CLIMATE CHANGE PATTERNS AND IMPACTS AS REVEALED BY LOCAL PERCEPTIONS AND SCIENTIFIC RECORDS IN A MOUNTAIN VILLAGE OF CENTRAL NEPAL

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DECLARATION

I, Uma Dhungel, hereby declare that the work presented in this thesis, entitled " **CLIMATE CHANGE PATTERNS AND IMPACTS AS REVEALED BY LOCAL PERCEPTIONS AND SCIENTIFIC RECORDS IN A MOUNTAIN VILLAGE OF CENTRAL NEPAL"** is the result of my original research and all the other sources of information used for this research are acknowledged properly. This work has not been submitted in whole or in part for any other degree or qualification at any other institution.

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LETTER OF RECOMMENDATION

This is to certify that Miss Uma Dhungel has completed this thesis entitled " **CLIMATE CHANGE PATTERNS AND IMPACTS AS REVEALED BY LOCAL PERCEPTIONS AND SCIENTIFIC RECORDS IN A MOUNTAIN VILLAGE OF CENTRAL NEPAL"** " under our supervision and guidance. The result of this work has not been submitted for any other degree to the best of our knowledge. We, therefore, recommend this dissertation for final approval and acceptance as a part of the requirement of a Master's Degree in Biodiversity and Environmental Management at the Institute of Science and Technology, Tribhuvan University, Kathmandu, Nepal.

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LETTER OF APPROVAL

The M.Sc. dissertation entitled "**CLIMATE CHANGE PATTERNS AND IMPACTS AS REVEALED BY LOCAL PERCEPTIONS AND SCIENTIFIC RECORDS IN A MOUNTAIN VILLAGE OF CENTRAL NEPAL**" submitted at the Central Department of Botany, Tribhuvan University by Ms. Uma Dhungel has been accepted for the partial fulfillment of her Master's Degree in Biodiversity and Environmental Management (BEM).

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TABLE OF CONTENT

LISTS OF TABLES

LISTS OF FIGURES

ABSTRACT

Climate change is a global phenomenon which has multiple impacts in different sectors. Impacts of climate change are felt at local level so studying local impacts of climate change has a huge benefit. However, due to the lack of weather stations and climatological data in Nepal many areas are still missing under the course of study for climate change impact. In such areas using global datasets as primary sources of climate change indicator and validating this with perception data will help to identify the local impacts of in small-communities and rural area. This study aims to find out the consistency between communities' perception and modeled climate data by using primary quantitative data and quantitative data collected from series methods like the key informants' interviews (KII), the focus group discussions (FGDs) and household survey as well as global climatological data sets. Two global climatological data sets: Fifth Generation of European Reanalysis (ERA_5) and the European Center for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission, and a bias-corrected multi-model ensemble comprising 13 General Circulation Models (GCMs) from the Coupled Model Intercomparison Project (CMIP-6) were used. The perception survey revealed that locals perceived changes in several climate indicators, such as droughts, floods, rainfall patterns, season length, and the coldest season's temperatures. Due to the changes in these indicators, impacts like introduction of invasive species, reduced soil fertility, increased conflicts over natural resources, higher rates of human diseases and livestock deaths, and increased rainfall levels were observed in Laprak. These perceptions of respondents depend upon various socio-economic factors like their place of residency, gender, and level of education. Comparing consistency between both data shows that there is an alignment among most of the precipitation- related patterns and perception of the respondents but mismatch among temperature-related trends perception of the respondents.

Keywords: Binary logistic regression, alignment, trend analysis, Laprak

शोधसार

गोरखा जिल्ला स्थित लाप्राक गाँउमा जलवायू परिवर्तनलाई दर्शाउने सूचकहरू र जलवायू परिवर्तनको असरको बारेमा अध्ययन गरिएको थियो । सो अध्ययनमा मानिसहरूका अवधारणाहरूको अध्ययनका साथ-साथै विश्वस्थरमा प्रयोग हुने जलवायू सम्बन्धी तथ्याङ्कहरू (Fifth Generation of European Reanalysis (ERA5) & General circulation Models (GCMs) समेत प्रयोग गरिएको थियो । यसरी गरिएको अध्ययनले मानिसहरूको धारणा र विश्वस्थरका तथ्याङ्कहरूमा समानताका साथ-साथै असमानता हुने दर्शाएको छ । लाप्राकका वासिन्दाहरुले पानीको मात्रा र त्यससँग सम्बन्धित परिवर्तनको सहि आँकलन गर्न सकेका छन् भने तापक्रम सँग सम्बन्धित घटनाहरूको बारेमा आँकलन गर्न कठिन हुने यो अध्ययनले देखाएको छ । यो अध्ययनले मानिसका धारणाहरुलाई प्रभाव पार्ने थुप्रै सामाजिक-आर्थिक कारकहरु (जस्तै: उमेर, बसोबास गरेको स्थान, पढाईको स्तर) प्रभाव हुने देखाएको छ । यो अध्ययनहरूले भविष्यमा देखापर्न सक्ने जलवायू परिवर्तन सम्बन्धी जोखिमहरूलाई न्यूनीकरण गर्न समयमै र उपयुक्त कदम चाल्नका लागि स्थानीय तह, व्यवस्थापकहरू र नीति निर्माताहरूलाई बहुमूल्य जानकारी प्रदान गरेको छ।

शब्दकुञ्जी: लाप्राक, समानता, जलवायू सम्बन्धी तथ्याङ्क

ACRONYMS AND ABBREVIATIONS

AR5	Fifth Assessment Report
CBS	Central Bureau of Statistics
CMIP	Coupled Model Intercomparison Project
CO_2	Carbon dioxide
DHM	Department of Hydrology and Meteorology
ECMWF	European Center for Medium-Range Weather Forecasts
ECS	Equilibrium Climate Sensitivity
ERA_5	Fifth Generation of European Reanalysis
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
GCMs	General Circulation Models
GLOFs	Glacial Lake Outburst Floods
GoN	Government of Nepal
IPCC	Intergovernmental Panel on Climate Change
KII	Key Informant Interview
MEA	Millennium Ecosystem Assessment
MoFE	Ministry of Forests and Environment
MoHA	Ministry of Home Affairs
PPM	Parts per million
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development

CHAPTER 1: INTRODUCTION

1.1 Background

Climate change represents a multifaceted and dynamic phenomenon, exerting diverse effects across different regions. It is defined after an extensive analysis of long-term patterns encompassing elements such as temperature, precipitation, pressure, and humidity in the surrounding environment (Abbas *et al.*, 2022). The increase in temperature is mainly attributed to human activities particularly those which involve the production of greenhouse gases (GHG) like CO_2, methane, and nitrous oxide (IPCC, 2023). The primary drivers of greenhouse gas emissions include the combustion of fossil fuels, forest clearance, industrial activities, and agricultural as well as livestock rearing practices (Bhatti *et al.*, 2024). The human-induced increased temperature is also changing the precipitation patterns (Trenberth, 2011), pressure, and humidity.

Climate change emerges as an existential threat to humanity in the contemporary era (Clayton *et al.*, 2015). The impacts of climate change are global, and complex, having huge range and impact sectors like ecological, environmental, and socio-economic sectors (Feliciano *et al.*, 2022). Climate change impacts have the potential to alter ecological and social systems globally (Evans, 2019). The ecological consequences of climate change are observed as a biodiversity loss in the global scenario (Bellard *et al.*, 2012). The negative impacts of climate change encompass a wide array of changes in biodiversity (Bellard *et al.*, 2012), including shifts in life cycles, the appearance of new physical characteristics, adjustments in habitat ranges and species distributions (Anderson, 2013), fluctuations in abundance, changes in migration patterns, and shifts in the frequency and severity of pest and disease outbreaks (Sintayehu, 2018). Furthermore, climate change affects phenology, physiology, and community structures, with additional stressors such as ocean acidification, invasive species introductions, and alterations in land use and nutrient cycles further exacerbating the situation (Bellard *et al.*, 2012).

The environmental consequences of climate change mainly include rising sea levels (Tebaldi *et al.*, 2021), inundation, erosion, and saltwater intrusion (Pramita *et al.*, 2021), changes in ocean chemistry (Lønborg *et al.*, 2020). Climate change also increases the occurrence and extent of extreme weather phenomena like wildfires, floods, hurricanes, and droughts (Huber and Gulledge 2011; Ebi *et al.*, 2021). The socio-economic consequences of climate change are far-reaching and impact communities and livelihoods globally (Dube *et al.*, 2016). Extreme weather events induced by climate change, such as hurricanes, floods, and droughts, have the potential to cause severe damage to homes, infrastructure, and businesses, resulting in displacement, loss of livelihoods, and economic instability (Bell and Masys, 2020). Similarly, people living in coastal areas are vulnerable to rising sea levels, erosion, and loss of land (Burkett and Davidson, 2012). The socioeconomic consequences of climate change vary across regions and have detrimental effects in developing nations due to their low adaptive capacity (Müller-Kuckelberg, 2012). Similarly, mountainous societies that are more reliant on rain-fed agriculture face increasing challenges due to diminishing precipitation, increasing flash floods, untimely precipitation, and rising temperatures causing declining in agricultural productivity and exacerbating food insecurity (Gentle and Maraseni, 2012).

Nepal ranks among the most vulnerable countries to climate change globally, holding the 12th position out of 180 countries in the Global Climate Risk Index 2021 (Eckstein *et al.*, 2021). Nepal, facing high vulnerability to both climate change and natural disasters, is encountering a range of extreme and gradual climate-related risks (World Bank, 2021). The nation has already experienced observable shifts in temperature and precipitation, encompassing changes in intensity, frequency, seasonality, and average values, along with the rise in occurrences of extreme weather events (Shrestha *et al.*, 2019). The increase in temperature has observed an increase in seasonal and annual temperatures while higher elevations have decreased (Dhm 2017; Talchabhadel *et al.*, 2018). The rate of temperature increase in this context is occurring at nearly double the pace of the global average (Acharya and Bhatta, 2013). At the same time, there has been a shift in the spatial distribution of rainfall, with a noticeable decline in rainfall occurring each month, particularly during the important monsoon season (June–September) (World Bank, 2020). The alterations in temperature and precipitation patterns have primarily affected the lives of agricultural-dependent communities living in rural areas of the country (Devkota, 2014). Around 80 percent of Nepal's population faces exposure to risks linked to natural and climate-induced hazards, such as extreme heat stress and flooding (MOHA, 2017).

While climate change is a global phenomenon, its impacts are felt locally (Pyhälä *et al.*, 2016). Therefore, investigating how communities perceive and experience climate change is crucial, especially in small-scale communities heavily reliant on the climate for their livelihoods (Ali *et al.*, 2023). The scientific evidence on climate change is robust but understanding how communities perceive and respond to this phenomenon is equally crucial. The public's perception of climate change plays a pivotal role in understanding challenges related to climate change adaptation and in designing potential solutions (Weber, 2010). However, the local perception is influenced by various factors, including individuals' characteristics, psychological aspects, life experiences, the information source they access, and the cultural and geographic context where they reside (Whitmarsh and Capstick, 2018). Research indicates that awareness, knowledge, and perceived risk related to climate change vary considerably across different regions worldwide (Arbuckle *et al.*, 2015). Therefore, this study focuses on the nexus of community perceptions and weather data, exploring how local populations interpret and respond to the impacts of climate change.

1.2 Justification of the study

Climate change is a multifaced and dynamic phenomenon that impacts various regions differently. Nevertheless, its effects are most acutely felt by local communities, often the first to bear the consequences (IPCC, 2014). Understanding local perceptions of climate change and its indicators, such as temperature, precipitation, and seasons, is crucial for grasping how they interpret climate-related changes. Through insights into the viewpoints of local communities, we can deepen our comprehension of global environmental change and its ramifications (Pyhälä *et al.*, 2016). In regions lacking instrumental climate records, local perceptions are considered a reliable foundation for determining climate variable changes (Alexander *et al.*, 2011; Shrestha *et al.*, 2019). In Laprak where there is no nearby weather station, perception data play a very important role in identifying climate change at the local level as well as it helps to identify the impacts of climate change at the local level. It is equally crucial in evaluating the tangible effects of climate change, as it provides insights into the responses and behaviors of local populations towards mitigation and adaptation strategies (Vignola *et al.*, 2010; Engels *et al.*, 2013). The perceptions of local populations regarding climate change serve as crucial indicators for creating, planning, and executing effective strategies for global environmental change adaptation (Patt and Weber, 2014). By integrating the insights and viewpoints of local communities, policymakers can develop context-specific and sustainable strategies to address the challenges posed by climate change at both regional and global scales (Nkoana *et al.*, 2018).

