are available throughout the year.

4.4.5 Communication

The area has been connected by different communication channels. The availability of mobile networks in the Thini region has led to a change in the people's lifestyle.

4.4.6 Challenges of mountain development in context of climate change

Table 4.9

Challenges of mountain development in context of climate change

Challenges	Frequency	Percentage
Limited infrastructure	51	85
Vulnerability to natural disasters	45	75
Poverty and limited economic opportunities	42	70
Loss of cultural heritage	33	55
Lack of access to education and healthcare	36	60
Other	9	15

Source: Field Survey, 2023

Table 4.9 shows that 85 percent of respondents recognized a lack of infrastructure, such as roads, energy, and communication, as a major obstacle. This restriction may make it difficult to access basic services, obstruct transportation, and hamper economic development in mountainous areas. Natural catastrophe vulnerability was also widely acknowledged, with 75 percent of responders mentioning the risk. Landslides, avalanches, and flash floods are common in mountains, and they pose a serious threat to infrastructure, human settlements, and livelihoods. Seventy percent of respondents cited poverty and a lack of employment possibilities as major challenges, highlighting how challenging it is to achieve sustainable development and improve living circumstances in mountain villages. 55 percent of respondents brought up the loss of cultural heritage, highlighting how crucial it is to protect indigenous identities, knowledge systems, and traditional practices in the face of the effects of climate change. Sixty percent of respondents cited a lack of access to healthcare and education, highlighting the challenges that can obstruct human development and well-being in mountainous locations. Additionally, 15 percent of respondents mentioned additional difficulties that were not on the list, indicating the existence of particular or situation-specific problems that have an impact on mountain growth in the context of climate change.

4.5 Impact on the livelihood

It was found that the majority of the people have changed their lifestyle to mitigate the impact of the climate change. People have begun to change their housing patterns from traditional roofing to galvanized tins or concrete structure building.

4.5.1 Positive aspects

The construction of roads and other mountain infrastructure has provided people with numerous options for socioeconomic advancement. People can now embrace and partake in tourism activities once their conventional occupations have been uplifted by socioeconomic growth. People have been able to do this because of climate change and infrastructure development.

The opening of contemporary eateries and lodging facilities serving cuisine popular in urban areas has aided in drawing additional investors to the region. According to one of the respondents, it has made it possible for people to go back to their hometown and make investments in the tourism and agricultural sectors.

4.5.2 Negative aspects

As the Thini people alter their way of life to lessen the effects of climate change and to benefit from the development of infrastructure, it directly affects their traditional values and the cultural heritage that it carried. It no longer had what made a museum of cultural heritage tick. The neighborhood would lose its traditional and historical importance if more and more non-traditional hotels and restaurants were built there. Likewise, the resources it once used were gradually depleted. One commenter, for instance, expressed dissatisfaction with the Shaligram's accessibility in the Kaligandaki River. As more visitors arrive, the region may experience the detrimental effects of mass tourism and gradually lose its charm.

In general, socioeconomic opportunities have been brought to people in mountainous areas by mountain development, including the building of highways. Many people have given up their usual jobs and turned to tourism as a result. Growth has been made possible by this transition, climate change, and better infrastructure. There are adverse effects, though. The region no longer qualifies as a cultural museum, which compromises its traditional values and cultural history. The historical value of the area is also at danger due to the increase in unconventional hotels and eateries. In addition, resources like the Shaligram stone are running out, and the increase in visitors could have a severe effect on the region's character in the future.

4.6 Mitigating measures

The local communities of Nepal's mountainous terrain are essential to preserving the ecosystem. They can make a difference by engaging in sustainable resource management practices, promoting organic farming and terrace cultivation, establishing protected areas, preserving traditional knowledge, promoting responsible tourism, implementing water harvesting and waste management systems, running awareness campaigns and educational programs, managing community forests, participating in reforestation and afforestation initiatives, and a host of other activities. In the mountainous region of Nepal, their active participation in these activities can considerably support environmental preservation and sustainable development.

In the case of the Thini village there has been little effort to mitigate the impact of climate change. Some of the measures observed during the study were as follow:

4.6.1 Shifting occupation

Approximately 45% of farmers altered their occupation from agriculture to business and cash crop production as a strategy to adapt to climate change. This shift allowed them to diversify their income sources. Similarly, they have reduced their dependency in agriculture and livestock only, they have began to focus on the tourism sector as well.