Integrating scientific observations with public perceptions is essential for developing a robust knowledge base and reducing uncertainties in adaptation planning (Marin, 2010; Shrestha *et al.*, 2019). Analyzing how individuals' perceptions of climate change align with their actions provides deeper insights into their responses to this global issue. It is crucial to recognize that current observations and surveys have primarily focused on developed countries, leading to a lack of evidence from the developing world (Roco *et al.*, 2015). Specifically, developing countries like Nepal have not received sufficient attention in comprehensive studies on climate change and its impacts (Shrestha *et al.*, 2012; Pandit *et al.*, 2014). Recently, researchers have initiated investigations into the extent and severity of climate change in Nepal by examining historical temperature and precipitation records (Duncan *et al.*, 2013). However, the analysis of historical climate records in Nepal is constrained by the scarcity of weather stations and inadequate data management and maintenance (Shrestha and Aryal, 2011; Bhattacharjee *et al.*, 2017; Karki *et al.*, 2017; Shrestha *et al.*, 2019). To address this gap, climate data generated through climatic models can play a crucial role in providing valuable insights for data-deficient regions like Nepal. Understanding how people perceive climate change and its impacts can enhance communication and outreach efforts to effectively engage and mobilize communities. Policymakers can utilize the findings of such studies to develop and implement context-specific climate change policies that cater to local needs and concerns. By combining scientific knowledge with public perspectives based on traditional ecological knowledge, more informed decision-making can be promoted, fostering sustainable adaptation strategies in response to climate change challenges.

1.3 Objectives

General objective

The overall objective of this study was to identify the pattern of climate change indicators and climate change impacts.

Specific objectives

The specific objectives of this study were:

1. To document local peoples' perceptions towards climate change indicators and impacts of climate change.
2. To examine the historical trends of climate change indicators in the study area.
3. To analyze the consistency between perceptions and the modeled climate data.

1.4 Limitations

This study has some limitations within which the findings of the study need to be interpreted carefully. The major limitations of this study are:

1. The survey was done only with the Gurung community to reduce the biases.
2. Climate indicators and climate change impacts that were selected in FGD were only asked in the household survey.

CHAPTER 2: LITERATURE REVIEW

Climate Change refers to a significant and enduring alteration in the Earth's climate, affecting its regular conditions over time (IPCC, 2023). These changes are contributed primarily by human activities (IPCC, 2023) resulting in increased greenhouse gas emissions. Climate patterns play a pivotal role in shaping natural ecosystems, as well as human economies and cultures, as many systems rely directly on them (Wang *et al.*, 2011). Consequently, climate change presents a huge challenge to societies and economies worldwide, given their interconnectedness with climate, including sectors such as agriculture, wildlife, and more (Malhi *et al.*, 2020). Climate changes can influence where and how people live, impacting land and water access and use, food production, and the availability of water resources (Mbow *et al.*, 2019).

The effects of climate change may be felt differently across different regions of the world (Anita *et al.*, 2010). Predicting precisely how climate change will impact us is challenging due to the complications of the global climate system (Palmer, 2012). Furthermore, the severity of the adverse effects of climate change is not solely dependent on the changing climate itself; it also relies on the sensitivity of human and natural systems to these changes. Some regions and communities particularly that of developing countries may be more susceptible and sensitive to the impacts of climate change than others (Müller-Kuckelberg, 2012).

2.1. Climate change at a global level

The warming of global climate is evident from observations and meteorological data, showing increased global average air and ocean temperatures, widespread melting of snow and ice, and a rise in average sea levels worldwide (Singh and Singh, 2012). Recent reports from IPCC in 2022 also provide strong evidence that anthropogenic activities are the primary reason for global climate change. Natural processes such as volcanism, desertification, droughts, floods, and forest fires can alter the concentration of gases in the atmosphere, thereby impacting the climate. However, the contribution of these natural processes to climate change is relatively small when compared to human activities (Zhang *et al.*, 2019).

The main factor driving global warming is the release of greenhouse gases into the atmosphere, including carbon dioxide, methane, chlorofluorocarbons, and nitrous oxide

(Kumar, 2018). These greenhouse gases, particularly carbon dioxide, trap heat, leading to rising global temperatures. The global mean surface temperature has risen by approximately 1.1°C since 1850-1900, and the rate of warming per decade has been about 0.2°C (IPCC, 2023). Extreme weather events like heat waves, droughts, and floods, the rate of sea level increase has reached approximately 1 mm per decade (Griggs and Reguero, 2021). Moreover, the Arctic warming at a pace twice as fast as the rest of the planet. This is causing the melting of sea ice, which is disrupting the Arctic ecosystem and affecting the migration patterns of animals (Cherry *et al.*, 2013; Vincent, 2020). Extreme weather events, including heatwaves, droughts, floods, wildfires, and tropical cyclones, are now increasingly occurring with greater frequency and intensity (Clarke *et al.*, 2022; IPCC, 2023; Meyer *et al.*, 2023). Extreme weather events are posing significant challenges to communities and ecosystems around the world (Mehrabi *et al.*, 2022). However, it is anticipated that the effects of climate change will excessively affect the poorest and most vulnerable populations globally (Swinburn *et al.*, 2019).

2.2. Climate change in Nepal

In recent decades, Nepal has experienced significant changes in its climate patterns, impacting temperature and rainfall throughout the country. There has been a noticeable change in the country's temperature (Talchabhadel *et al.*, 2018) as well as the precipitation pattern (Pokharel *et al.*, 2020). There is a significant shift happening in the high mountains where rain is replacing snow during precipitation events, resulting in a significant loss of water from Himalayan glaciers (Molden *et al.*, 2016). This change is accompanied by a rise in extreme rainfall events, particularly in the western mid-hills and central high mountain regions (Chhetri *et al.*, 2021; Regmi and Bookhagen, 2022). Additionally, there are predictions of increased variability and unpredictability in Nepal's rainfall patterns (Tiwari *et al.*, 2010; Karki and Gurung, 2012).

At present, the southeastern regions of Nepal experience greater rainfall during the monsoon season, whereas the northwestern high mountain regions receive increased snowfall during winter (Shrestha and Aryal, 2011; Karki *et al.*, 2017; Talchabhadel *et al.*, 2018). Additionally, hilly regions typically receive more pre-monsoon rainfall compared to the southern Terai plains (Shrestha *et al.*, 2010; Panthi *et al.*, 2015).

However, projections indicate that high mountains will experience more significant changes in rainfall patterns in the future (Chapagain *et al.*, 2021).

There is increase in daily extreme rainfall incidents of flash floods in central lowland regions (Karki *et al.*, 2017; Talchabhadel *et al.*, 2018) but in the western mountainous region, there are increased risks of soil erosion and landslides due to intensified high-intensity rainfall (Karki *et al.*, 2017; Karki and Ojha, 2021). Furthermore, changes in rainfall patterns are affecting the dynamics of monsoonal floods in Terai floodplains, with an increase in flash floods attributed to faster glacial melt and increased extreme daily rainfall (Dhm, 2017). The higher occurrence of extreme rainfall over mid-hill regions is leading to a greater number of monsoon landslides (Chhetri *et al.*, 2021).

Projections indicate that Nepal will experience significant fluctuations in temperature and precipitation patterns in the medium and long term. The temperatures are projected to rise by 0.92–1.07°C from 2016 to 2045 and 1.3–1.8°C from 2036 to 2065 compared to the reference period of 1981–2010 (MOFE, 2019; World Bank, 2021). Additionally, annual precipitation is forecasted to increase, with estimates ranging from 2–6 percent to 8–12 percent in both the medium and long term, especially in elevated regions (Babel *et al.*, 2014; Chhetri *et al.*, 2021). Furthermore, the changing climate is anticipated to have contrasting impacts on different seasons. Winters are projected to become drier, while monsoon summers are expected to become wetter, potentially experiencing a threefold increase in rainfall (Swain and Hayhoe, 2015; Chapagain *et al.*, 2021).

This shift in precipitation patterns could significantly affect Nepal, with the number of individuals affected by river flooding each year, attributed to climate change, potentially more than doubling by 2030 (Wassmann *et al.*, 2009; Islam *et al.*, 2019). The World Bank and Asian Development Bank (2021) estimate that around 350,000 people will be affected in 2030 compared to 157,000 in 2010. The economic repercussions of such flooding events are projected to triple, exacerbating vulnerability to climate-related hazards in Nepal (World Bank, 2022).

2.3. Impacts of climate change in Nepal

The impacts of climate change are notably more severe in Nepal compared to other regions (Shrestha & Aryal, 2011). Several factors like fragile landscapes, extreme climatic conditions, recurrent climatic hazards, low economic capacity among the population, political conflicts, and inadequate governance collectively contribute to the increasing vulnerability of climate change in the country (Mainali and Pricope, 2017). The pattern of temperature, as well as precipitation, changed across the country due to climate change (Dawadi *et al.*, 2022).

Climate change already poses substantial threats to various sectors in Nepal, including food security, human settlements, water resources, and the tourism industry (Karki *et al.*, 2009). The effects of climate change vary significantly across different regions of Nepal, influenced by factors such as topography, remoteness, dependence on climate-sensitive livelihoods like agriculture and animal husbandry, accessibility, infrastructure development, and economic capacity (Mainali and Pricope, 2017). This vulnerability is particularly apparent in the high-altitude mountainous terrain of the country (Tiwari *et al.*, 2020), where a majority of households depend heavily on natural resources for their livelihoods (GoN, 2010; Gentle and Maraseni, 2012).

2.3.1. Impacts on agriculture and livestock

The change in the temperature and precipitation pattern had negative impacts on various sectors including agriculture globally (FAO, 2019). Climate change has both negative and positive effects on the agriculture sector in Nepal (Maharjan and Joshi, 2013; Bocchiola *et al.*, 2019). But the negative impact of climate change on Nepal's agriculture overshadows the positive impacts (Bocchiola *et al.*, 2019). In contrast, the impacts of climate change on the livestock sector are predominantly negative (Gaughan *et al.*, 2012). The magnitude of this impact is greater for the low-income communities of rural areas of the country whose dependency is more on the agriculture sector (Dillon *et al.*, 2011).

The negative impacts of climate change on agriculture were primarily due to the rising CO_2 levels affecting respiration (Dusenge *et al.*, 2019), changing temperature, and rainfall (Malhi *et al.*, 2021), unpredictable weather patterns (Sapkota *et al.*, 2010). Some other observed impacts of climate change in Nepal, directly related to the agriculture of the country are erratic rainfall patterns, unpredictable onset of monsoon seasons, glacial retreat, storms, landslides, and drought (Gentle and Maraseni, 2012). Similarly, the primary causes of impact to the livestock are increased temperature and increased frequency and intensity of heat waves (Gaughan *et al.*, 2012).

The increased trend of rainfall positively affects the production of paddy in some of the areas of Nepal (Maharjan and Joshi, 2013). However, due to the unpredictable weather pattern, some areas of the country reported crop failure as well as decreased production of some of the traditional varieties of paddy (Sapkota *et al.*, 2010). The irregular and extreme weather events have significantly decreased crop yield across the country (Poudel and Kotani, 2013). As a consequence of climate change, the regional yield of the country decreased by 12.5% in the Mid-western part and by 6% in the Far-western regions in 2005 (Regmi, 2007). Increased temperatures have a negative impact on irrigation systems and also on crop growth and yields (Hatfield *et al.*, 2011). The frequent occurrence of prolonged dry spells is making the country's farming sector more unpredictable, which directly affects the lives of those who rely on these resources (Ghimire *et al.*, 2010).

The impacts of climate change on livestock can be categorized as either direct or indirect. Direct impacts encompass various diseases such as those transmitted by vectors, linked to soil, water, or floods, associated with rodents, or influenced by air temperature and humidity, as well as those sensitive to climate (Grace *et al.*, 2015). Indirect impacts happen in more complicated ways and involve things like animals trying to cope with temperature changes, how climate affects tiny organisms, the spread of diseases carried by insects, how well animals can fight off infections, not having enough food or water, and getting sick from the food they eat (Yatoo *et al.*, 2012). Further, increased temperature also caused stress in both terrestrial as well as aquatic animals resulting in less growth, decreased productivity, weak immune systems, and sub-optimal behaviors (Koirala and Bhandari, 2019). An increase in heat stress reduced the rate of feed intake in animals, resulting in a decrease in growth rate (Rowlinson, 2008). Rise in temperature and humidity not only increased mortality rate among the livestock but also the poultry (Dhakal *et al.*, 2013).

2.3.2. Impacts on biodiversity

Climate change has profoundly impacted the biodiversity of Nepal (Lamsal *et al.*, 2017; Bhattacharjee *et al.*, 2017; Paudel *et al.*, 2021). The impacts were mainly caused by rising temperatures, shifting precipitation patterns, and extreme weather events, which have altered habitats and disrupted ecosystems (Thorn, 2019). These changes in climate indicators lead to changes in species distribution and abundance (Paudel *et al.*, 2021).

Increasing temperature is causing the retreat of glaciers in the Himalayas and poses a threat to freshwater ecosystems and dependent species (Shrestha and Aryal, 2011), while changes in monsoon patterns affect the timing of flowering and fruiting in plants. Glacial melting, influenced by rising temperatures, not only disrupts river flow patterns but also the freshwater biodiversity essential for sustaining life (Shrestha and Aryal, 2011). Changes in precipitation patterns disrupt habitats, affecting both terrestrial and aquatic species (Lamsal *et al.*, 2017).

The changes in the phenology of plants are affecting food availability for animals (Malla, 2008; Atreya and Kaphle, 2020) which is also impacting the communities that rely on agriculture for their livelihood. Additionally, the spread of invasive species (Bellard *et al.*, 2013; Tittensor *et al.*, 2014; Shrestha *et al.*, 2019), disease, and wildfire amplified by climate change is also causing huge problems to the native biodiversity of the country (Bhatt, 2020). High-altitude plants and animals, reliant on specific climatic conditions, face increased risks as their habitats shrink and fragment (Bhattacharjee *et al.*, 2017; Dahal *et al.*, 2021). Climate change impact causing habitat loss and fragmentation further increases the risks faced by endemic species like the red panda and snow leopard (Bist *et al.*, 2021).

2.3.3. Impacts on waterbodies

Climate change has a major impact on the water resources of Nepal (Shrestha and Aryal, 2011). The combined impact of rising temperatures and unpredictable precipitation patterns have reshaped the water balance as well as the hydrological dynamics of the country (Shrestha *et al.*, 2015; Qazi *et al.*, 2020). Rising temperatures have multifaceted effects on various environmental processes. Increasing temperature is more common in the middle hills and high Himalayas (Mainali *et al.*, 2015) of Nepal resulting in increasing water demand (Shrestha *et al.*, 2015). The increasing temperature has also increased the evaporation rates leading to increasing drought events impacting the agricultural production of the country (Hamal *et al.*, 2020). The increase in temperature also increases water demand both for agricultural purposes as well as for daily livelihood activities. The warming climate has led to the retreat of glaciers, significantly diminishing water availability for farming, especially during dry seasons (Chaulagain, 2015; Dahal *et al.*, 2018). Consequently, many regions in Nepal face severe water shortages for irrigation during crucial agricultural periods, leading to reduced crop production (Thapa and Scott, 2019).

Climate-induced water stress in agriculture results in crop failure, and decreased productivity while malnutrition, and sanitation-related problems in human settlements (Joshi and Joshi, 2017). Variations in precipitation could have significant implications for hydrology and water resources (IPCC, 2001). Climate change may also increase the frequency and severity of floods, along with a decline in water quality (Vilet *et al.*, 2023).

2.4. People's perception and its role in climate science

Local perceptions and traditional knowledge play a crucial role as valuable sources of information in climate change research, aiding in a more comprehensive understanding of regional climatic changes and their localized impacts (Lehner and Stocker, 2015; Altea, 2020). Climate change perceptions encompass individuals' evaluations and perspectives on climate change and its various aspects (Weber and Stern, 2011). Rural populations, especially farmers, occupy a distinct position, offering firsthand observations that provide valuable insights into the manifestations, relevance, and impacts of climate change or variability (Chaudhary and Bawa, 2011; Altea, 2020).

These local perspectives become essential in complementing general climate models and identifying anomalies not captured otherwise, thus enriching scientific climate analysis and addressing gaps in weather data (Macchi, *et al.*, 2015). Additionally, exploring how people understand and perceive weather phenomena provides an overview of the local social and cultural contexts in which global concepts like climate change are interpreted (Bickerstaff, 2004). Such knowledge can play a crucial role in acknowledging various regional and local approaches to climate change, which are shaped by the frames and values influencing people's behaviors and responses (Castree *et al.*, 2014).

Furthermore, it is said that perceptions of climate change and its impact on activities and livelihoods play a significant role in influencing individuals' decisions to act or not (Alessa *et al.,* 2008), as well as in guiding the adoption of short- and long-term adaptation measures (Reckien, 2014). Therefore, documenting perceptions of climate change and its impact is critical for scientific understanding of climate change patterns as well as for planning for adaptation measures.

Giving importance to people's perception of climate change indicators and impact assessment, it is equally crucial to analyze historical climate data alongside projections for future climate trends (Hampe and Petit, 2005). This data helps to understand how the climate is changing and to project how it may change in the future. Historical climate data provides a baseline understanding of the climatic conditions in the area over the past decades or centuries. This historical context is essential for identifying trends, patterns, and natural variability in the climate, allowing researchers to differentiate between natural climate variations and human-induced changes (Stott *et al.*, 2010). By comparing current climate data with historical records, scientists can contextualize the present climate change indicators. This helps in discerning whether the observed changes are part of natural climatic fluctuations or represent abnormal shifts outside of the historical range (Bradley *et al.*, 2003). Future climate data, derived from climate models and scenarios, helps in projecting the potential trajectory of climate change (Parry *et al.*, 2004). Policymakers rely on climate change projections to formulate effective policies and strategies for adaptation and mitigation. Understanding the potential magnitude and timing of future climate change allows us to plan preparedness after informed decision-making and the allocation of resources to address specific challenges (Wise *et al.*, 2014).

2.5. Research gap

In Nepal, recent studies have primarily focused on adaptation and mitigation aspects of climate change, with only a limited number examining the perceptions of local communities (CBS, 2017) in conjunction with climate data (Uprety *et al.,* 2017; Shrestha *et al.,* 2019). The absence of comprehensive models and global-level data in national climate change studies has hindered the identification of actual climate-affected groups, impeding effective adaptation and mitigation efforts. Notably, developing nations like Nepal have been overlooked in comprehensive climate change studies and impact assessments (Shrestha *et al.*, 2012; Pandit *et al.*, 2014). Researchers have only recently started to work into the scope and seriousness of climate change in Nepal, utilizing historical temperature and precipitation data (Duncan *et al.*, 2013). Unfortunately, the analysis of historical climate data in Nepal is constrained by the scarcity of weather stations and inadequate management and maintenance of available data (Shrestha and Aryal, 2011; Bhattacharjee *et al.*, 2017; Karki *et al.*, 2017; Shrestha *et al.*, 2019).

This study by integrating advanced models and global-level data into the analysis of historical trends in climate will provide a more comprehensive understanding of the impacts (Brönnimann *et al.*, 2019). This approach can facilitate a more accurate identification of vulnerable communities and areas (Anderson, 2005), enabling policymakers and researchers to tailor adaptation and mitigation strategies (Cvitanovic *et al.*, 2019) to the specific challenges faced by different regions. Additionally, it can contribute to a more nuanced assessment of the overall climate scenario in Nepal, considering global patterns and trends. This holistic approach is crucial for developing a robust and informed response to the complex challenges posed by climate change in a country like Nepal where there are very few weather stations and is high impact of climate change.

CHAPTER 3: MATERIALS AND METHODS

3.1. Study area

The field study was conducted in the Laprak region of Gorkha District (Figure 1), Nepal, from February 2 to 9, 2022. This district covers an area of 3,642 km^2 and is bordered by Tibet to the north, Dhading to the east, and Manang and Lamjung to the west, with Tanahun and Chitwan districts forming the southern boundary. The district exhibits diverse topography, ranging from elevations as low as 228 meters to as high as 8156 meters above sea level. Gorkha district varies across a spectrum, transitioning from lower tropical to upper tropical, sub-tropical, temperate, subalpine, alpine, and trans-Himalayan zones, extending to the naval zone (Lilleso *et al.*, 2005). The significant variations in topography and climate, combined with the fact that Gorkha District lies at the convergence of the Western and Eastern Himalayan floristic regions (Singh and Singh, 1987), underscore its ecological and botanical importance.

Laprak Village (28°1394.80 N and 84°48912.70 E) is situated in the Gorkha District at an elevation of 2,300 m above sea level (Gurung, 2011), and rests along the Raizo Khola valley. The climate of Laprak is moderate from March to September while winter rises to its peak with snowy days from October to January (Gurung, 2011). Due to the slow progress in establishing a bus route, the majority of Laprak's population still relies heavily on foot trails connecting to Barpak for transportation.

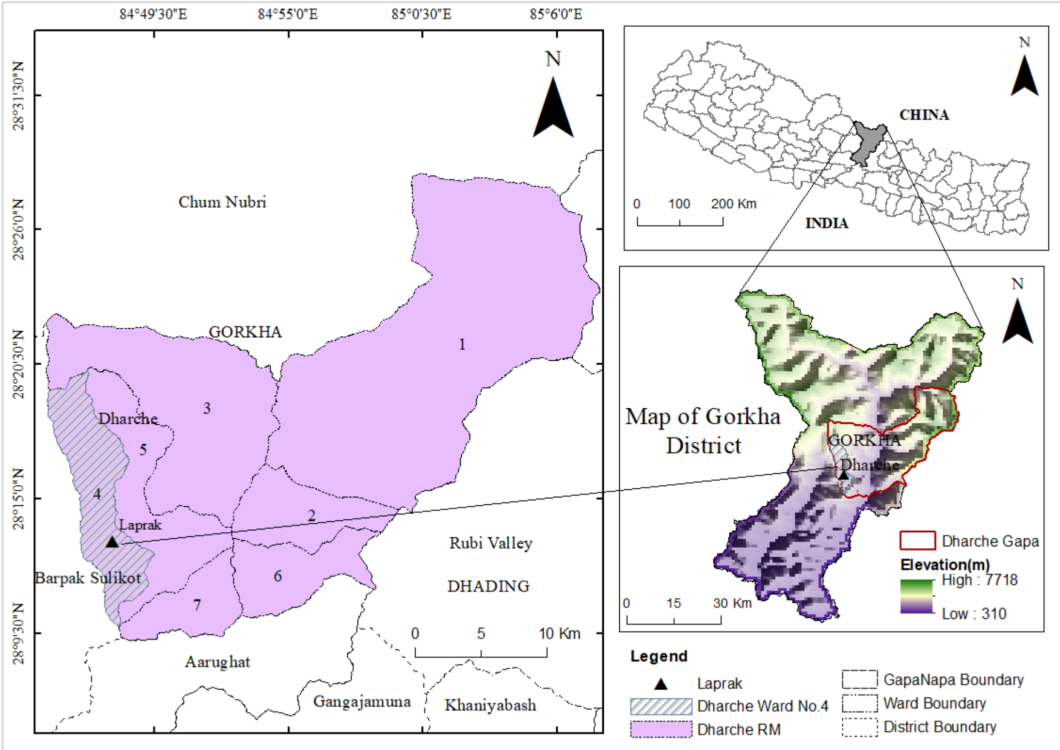

Figure 1: Map of the study area

3.1.1. Population and household

Laprak village is situated in Ward Number 4 of the Darche Rural Municipality within the Gorkha District. The overall population of Gorkha district is recorded at 251,027 individuals, with a gender distribution of 47% male and 53% female (CBS, 2021). Similarly, Dharche Rural Municipality has a total population of 14,263, with 48% male and 52% female, resulting in a male-to-female sex ratio of 88.92 (CBS, 2021).

The population showcased significant diversity in terms of ethnicity. The 2021 census revealed that the primary castes in Dharche were Gurung, Ghale, Bishwokarma, Brahman, Magar, Tamang, Kshetri, and others. Notably, the Gurung community comprised the major ethnic group in Dharche, making up 83% of the total population followed by the Ghale community at 12%, and the Bishwokarma community at 4% (CBS, 2021).

Furthermore, Dharche Rural Municipality had a total of 3,808 households, with an average household size of 3.75 persons per household (CBS, 2021). Wood was the primary source of fuel for 93.2% of households, highlighting their dependency on it. In terms of economic activities, agriculture played a crucial role, with 57.3% of the population relying on it. Wholesale and retail trade accounted for 12.5% of economic activity, followed by construction work at 8.1%. The remaining portion engaged in various other activities (CBS, 2021).

3.1.2. Vegetation

The Gorkha district is divided into six distinct climatic zones, as identified by Negi (1994), each characterized by its dominant plant species. These encompass *Pinus roxburghii*, *Pinus wallichiana*, *Juniperus recurva*, *Juniperus indica*, *Ephedra gerardiana*, *Abies spectabilis*, and *Rhododendron arboreum* (Sapkota *et al.*, 2017). In this region, two primary types of vegetation are found: Eastern Himalayan humid vegetation and Western Himalayan drier vegetation (Sapkota *et al.*, 2017). The Eastern Himalayan vegetation showcases rhododendrons (*Rhododendron arboreum*), laurels (*Litsea cubeba*), and green oaks (*Quercus leucotrichophora*), as prominent species. Conversely, the Western Himalayan vegetation is distinguished by species like *Picea smithiana*, *Pinus wallichiana*, and *Tsuga dumosa* (Sapkota *et al.*, 2017). During field studies conducted in Laprak, mixed forests comprising medium-sized evergreen trees such as rhododendrons (*Rhododendron arboreum*), green oak (*Quercus leucotrichophora*), and *Pinus wallichiana* were observed.

3.2. Data collection and analysis

The data for this study was gathered from both qualitative and quantitative approaches. Firstly, background information including data about the weather station, study site, and insights into the village's social, cultural, and educational groups were collected. For the perception survey, various data collection methods such as questionnaires, interviews, focus group discussions (FGDs), and key informant interviews (KII) were employed. The whole study area was divided into three parts; a village near the road access (Village 1), a village near the river (village 2), and a village at the top having no access to the road and far from the river (village 3) to collected the information about difference between the residents of different areas. A total of three KII, one in each village, and three FGDs were conducted following 133 household surveys. The language used for discussion and interviews was Nepali, but in the household survey where respondents were enabled to respond, a member of the local Gurung community acted as a translator.

A key Informant Interview (KII) with one key persons in each village was conducted, and after that, an FGD with a bit larger group than for KII was conducted to verify the information gathered from KII. From KII the major changes in the climate indicators and the impact caused by those changes we listed out. While with FGD further discussion on those changes in climate indicators and the impact caused by climate change were finalized. From KII and FGD, four climate indicators (temperature, precipitation, duration of season, and extreme events) and fifteen impacts of climate change in three different aspects (impact on biodiversity, impact on agriculture and livelihood, and impact on weather and ecosystem) were finalized. Lastly, a household survey was conducted to verify that qualitative information was obtained from KII and FGDs (Figure 2).