4.6.2 Changing cropping patterns

Majority of the farmers has changed their cropping patterns by replacing traditional crops with those suitable for the changing climate. For example, they started mixing buckwheat and wheat with apples, indicating the adoption of agroforestry practices. Similarly, the import of foreign apples in the region were also practiced as per one KII. Further the cultivation of various vegetables also shows the changing pattern of the people in the cropping patterns.

4.6.3 Adoption of chemical fertilizers and insecticides

Farmers resorted to using chemical fertilizers and insecticides to combat lower productivity and increased pest infestation in agricultural lands. The tree roots were mostly covered with snow preventing infestation, however due to the melting of the snow, there have been various cases of infestation and hence they had to resort using the fertilizers and insecticides.

4.7 Summary of the chapter

The Thini area has huge cultural and historical significance. The tradition and culture of the village has been a major part of its identity along with their traditional livelihood pattern. However, with climate change the patterns of their livelihood have been impacted. The impact has been more visible as it has been impacting their way of life and economic activities as well. The change in housing pattern, agriculture and even the change in biodiversity has been observed. Similarly, it also has an impact on their seasonal migration as well.

The mountain development has provided various opportunities for the people in the Thini village to uplift their socio-economic condition. The construction of the roads connecting the village has provided people with access to different markets as well as the development of

education and health facilities has been evident. It has also led to the establishment of different restaurants and hotels in the Thini village.

It was found that both climate change and mountain development had positive and negative impact on the overall livelihood of the people. From the perspective of tourism, it has provided an opportunity of economic prosperity with the loss of traditional and cultural heritage that the Thini village has possessed.

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

The Thini region in Nepal is currently facing a range of difficulties and transformations, including the impacts of climate change, developmental activities, and the need for adaptation and mitigation strategies.

Concerning the effects of climate change, the area has observed alterations in temperature, precipitation, and wind patterns, which are affecting ecosystems, biodiversity, and the distribution of plant and animal species. The community is cognizant of these impacts, with some individuals noting changes in climate patterns over the past ten years. Respondents have identified various challenges, such as shifting rainfall patterns, a rise in natural disasters, fluctuations in temperature extremes, water scarcity, and land degradation.

Developmental endeavors, particularly the construction of roads, have brought opportunities for the community, including enhanced infrastructure, access to services, and the development of tourism. However, there are concerns regarding environmental degradation, the erosion of cultural heritage, and changes to traditional ways of life.

The community has taken steps to mitigate the impact of climate change, such as altering housing patterns, adopting sustainable practices, and engaging in tourism and agriculture. While there are positive aspects, such as socio-economic development and improved access to services, there are also negative repercussions, such as the loss of traditional values and cultural heritage.

To address these challenges, suggested mitigating measures include the conservation and restoration of ecosystems, sustainable management of resources, climate change mitigation, environmental education and awareness, sustainable consumption and production, collaborative efforts, policy interventions, and the empowerment of local communities. These measures aim to safeguard the environment, promote sustainable development, and actively involve local communities and stakeholders.

The findings highlight the complex interplay between climate change, development activities, and the need for adaptation and mitigation in the Thini area. It emphasizes the importance of balancing socio-economic development with environmental conservation and the active involvement of local communities in shaping the future of the region.

5.2 Conclusion

The major sources of economic livelihood in the region have been tourism. Climate change and sustainable tourism development has provided a measure for livelihood among the people of Thini region, which aligned with the findings of Nyaupane and Timothy (2022).

As with Steiger et al. (2022) results about changes in climatic patterns, ecosystem disturbances, and the need for adaptation measures, the effects of climate change on mountain tourism described in this study are consistent with those findings. The research found that there has been a shift in the tree line in the region and change in biodiversity. The apple trees began to grow at higher altitude and trees within the Thini village began to be infected by various pest, which according to various account were unusual.

The Thini region has experienced a notable shift in climate with warmer winters, which has had various effects on different aspects of life in the area. Tourism has become more feasible in the winter season due to the milder weather, attracting more tourists to the region. This has led to a decrease in seasonal migration as people find opportunities to stay and work in the area throughout the year.