3.2.1. Perception data analysis

Descriptive statistics such as frequency and percentage were used to analyze survey results of socioeconomic characteristics of the sample, and perceptions of the respondents towards climate change indicators. Chi-square tests were employed to identify statistical significance between the perception of climate change indicators (temperature, extreme events, rain amount in different seasons, and duration of different seasons) and socio-economic factors (e.g., age, gender, education, area, and year of residency).

The perception of climate change impact among respondents is represented as a categorical variable with binary outcomes, thus making binary logistic regression an appropriate method for analyzing such data (Train, 2009). The binary logistic regression model was employed to identify the factors influencing the perception of climate change impact, utilizing the formula provided in the equation below:

$$\log\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_{ik} \quad \ldots\ldots\ldots\ldots$$

In the above equation, "i" represents the ith observation in the sample, and Pi denotes the predicted probability of a respondent perceiving the impact of climate change, which is coded as a dummy variable with a value of 1 if the respondent has perceived the impact and 0 otherwise (1 - Pi). β_0 represents the intercept term, while β_1, β_2, and β_k are the coefficients associated with each explanatory variable x_1, x_2, up to x_k. The term (P_i /1-P_i) signifies the odds ratio (Train, 2009; Greene, 2012).

Respondents' perception was used as a dependent variable while socio-economic factors like age, gender, education, area, and year of residency were used as independent variables. The analysis of perception data was done by using IBM SPSS Statistics 25.

3.2.2. Climate data analysis

Climate data were collected from two distinct sources: Fifth Generation of European Reanalysis (ERA_5) data, from the European Center for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission, and a bias-corrected multi-model ensemble comprising 13 General Circulation Models (GCMs) from the Coupled Model Intercomparison Project (CMIP-6). To assess historical intra-annual and decadal trends, climate variables such as daily rainfall and temperature, collected from ERA_5 data (Hersbach *et al.*, 2020), were employed.

The climate data were collected from two different sources; ERA_5 data from the European Center for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission and a multi-model ensemble consisting of 13 General Circulation Models (GCMs) from Coupled Model Intercomparison Project (CMIP-6). To evaluate historical intra-annual and decadal trends, climate data such as daily rainfall and temperature are collected from ERA_5 data (Hersbach *et al.*, 2020) while to predict the trend of climate indicators like climate extreme indices for historical period multi-model ensemble consisting of 13 General Circulation Models (GCMs) from Coupled Model Intercomparison Project (CMIP-6) was utilized (Mishra *et al.*, 2020).

ERA_5, the latest climate reanalysis conducted by ECMWF, offers comprehensive hourly data on a wide range of atmospheric, land-surface, and sea-state parameters, along with associated uncertainty estimates (Hersbach *et al.*, 2020). The dataset could be accessed through the Climate Data Store, displayed on standard latitude-longitude grids with a resolution of $0.25° \times 0.25°$, and included atmospheric parameters defined across 37 pressure levels (He *et al.*, 2020). Researchers frequently employed ERA_5 as observational data for correcting numerical model biases (He *et al.*, 2020; Hersbach *et al.*, 2020).

The precision of ERA_5 stemmed from its meticulous integration of historical observations, notably satellite data, utilizing advanced data assimilation and modeling frameworks (Jiao *et al.*, 2021). This integration empowered ERA_5 to provide more precise estimations of atmospheric conditions (Jiao *et al.*, 2021).

On the other hand, GCMs (Global Climate Models) represent the latest phase of a collaborative global effort involving modeling groups. The models were chosen based on their equilibrium climate sensitivity (ECS) values, which represent the anticipated long-term warming resulting from a doubling of atmospheric carbon dioxide (CO_2) concentrations (Dotse *et al.*, 2023). Specifically, the chosen General Circulation Models (GCMs) demonstrated relatively low equilibrium climate sensitivity, ranging from 1.9 to 3.0, aligning with the conclusions drawn in the fifth Assessment Report (AR5) (Nurse, 2014). Daily temperatures as well as precipitation data were analyzed to assess changes in patterns. To analyze the historical climate of the Laprak area, a multi-model ensemble consisting of 13 General Circulation Models (GCMs) from the Coupled Model Intercomparison Project (CMIP-6) was utilized (Mishra *et al.*, 2020). CMIP-6 offers access to data generated by the most recent advancements in climate and Earth system modeling, which are pivotal for informing the Intergovernmental Panel on Climate Change Assessment Report 6 (Eyring *et al.*, 2016). Notably, Earth system model (ESM) projections provided by CMIP-6 exhibit a higher signal-to-noise ratio and enhanced detectability for temperature change (Kumar *et al.*, 2013).

The analysis of annual and seasonal trends in historic climatic conditions was conducted utilizing a non-parametric Mann–Kendall test, using the Kendall R-package (McLeod, 2015). Sen's slope estimator, which is based on Kendall's τ (Sen, 1968), was employed to assess the magnitude of trends using the ZYP R-package (Bronaugh and Werner, 2015). A comprehensive examination was carried out, encompassing 16 climate extreme indices based on the definitions established by the CCl/CLIVAR (Climate and Ocean: Variability, Predictability and Change)/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI). The detailed definitions for 16 of these climate extreme indices are provided in Table 1.

Table 1: Definitions of climate extremes

S.N.	Acronym	Indicator name	Definitions	Units
1.	**TXx**	Max Tmax	Annual maximum value of daily maximum temperature	°C
2.	**TXn**	Min Tmax	Annual minimum value of daily maximum temperature	°C

3.	**TNx**	Max Tmin	Annual maximum value of daily minimum temperature	°C
4.	**TNn**	Min Tmin	Annual minimum value of daily minimum temperature	°C
5.	**TX90p**	Warm days	Percentage of days when TX>90th percentile	%
6.	**TX10p**	Cool days	Percentage of days when TX<10th percentile	%
7.	**TN90p**	Warm nights	Percentage of days when TN>90th percentile	%
8.	**WSDI**	Warm spell duration index	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
9.	**CSDI**	Cold spell duration index	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
10.	**RX5day**	Max 5-day precipitation amount	Annual maximum consecutive 5-day precipitation	mm
11.	**R20mm**	Number of very heavy precipitation days	Annual count of days when PRCP>=20mm	Days
12.	**CDD**	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
13.	**CWD**	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
14.	**R95p**	Very wet days	Annual total PRCP when PR>95th percentile	mm
15.	**R99p**	Extremely wet days	Annual total PRCP when PR>99th percentile	mm
16.	**PRCPTOT**	Annual total wet-day precipitation	Annual total PRCP in wet days (PR>=1mm)	mm

Source: https://etccdi.pacificclimate.org/list_27_indices.shtml

Figure 2, illustrates the schematic that outlines all the processes involved in the study.

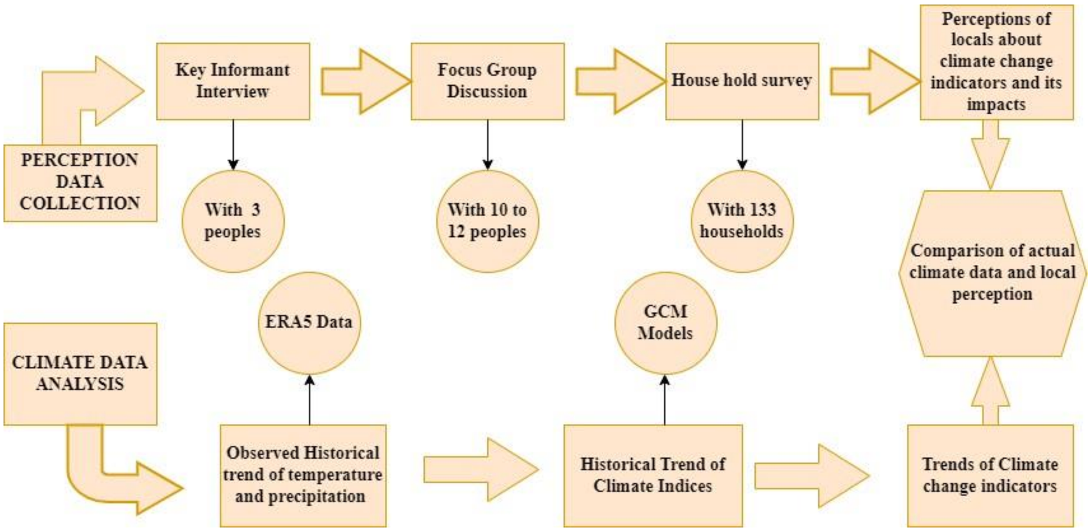

Figure 2: Schematic flow chart showing methodology adopted for this study

CHAPTER 4: RESULTS

4.1. Demographic characteristics of the respondents

The survey provided insights into the diverse socio-economic characteristics of the 133 respondents within the study area (Table 2). These participants exhibited variations in gender, age, education, occupation, income, and knowledge about climate change. More than half of the respondents (64%) were female. When considering the age distribution, the majority (39%) fell within the 30-49 years old category, followed by those older than 50 years (35%), while the remaining 26% were between 18 to 29 years old. The Gurung community was selected for the survey as it represented a significant portion of the total population in the study area, allowing us to gain deeper insights into their perspectives on the subject. So, there was no variation in the ethnicity of the respondents. More than half of the respondents had never been to formal education (53%), whereas the remaining 47% had attended some formal education.

Table 2: Socio-demographic characteristics of the respondents

Indicators	**Type**	**Number of respondents (n)**	**%**
Sex	Male	48	36
	Female	85	64
Age group (years)	18 -29	35	26
	30-49	52	39
	50-80	46	35
Ethnicity	Gurung	133	100
Education	Formal education	63	47
	No formal education	70	53
Livelihood activity (major)	Agriculture & livestock rearing	82	61
	Gathering of NTFPs	8	6
	Service	8	6
	Business	18	14

	Wage labor	15	11
	Others (unemployed, retired, unable to work)	3	2
Year of living in the locality	> 10	3	2
	10-20	11	8
	21-30	30	23
	31-40	29	22
	< 40	60	45
Knowledge about climate change	Aware	28	21
	Unaware	106	79
Ownership of land	Own land	121	90
	Others (borrow land, rented land, common land)	13	10

The majority of the population (61%) was involved in agriculture-related activities, indicating its importance in the study area. The remaining 36% were found engaged in various other activities such as gathering non-timber forest products (NTFPs), service-oriented work, business ventures, and wage labor. Additionally, a small proportion of the respondents (3%) were unemployed. Concerning land ownership, around 90% of the respondents reported possessing significant landholdings. In terms of occupations, more than half of the respondents (62%) relied on agriculture and livestock rearing for their livelihood. Business activities accounted for 14% of the respondents, while 11% were engaged in wage labor. The rest of the respondents were involved in other diverse activities (Table 2).

The respondents have a very low awareness of the word ‘climate change’ and its impact. Nearly 79% of the respondents were unaware of the term "climate change." Only a small proportion (21%) had heard about the term from various sources, including formal education, media, family, friends, neighbors, and other channels.

4.2. Local perceptions of climate change indicators

Most of the respondents (95%) felt that the annual average temperature had remained the same, while the remaining 5% noticed a drop in the annual temperature. However, a majority (85%) believed that the temperature during the coldest season had decreased in recent years. In contrast, the perception of the temperature during the hottest season aligned with the general temperature perception, as 95% indicated that there had been no change in the hottest season's temperature (Figure 3).

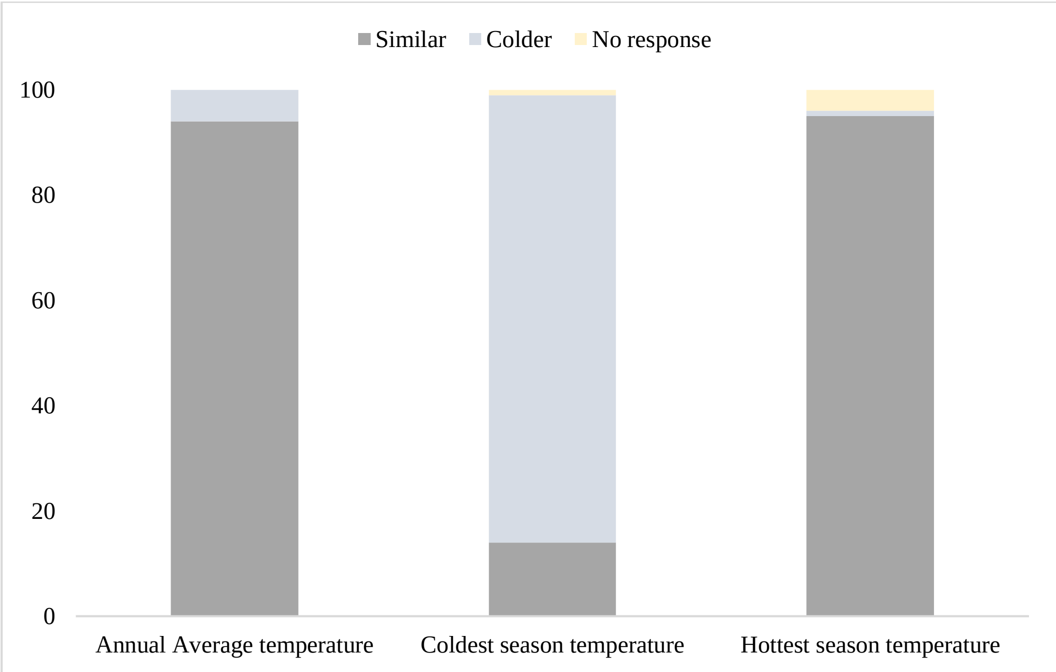

Figure 3: Perception related to temperature

About 40% of the respondents observed that the occurrences of extreme floods remained unchanged, while 28% noted an increase in the frequency of such events in the Laprak area. In contrast, responses concerning extreme drought were more straightforward. A majority (60%) believed that the drought situation remained unchanged compared to before. Following this, 8% of the respondents thought that droughts had become less frequent (Figure 4).

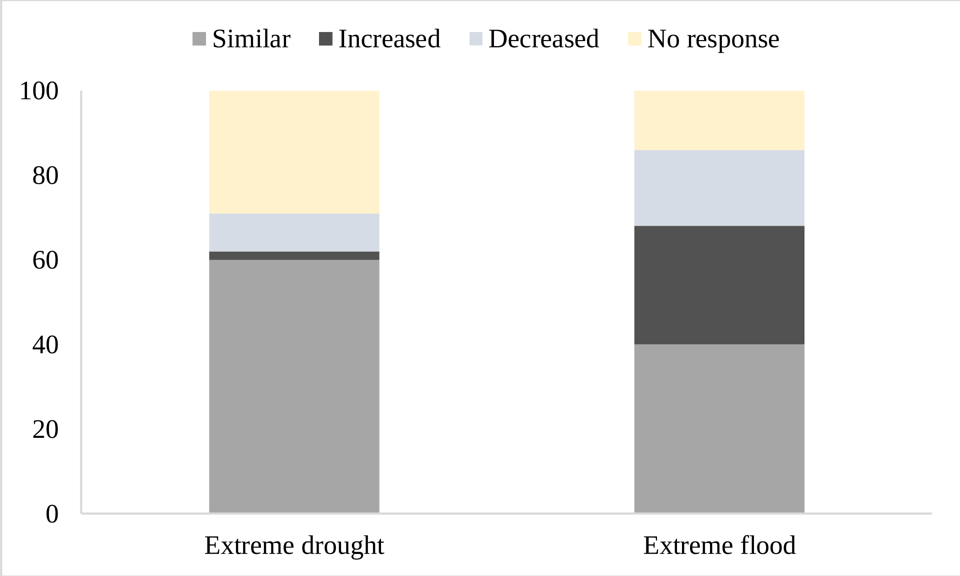

Figure 4: Perception related to extreme event

As the temperature decreased, over 85% of the respondents noted an increase in rainfall during the rainy season. However, opinions about rainfall during the dry season were more varied. About 39% stated that there is greater rainfall during the dry season, while 38% indicated no change in dry season rainfall. Some respondents did not provide a response regarding the amount of rainfall (Figure 5).

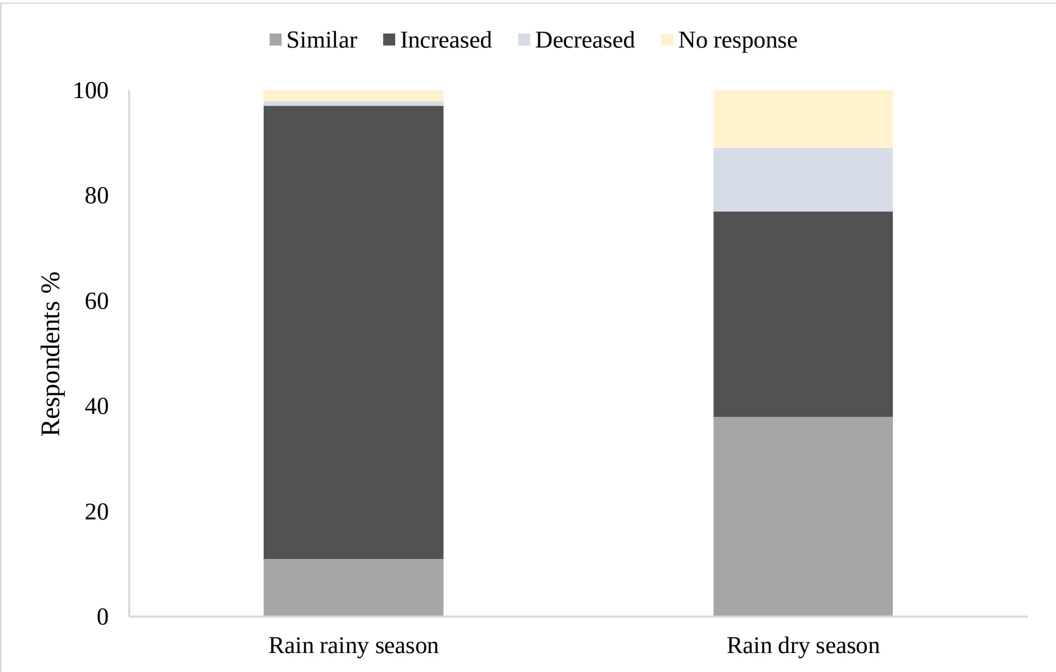

Figure 5: Perception related to rainfall amount

The respondents had varied perceptions of the season's duration. More than half of them (73%) stated that the rainy season had become longer. Meanwhile, 14% perceived the rainy season to remain unchanged, and only 1% mentioned it had become shorter. However, the perception of the dry season's duration differed. A majority (70%) believed that the dry season had become shorter. Additionally, 7% thought the dry season had lengthened, and 11% believed it remained the same as before where 12 % did not respond for both the seasons (Figure 6).

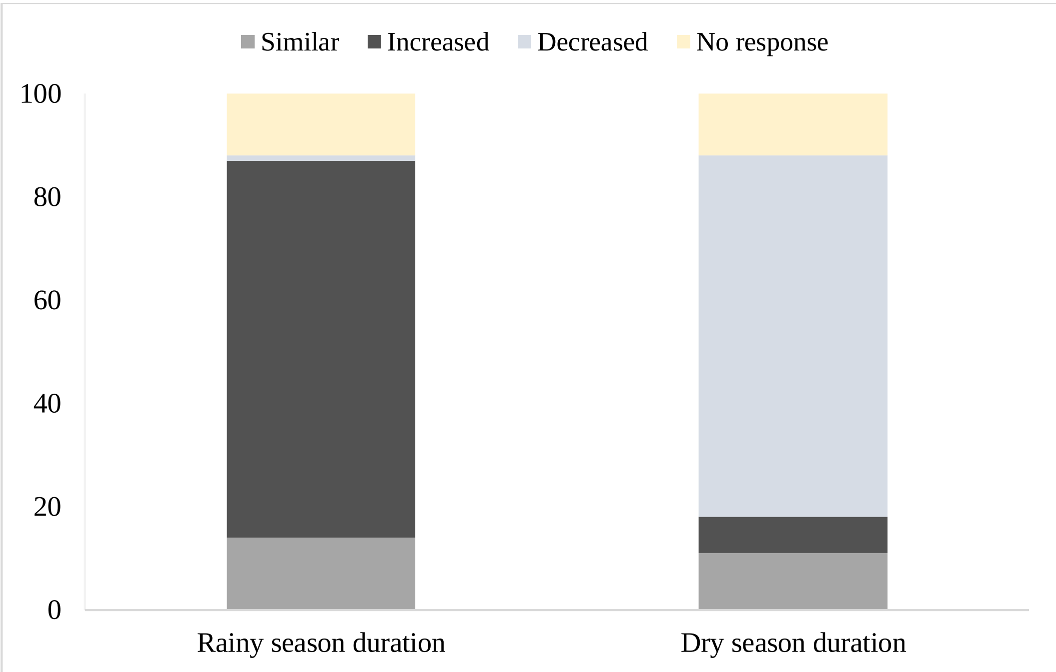

Figure 6: Perception related to duration of season

The perception of temperature among respondents showed no statistically significant difference when compared to other socio-economic parameters such as age, gender, education level, year of residency, and the location of the study site. However, a notable difference was found in the perception of general temperature concerning the area. Similarly, there was no statistical significance in the perception of the coldest season temperature and the hottest season temperature concerning other socio-economic parameters. However, when it came to extreme events, both the perception of extreme droughts and extreme floods showed statistical significance with the area of residence (Table 3).

Table 3: Significance of perception of climate indicators

Variables	General temperatu	Coldest season	Hottest season	Extreme drought	Extreme flood	Rain dry season	Rain rainy season	Rainy season	Dry season duration
Age	0.244	0.826	0.437	0.602	0.82	0.419	**0.024***	0.563	**0.005****
Gender	0.33	0.138	0.321	0.539	0.369	0.367	0.534	0.438	0.590
Education	0.892	0.927	0.296	0.977	0.606	0.715	0.318	0.930	0.208
Year of residency	0.579	0.869	0.225	0.66	0.366	0.558	0.094	0.726	0.393
Area of residency	**0.01****	0.2	0.622	**0.00*****	**0.00*****	**0.001****	0.128	**0.016***	**0.00*****

*< 0.05, **< 0.01 and ***< 0.001. The bold values indicate statistically significant values at 5% or below.

The perception of rain amount during the rainy season was found to be significant about the age of the respondents, whereas the perception of rain amount during the dry season showed statistical significance based on the area of residency. Similarly, individuals' perception of the rainy season's duration exhibited statistical significance with the area of residency, while the perception of dry season duration was statistically significant in connection with both the age of the respondents and their area of residency (Table 3).

4.3. Local perception of climate change impact

Three types of impacts were observed in biodiversity namely: occurrence of invasive species, change in the level of lake or pond water, and change in pasture cover, surface, or abundance. Approximately 21% of the respondents reported observing *Banmaara* (*Ageratina adenophora*) in their fields or peripheral region of the nearby forest areas (Figure 7). This species, which was previously confined to the peripheral region of forests, has now started spreading to the adjacent crop fields, leading to significant damage and losses in crop production.

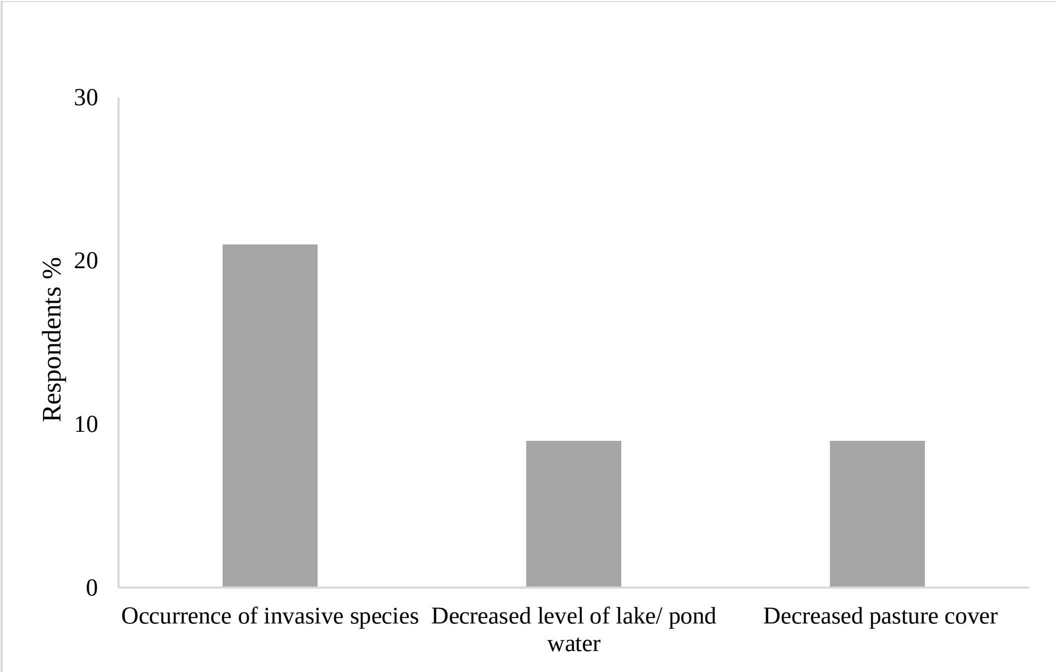

Figure 7: Impact of climate change on biodiversity and ecosystem

Furthermore, a smaller proportion of respondents, specifically 9%, expressed concerns about the declining pasture cover and surface in pasturelands (Figure 7). These respondents also noted a decreasing trend in water levels within lakes and ponds in the pasture, which is posing challenges for the livestock herders in the area.

Similarly, the impact of climate change on agriculture and livelihood in the Laprak area was specified mainly in four different topics; conflicts over natural resources, soil productivity, human diseases, livestock mortality, and problems with transportation. Most of the respondents (60%) mentioned the conflicts over natural resources, particularly pasturelands (Figure 8).