The warmer winters have also resulted in a decrease in snowfall, affecting the traditional patterns of life in the region. With changes in rainfall patterns, the agriculture sector has been impacted, with a shift towards cash crops like vegetables. However, the region is facing challenges with apple trees being infected and potatoes not being grown as effectively. The development of road infrastructure has made it easier for tourists to access the region, leading to further support for its development and economic growth. Efforts have been made to raise awareness among the people about the changing climate and its implications.

Health facilities have improved in response to the growing population and the influx of tourists. However, the transformation in housing patterns and modern communication have brought both benefits and challenges to the region. Unfortunately, the changes in housing

patterns and modernization have also led to the deterioration of traditional culture and values. The region is grappling with preserving its unique heritage amidst the rapid changes.

The climate change impacts on the Thini region have been found and is impacting significantly, causing the change in cultural and livelihood pattern. The mountain region of the Nepal is known for its cultural diversity and its natural beauty, which is being slowly deteriorated because of climate change. Hence there is an urgent need to take adaptive measures to reduce the effect of climate change. One of the major steps would be the sustainable development of the mountain region.

APPENDIX I

INFORMED CONSENT FORM

Date ……..…… (day/month/year)

I, (Mr./Mrs./Ms.) …….……..…..……...……hereby have signed the consent to declare that:

1. Before signing the certificate of consent, I have been explained the objectives and methods of the study.

2. I have had the opportunity to ask questions about the study and any questions that I have asked to have been answered to my satisfaction.

3. I have the right to withdraw from the study at any time if I feel uncomfortable.

4. The investigator will keep the information confidential, and my personal data will not be declared in any case except the academic purposes.

5. The investigator will provide additional necessary information about the study, if there is any.

I have read and understand the above information and I consent voluntarily to participate as a participant in this research.

Signature/Fingerprint……. (Respondent/informant)

Signature…… (Researcher)

SSP Shankar Khanal

APPENDIX II

QUESTIONNAIRE SURVEY QUESTIONNAIRE

Section 1: Demographic Profile of the respondents

1. Name: …….
2. Gender: Male Female
3. Age:
   - Below 20
   - 20-40
   - 41-70
   - 71 and above

Section 2: Knowledge and Awareness

4. How familiar are you with the concept of climate change?
   - Yes
   - No
5. Have you observed any changes in weather patterns or natural resources in your mountain region over the past decade?
   - Yes
   - No
6. If yes, please briefly describe the changes you have observed:

_____

Section 3: Climate Change Impacts

7. 9. In your opinion, what are the most significant impacts of climate change on mountain regions and their people? (Select all that apply)
   - Erratic rainfall patterns
   - Increasing frequency of natural disasters
   - Changing temperature extremes
   - Water scarcity
   - Land degradation
   - Other (please specify): _____
8. How has climate change affected your daily life or the lives of people in your mountain community? _____

Section 4: Mountain Development

9. What is the impact of development activities?
    - Improved infrastructure and access to services
    - Environmental degradation
    - Socioeconomic development

10. What are the key challenges to mountain development in the context of climate change? (Select all that apply)
    - Limited infrastructure (e.g., roads, energy, communication)
    - Vulnerability to natural disasters
    - Poverty and limited economic opportunities
    - Loss of cultural heritage
    - Lack of access to education and healthcare
    - Other (please specify): _____

11. In your opinion, what are the priority areas for mountain development in the face of climate change? _____

Section 5: Condition Comparison over 30 years period of time

Parameters of Impact of Climate Change	**Highly Increased (1)**	**Slightly Increased (2)**	**Same as before (3)**	**Slightly Decreased (4)**	**Highly Decreased (5)**
Agricultural Production					
NTFP's Production					
Human Injury					
Forest Fire					
Mosquitos and other insects					
Crop Disease					
Invasive Species					
Water Resources					

12. What role do you think local communities can play in conserving the environment in the mountainous region of Nepal?

Thank you for participating in this survey! Your input is valuable in understanding the perspectives and experiences of people living in mountain regions.

APPENDIX III

QUESTION FOR INTERVIEW SCHEDULE

Name: ……

Organization: ……

Position: ……

1. How long have you living in the Thini village?
2. What are the changes that you have seen in the Thini village in the recent years?
3. How those changes have impacted your day to day life?
4. Can you provide one example of the change that you had experienced?
5. What are the adaptive measures that people had taken to tackle the impact?
6. What are the various development that has been done in this area?
7. How such development activities has impacted the lives of the people in this area?
8. How does the development activities in the area had helped to mitigate the impact of the climate change?

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