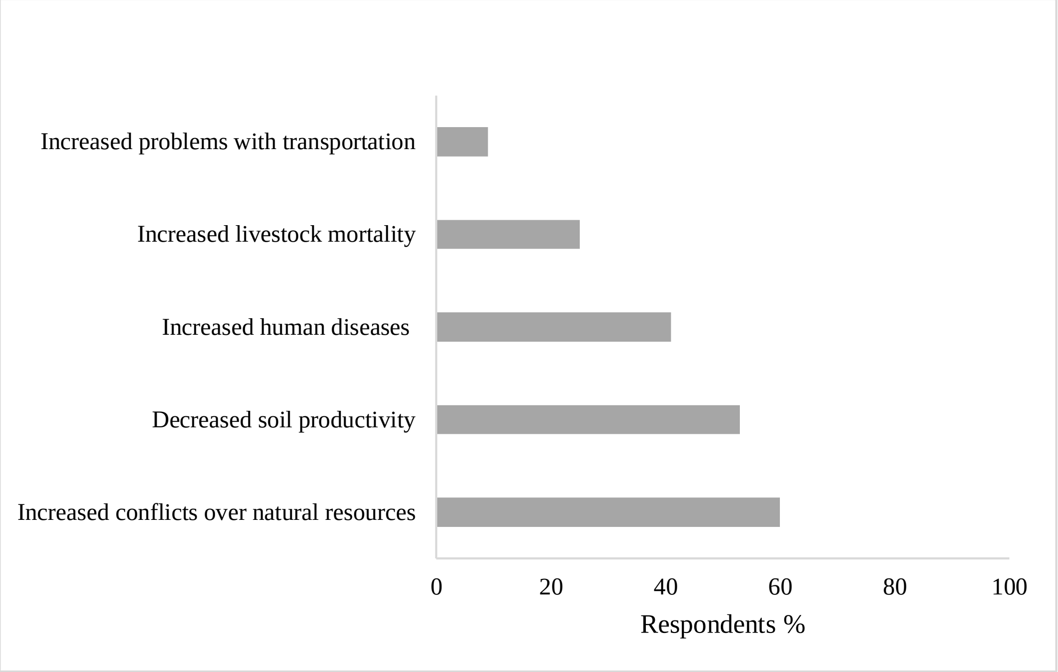

Figure 8: Impact of climate change on agriculture and livelihood

Similarly, more than half (53%) of the respondents reported a decrease in soil productivity, leading to reduced yields of crops such as maize, potato, and barley. 41% of respondents reported an increase in skin-related diseases while 25% of the respondents noted an increase in livestock mortality due to colder conditions and the emergence of new diseases affecting the animals (Figure 8).

Local people's responses regarding weather and ecosystem changes did not show a clear pattern. Approximately 15% of the respondents reported an increase in rain-induced soil erosion, while only 16% observed changes in the transition between seasons (Figure 9).

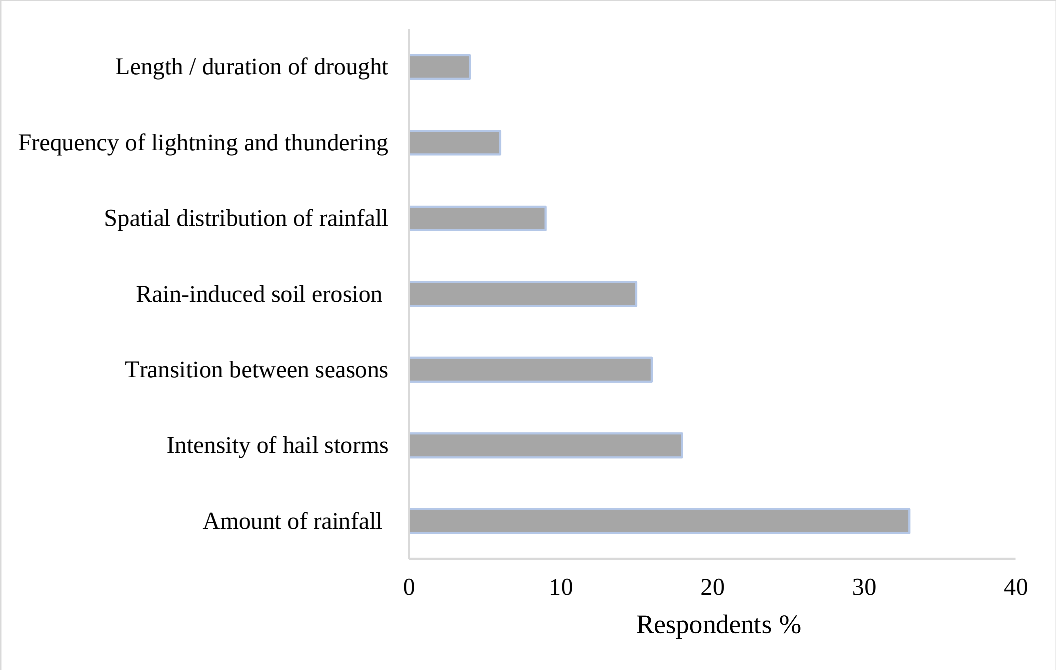

Figure 9: Impact of climate change on weather and ecosystem

On the other hand, a slightly larger portion, 33% of the respondents, mentioned that the amount of rainfall during specific seasons has increased. Moreover, a portion of the respondents, 18%, noted an increase in the intensity of hailstorms in the area in recent times. Lastly, 9% of the respondents observed a change in the spatial distribution of rainfall within the area (Figure 9).

Table 4: Significance estimates for the perception of the impact of climate change

The value in the small bracket indicates the significance level while the value before that is Expected (B).

Variable	**Soil productivity**	**Amount of rainfall**	**Intensity of hail storms**	**Level of lake / pond water**	**Livestock mortality**	**Incidence of human diseases**	**Conflicts over natural resources**	**Problems with transportation**	**Occurrence of weed species**	**Frequency of lightning and thundering**	**Spatial distribution of rainfall**	**Transition between seasons**	**Pasture cover, surface or abundance**
Area	0.012(0. 764)	0.852 (**0.001**) **	0.038 (0.551)	-0.031 (0.605)	-0.023 (0.621)	-.036 (0.351)	-0.073 (0.097)	0.025 (0.794)	-0.071 (0.132)	-0.003 (-**0.003**) **	0.034 (0.701)	0.080 (0.093)	-0.001 (0.999)
Gender	-0.541 (1.718)	-0.092 (0.834)	0.983 (**0.004**) **	-0.704 (0.096)	0.095 (0.703)	0.353 (0.118)	-0.081 (0.724)	1.461 (**0.004**) **	0.090 (0.746)	1.872 (1.872)	1.171 (**0.011**) *	0.546 (0.075)	0.270 (1.310)
Education	0.023 (1.023)	-0.077 (0.181)	0.020 (0.746)	0.020 (0.712)	0.036 (0.407)	0.022 (0.548)	0.056 (0.164)	0.024 (0.802)	0.014 (0.745)	0.014 (**0.014**) *	0.006 (0.949)	-0.047 (0.250)	0.033 (1.034)
Year of residency in area	-0.218 (0.588)	-0.32 (0.388)	-0.254 (0.645)	0.211 (0.761)	-0.345 (0.444)	0.204 (0.613)	-0.419 (0.297)	0.194 (0.773)	-0.691 (0.201)	1.001 (1.001)	0.113 (0.877)	-0.345 (0.520)	-0.339 (0.712)
Age	-0.032 (0.526)	0.48 (0.232)	-0.006 (0.936)	-0.085 (0.355)	0.074 (0.184)	-0.085 (0.097)	0.005 (0.920)	0.033 (0.740)	-0.110 (0.069)	-0.131 (-0.131)	-0.189 (0.224)	0.072 (0.302)	0.078 (1.082)

There was no significant relationship found between the perceived alteration in soil productivity and the socio-economic parameters of the respondents. However, the perception of changes in the amount of rainfall displayed a statistically significant relation with the (E. (B)=0.852, p = 0.001] area of residency of the respondents. This shows that the perception of rainfall differs with the respondent's area of residency. Similarly, the perception of changes in the intensity of hailstorms was also statistically significant [E (B)= 0.983, p= 0.004] with the gender of the respondents (0.983) (Table 4). This indicates that both males and females perceived different kinds of changes in hailstorm intensity.

On the other hand, perceptions regarding alterations in lake and pond water, livestock mortality, frequency of human disease incidents, and conflicts over natural resources did not show significant connections with the socio-economic parameters of the respondents. But the frequency of transportation problems was statistically significant [E (B)= 0.0141, p =0.004] with the gender of the respondents. This indicates that males and females had different perceptions of transportation-related problems (Table 4).

Impacts such as the appearance of weed species, shifts in seasonal transitions, and variations in pasture cover, surface, or abundance demonstrated no statistical significance about socio-economic parameters. However, the impact of changes in the spatial distribution of rainfall had a statistically significant relationship [E(B) =1.171, p= 0.011] with the gender of the respondents (Table 4). This indicates that both males and females perceived rainfall patterns differently in terms of their location.

4.4. Trend analysis of historical data

4.4.1. Historical trend of climate indicators in Laprak

Laprak underwent annual warming of 0.045°C (p=<0.003) from 1979 to 2020 (Figure 14). The lowest and highest mean annual temperatures were registered in 1997 and 2016, measuring -5.67 and -0.66 respectively. The region's maximum temperature climbed by 0.027°C each year (p=<0.004), while the lowest temperature escalated by 0.032°C per annum (p=<0.002) (Figure 10).

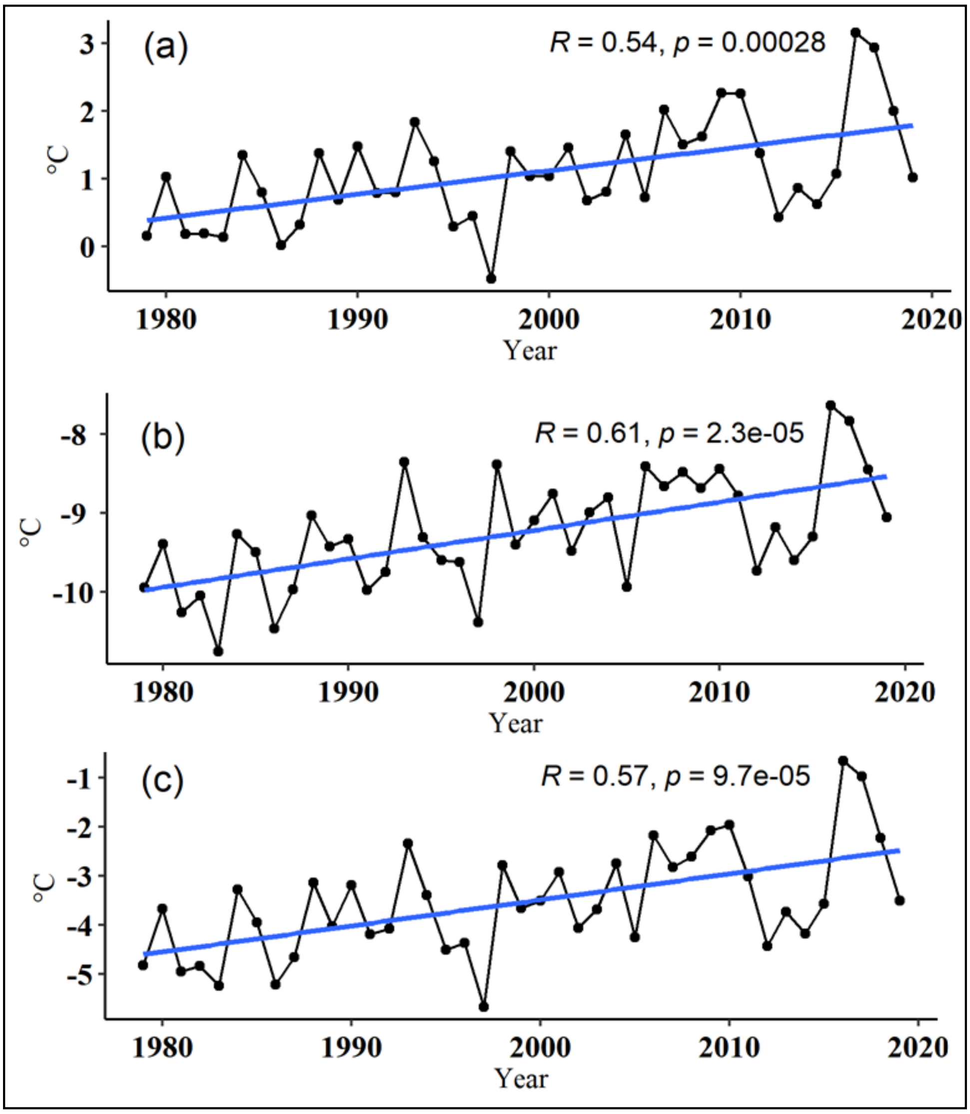

Figure 10: Trend of maximum (a), minimum (b) and mean temperature (c) in Laprak from 1979-2019.

(R= Correlation coefficient, p= probability value)

Table 5: Historical temperature trend in Laprak (1979-2020)

Temperature	**Sen Slope**	**p-value**
Maximum temperature	0.027	0.004**
Minimum temperature	0.032	0.002**
Mean temperature	0.045	0.003**
** ≤ 0.05		

The highest maximum temperature recorded was 3.15°C in 2016, while the highest minimum temperature was noted at -7.63°C in 2009. Overall, the increase in temperature was primarily noticeable in the minimum temperature compared to both the mean and maximum temperatures (Table 5).

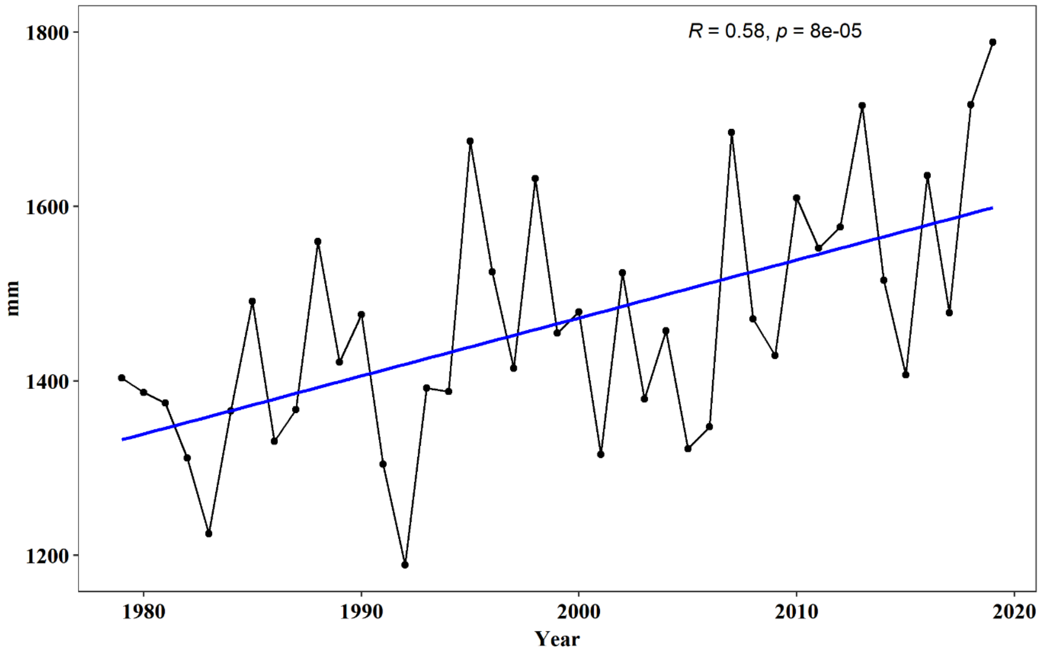

Figure 11: Trend of annual precipitation in the Laprak area

(R= Correlation coefficient, p= probability value)

Table 6: Historic precipitation trend in Laprak (1979-2020)

Precipitation	**Sen Slope**	**p-value**
Total Annual Precipitation	5.889	**0.002****
Pre-monsoon	-0.035	0.955
Monsoon	6.358	**0.0008*****
Post-monsoon	-0.0903	0.831
Winter	-0.364	0.7961

*** ≤ 0.001, ** ≤ 0.05

As for precipitation, Laprak has experienced an increase of 5.889 mm (p=<0.002) per year. The precipitation has increased by 5.89mm (p=<0.002) per annum from the year 1979 to 2020. In terms of seasons, pre-monsoon, post-monsoon, and winter precipitation decreased by 0.035mm/year, 0.09mm/year, and 0.36mm/year respectively (Table 6). However, the monsoon season precipitation increased by 3.36mm/year. The highest decrease was found in the premonsoon period followed by the post-monsoon period and winter season (Table 6). The yearly changes in precipitation are shown in Figure 11 above.

4.4.2. Historical trend of climate extremes in Laprak

The historical temperature extremes, such as warm days (TX90p) (0.159% per year) and warm nights (TN90p) (0.261% per year) have a significant increase trend in Laprak between 1951 to 2015 (Table 7).

Table 7: Historical trend of climate extremes in Laprak (1951-2015)

Climate Extreme Index	**Sen Slope**
CDD	-0.020
CWD	0.012
R99p	-0.104
R95p	-0.122
WSDI	**0.157****
CSDI	**-0.116****
R20mm	**0.142*****
PRCPTOT	**5.931*****
TX10p	**0.108*****
TX90p	**0.159*****
TN90p	**0.261*****
TXx	**0.004****
TXn	**0.016*****
TNn	**0.028*****
TNx	**0.016*****
RX5day	**0.187*****

*** ≤ 0.001, ** ≤ 0.05, * ≤ 0.10

Similarly, other temperature extremes like warm spell duration (WSDI) (0.157 days per year), an annual maximum value of daily maximum temperature (TXx) (0.004°C per year), an annual minimum value of daily minimum temperature (TNx) (0.016°C per year), and an annual minimum value of daily maximum temperature (TNn) (0.028°C per year), all showed a significant increasing trend in the Laprak area (Table 7, Figure 12). The temperature extremes like the annual minimum value of daily maximum temperature (TXn) (0.016°C per year), the annual minimum value of daily minimum temperature (TNn) (0.028°C per year), and cool days (TX10p) (0.108 % per year) (Table 7).

The historical trend of total precipitation (PRCPTOT) also demonstrated a significant (5.931mm per year) increase in Laprak (Table 7). Similarly, there was a significant increase (0.142mm per year) in the number of very heavy precipitation days (R20mm), and Max 5-day precipitation amount (RX5day) (0.187mm per year) between the years 1951 to 2015. Likewise, an increasing trend (0.012 days per year) was also observed in the consecutive wet days (CSD) (Table 7, Figure 13).

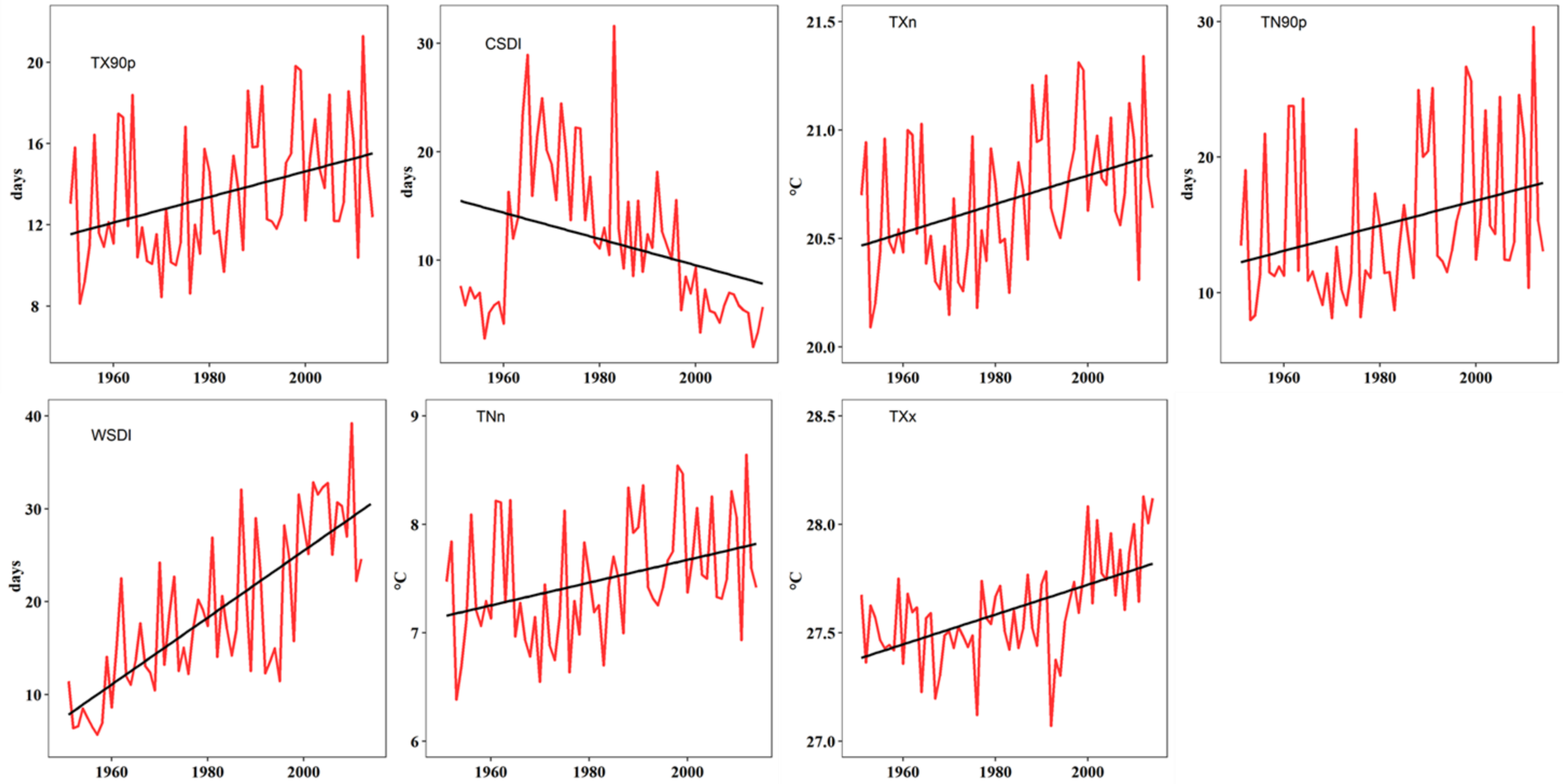

Figure 12: Historical trend of temperature-related indices in Laprak

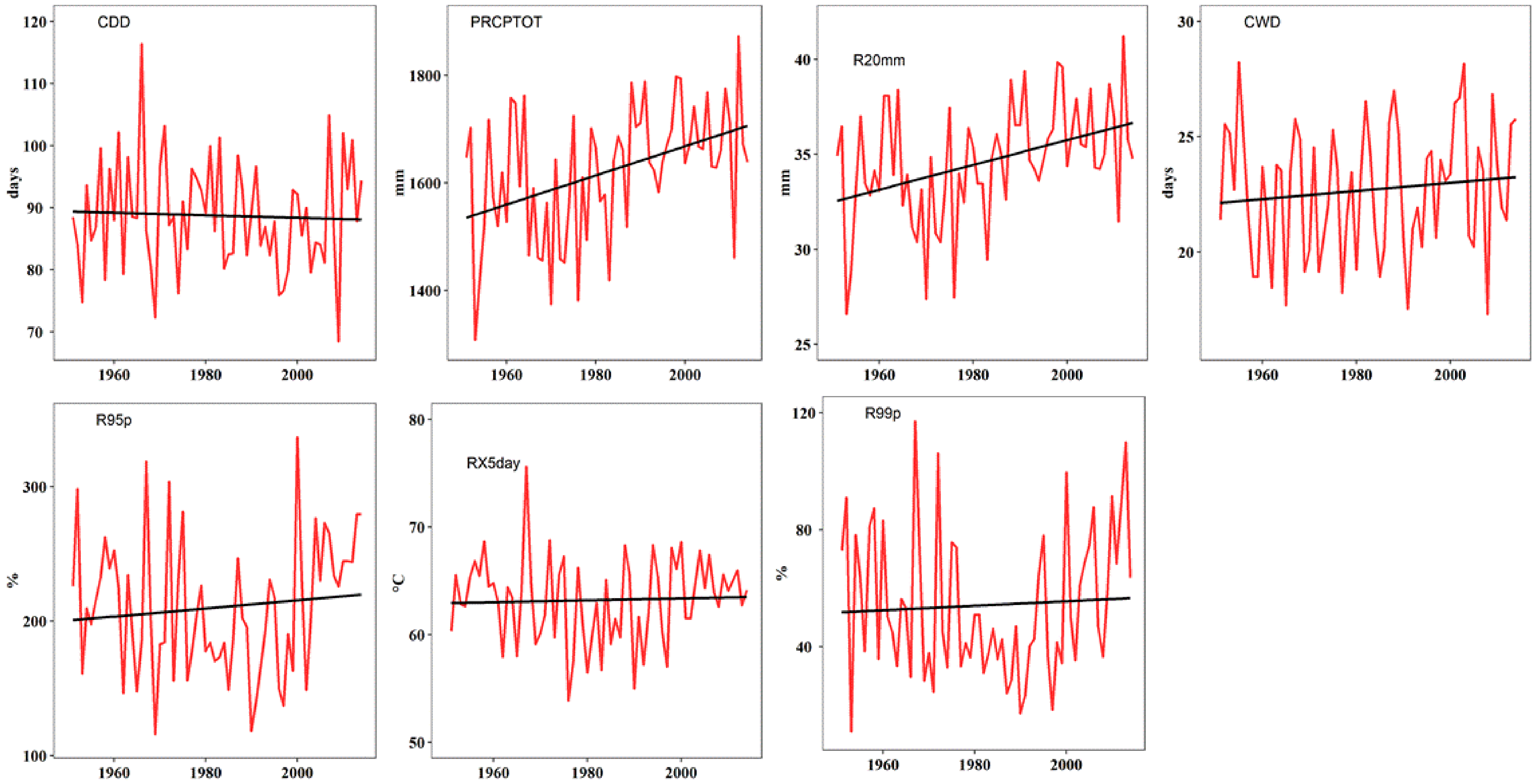

Figure 13: Historical trend of precipitation-related indices in Laprak

But the decreasing trend was also observed in some of the indices like in very wet days (R95p) (-0.122 mm per year), extremely wet days (R99p) (-0.104 mm per year) and Consecutive dry days (CDD) (-0.020 mm days per year) (Table 7, Figure 13).

4.5. Comparing the perception with climate data

An agreement between local perceptions and climate change trends was higher for precipitation than for temperature-related indices (Table 8). Local perceptions about temperature did not align with the actual temperature trend. The majority of locals (94%) perceived the general temperature as unchanged from before, but the actual trend was a significant increase of 0.045°C/year. There was also a discrepancy in the perception of the hottest seasonal temperature. Similarly, there was a contrast between the perception and the actual trend of the hottest season temperature, with the actual trend increasing (+0.27°C/year) while it was perceived as unchanged from before (Table 8). But for the coldest season temperature, most of the respondents (85%) perceived the coldest season temperature as decreasing compared to before, which aligns with the actual trend of cool days which was also increasing by 0.108 % per year (Table 8).

A higher percentage (60%) of respondents perceived extreme drought as unchanged, similarly, in reality, the number of consecutive dry days also decreased (0.020% per year). The perception of extreme floods remained the same, but the actual trend differed, as the number of heavy very heavy precipitation days increased significantly by 0.142mm/year (Table 7).

Table 8: Alignment and discrepancy between perception and climate data

Climate indicator	**Dominant perception**	**Perception frequency**	**Actual trend**	**Comparison**
General temperature	Same	94%	+0.045°C/year	
Coldest season temperature	Colder	85%	0.108 % per year	
Hottest season temperature	Same	95%	+0.27°C/year	
Extreme drought	Same	60%	-0.020%/year	

Extreme flood	Same	40%	+0.142mm/year	
Rain rainy season	Higher	86%	+6.358mm/year	
Rain dry season	Higher	39%	-0.0903mm/year	
Rainy season duration	Longer	73%	+0.012%/year	
Dry season duration	Shorter	70%	-0.020%/year	

The red color in the table indicates the discrepancy in perception and model data while the green color indicates the alignment between perception and model data.

The perception of rainfall (86%) was mentioned higher which matches the modeled trend with a 5.931mm/ year increase (Table 7). The actual trend of precipitation and rain amount matched the actual trend as the majority (73%) of the respondents perceived a longer rainy season than before same was also observed with an increase (+0.012%/year) trend of consecutive wet days. Similarly, the shorter dry season was perceived by the majority (70%) of the respondents as perfectly aligning with the increasing trend of consecutive wet days (+0.012%/year) as well as monsoon precipitation (+6.358mm/year) (Table 8).

CHAPTER 5: DISCUSSION

5.1. Locals perception of climate indicators

Nine local climate indicators were utilized to identify the locals' perceptions of climate change. The majority of the respondent's perceptions did not match with modeled data in the case of temperature. This is similar to the results reported done by Maharjan and Joshi, (2013) where some participants also described experiencing cooler winters and no change in summer temperatures. However, many previous studies like Shrestha and Aryal, (2011), Uprety *et al.*, (2017), and Shrestha *et al.*, (2019) conducted in Nepal did not support this finding. The temperature perception which did not match the global scenario in this study is may be due to the season of data collection (i.e. February) when there is extreme snowfall in the Laprak area. Another reason for the difference between perceptions and the actual temperature trend would be the slow rate of temperature increase in the Laprak area. According to Diggs (1991), people find it very difficult to notice gradual changes in climate events. Laprak is situated in the mid-hill region of the country, where temperatures are generally low, causing people to view small temperature increases as normal or consistent with the past. Another reason for the mismatch in the perception and trend in the temperature is the visual prominence of the temperature (Maharjan *et al.*, 2013). In that study, respondents explained they could easily predict the change in the precipitation as that is easily noticeable or visible but for temperature that is not possible.

The change in the precipitation-related indices pattern was in alignment with the perception of the locals. Most of the respondents perceived an increase in the amount of rainfall in the given season, as well as a longer duration of the rainy season than before. Results of the current study are mismatched with the previous study done by Shrestha *et al.,* (2019). This might have been associated with different rainfall amounts and patterns within the country (Uprety *et al.*, 2017). In general, the eastern areas of Nepal tended to experience more wet conditions than the western areas.

Most of the respondents explained more extended monsoon season but, in a study, done by Tiwari *et al.,* (2010) and Shrestha *et al.,* (2019) respondents described the later onset of the monsoon. This may be the reason for the increasing trend of total precipitation as well as seasonal precipitation in this study area.

The perception regarding extreme events like drought and flood matches with the modeled trend of these events. In this study, most of the respondents explained the same drought as before which did not align with the previous studies (Tanner *et al.*, 2018; Shrestha *et al.*, 2019). This contrast with the previous study may be because of the increasing trend of total precipitation as well as seasonal precipitation in this study area.

Perception of the respondents depends on the age of the respondents, which also resembles the study done by Roco *et al.*, (2015), and Habtemaria *et al.*, (2016). However, this result contrasts with some studies done in Nepal (Piya *et al.*, 2012). The geography of the area where people live also determines the perception of climate change (Weber, 2010; Spence *et al.*, 2012). These findings also indicated a significant impact of the area on people's perception of climate change indicators.

The perception regarding changes in the intensity of hailstorm shows a significant relationship with the gender of an individual. This resembles the earlier study done by Pearse, (2017) which clearly explains climate change is a problem that affects everyone, but it affects women differently than men. However, some studies done within the country did not show a difference between the exposure of impacts between the genders (Gentle *et al.*, 2014).

5.2. Perceived impacts of climate change

Locals perceived three main impacts of climate change on biodiversity. These were the introduction or occurrence of invasive alien plant species, changes in the level of lake or pond water, and changes in pasture cover. This kind of result was also observed in the Chitwan-Annapurna Landscape of Nepal where most of the respondents perceived the impact of invasive species and a decrease in pasture cover due to climate change impact (Adhikari *et al.*, 2019). Such an increase in invasive species in crop fields was also observed in many previous studies done in Nepal (Chaudhary and Bawa, 2011; Shrestha *et al.*, 2021).

Respondents observed the introduction of mosquitoes as a problem caused by transportation which is one of the major issues observed in the mid-hills of Nepal (Chaudhary and Bawa, 2011; Uprety *et al.*, 2017) as an increasing temperature as well as due to transportation. Many of the respondents explained the increased rate of livestock mortality due to increased extreme events of snowfall in the area. This result is consistent with many studies conducted in different parts of the world (Sarkar and

Padaria, 2016; Thakur *et al.*, 2018;) on the impact of climate change. The impact of climate change on livelihood was also observed as a decrease in soil productivity and increased livestock mortality which was also observed in previous studies conducted on the western side of the country by Shrestha *et al.*, (2021).

In the current study, the impact of climate change on weather and the ecosystem did not show a clear pattern but respondents were aware of the change in rainfall amount and pattern and spatial distribution, change in the duration of the season, and also in the change in the intensity of hail storm in the area. The perception of climate change risk and awareness was distributed unevenly around the world (Lee *et al.*, 2015) and depended on many other factors. Climate extreme events were found to have different levels of impact on different age groups of people (Weber and Stern, 2011; Hasen *et al.*, 2014).

5.3. Trend of modeled climate data

The effects and extent of climate change vary across different geographical locations (Warren *et al.*, 2006). Gaining knowledge about the regional aspects of climate change is fundamental in identifying its impact at that level (Malone and Engle, 2010). Analyzing meteorological factors such as temperature and precipitation helps to know the changing nature of these elements, thus enabling an understanding and response to the implications of climate change (Lebel, 2013). The analysis of historical and projected data trends has extensively helped to know how climate change influences the occurrence and intensity of extreme weather occurrences (Baker *et al.*, 2016).

Through the examination of historical and projected climate data, we can establish meaningful connections between past shifts and potential future outcomes. This process not only enables well-informed decision-making but also aids in crafting effective strategies to mitigate the consequences of climate change (Dulal, 2009). Highlighting this significance, the IPCC emphasizes the evaluation of historical and future climate trends as a fundamental tool in the development of approaches aimed at addressing the impacts of climate change (Levermore, 2008).

5.3.1. Historic trend of temperature extremes

The indices related to extreme temperatures, such as the highest daily temperature of the year (TXx) and the lowest nighttime temperature of the year (TNn), have shown a clear upward trend in the Laprak region. This observation is consistent with findings from previous studies (Baidhya *et al.* 2008; Sheikh *et al.*, 2015; Shrestha *et al.*, 2017). However, this pattern sharply contrasts with the trend observed in Dumkauli and Chame, where a notable decrease in these indices was identified (Adhikari and Mathema, 2023).

The trend of increasing nighttime temperatures (TNn) and warmer daytime temperatures (TXx) has also been observed at numerous weather stations across South Asia countries like Nepal, India, Sri Lanka, and Pakistan (Sheikh *et al.*, 2015; Naveendrakumar *et al.*, 2019). This divergence in trends may be attributed to a range of factors, including geographical variations and local climatic influences. Similarly, the indices reflecting the coldest daytime temperature of the year (TXn) and the warmest nighttime temperature of the year (TNx) also demonstrated an increase which is also similar to the previous studies (Sheikh *et al.*, 2015; Shrestha *et al.*, 2017). Baidya *et al.*, (2008) advocated the increasing trend of TNx but a decreasing trend of TXn. The contrast observed in the trend of TXn is due to the location of the stations.

The trend of percentile-based extreme temperature indices, namely TX10p and TX90p, exhibited a significant increase. This outcome contrasts with similar research conducted by Sheikh *et al.*, (2015) and Shrestha *et al.*, (2017) where the trend of these indices was declining. Likewise, the occurrence of warm nights (TN90P) has also displayed a significant increasing trend in our study area, which is in line with the results of previous studies (Baidya *et al.* 2008; Zhou and Ren 2011; Sheikh *et al.* 2015; Shrestha *et al.*, 2017).

The warm spell duration indicator (WSDI) in Laprak is showing an increasing trend, while the cold spell duration indicator (CSDI) is exhibiting a negative trend. These trends align with findings from previous studies (Baidya *et al.*, 2008; Sheikh *et al.*, 2015; Shrestha *et al.*, 2017; Shi *et al.*, 2018). The decrease in cold spell duration (CSDI) has negative consequences for human health in countries like Sweden (Rocklöv *et al.*, 2014), Korea, and Japan (Lee *et al.*, 2018). Additionally, it affects the phenology of autumn plant species in grasslands (Zhao *et al.*, 2023).

5.3.2. Historic trend of precipitation extremes

The annual total wet day precipitation (PRCPTOT) in the Laprak area has displayed an increasing trend. This finding is in line with previous research (Baidya *et al.*, 2008;

Shrestha *et al.*, 2017). However, Ajjur and Riffi (2020) proposed a mixed trend, and suggested a decreasing trend in PRCPTOT. These discrepancies in the observed trends could be attributed to variations in the geographical areas of the studies conducted. The number of very heavy precipitation days (R20mm) in the Laprak area is exhibiting an increasing trend, which is a trend observed globally in many regions (Osborn *et al.*, 2000; Alexander *et al.*, 2016). This finding corresponds with the outcomes of studies conducted by Baidhya *et al.*, (2008), Ajjur and Riffi, (2020), and Shrestha *et al.*, (2021). However, it contrasts with the results of Adhikari and Mathema (2023), which reported a decreasing trend. This mismatch in the result could be the mixed patterns of rainfall across Nepal (Karki *et al.*, 2017). Changes in the indices of 5-day (RX5day) precipitation in our study show an increasing trend. This finding is consistent with a study conducted by Ajjur and Riffi, (2020). But Shiekh *et al.*, (2015) and Karki *et al.*, (2017) suggest a decreasing or no trend in RX5day.

The percentile-based precipitation indices R95p and R99p both exhibit non-significant decreasing trends in our study. This result contrasts with many previous studies (Baidhya *et al.*, 2008; Shiekh *et al.*, 2015; Karki *et al.*, 2017; Ajjur and Riffi, 2020). These discrepancies arise because the R95 and R99 indices are based on long-term percentile thresholds, which might differ from station to station but not necessarily on an inter-annual scale (Karki *et al.*, 2017).

Regarding the trend of consecutive dry days (CDD) in the Laprak area, it is indeed displaying a decreasing trend. This outcome is consistent with earlier research findings (Sheikh *et al.*, 2015; Sun *et al.*, 2016). Similarly, the trend of consecutive wet days (CWD) in our study area has increased, but the general trend observed across the country is mixed (Karki *et al.*, 2017). Our findings contrast with many previous studies (Sun *et al.*, 2016; Shi *et al.*, 2018; Ajjur and Riffi, 2020). This contrast between the overall trend and our specific result could potentially be attributed to the increasing trend of precipitation in the Laprak area.

CHAPETR 6: CONCLUSION

6.1. Conclusion

The study's findings indicated that residents observed shifts in climate indicators, including droughts, floods, rainfall patterns, season lengths, and the coldest season's temperatures. These alterations in climate indicators had significant consequences for biodiversity, agriculture, livelihoods, weather patterns, and the whole ecosystem. As a result of these changes, local communities had to deal with various impacts, such as the introduction of invasive species, reduced soil productivity, increased conflicts over natural resources, increased human diseases and livestock mortality, and higher levels of rainfall. The way these impacts are perceived depends on several socio-economic factors, such as the location of residence, and the gender of the respondents. In the study area, there is a noticeable and consistent climatological trend of increasing temperature and precipitation across the historical period. The comparison of the perceptions of residents with climatological data shows the alignment in the context of the rising trend in precipitation, extended dry seasons, and increased rainfall amounts. However, a mismatch has been observed with the temperature trend. This indicates that the indicators of climate change which have high visible impacts are perceived more easily. In areas where long-term weather data is not available, integration of local perceptions in climate change studies can improve our understanding of climate change patterns and their socio-ecological impacts.

6.2. Recommendations

Based on the study's findings, the following recommendations are presented to both local communities and government officials.

- Education and awareness programs related to climate change indicators and their impacts at the local level will help locals minimize the impacts and increase knowledge about climate change. Which will help local government to develop local adaptive strategies.
- Analyzing socio-economic factors like gender, education, and area of residency will help to provide the extent of impacts at the local level.

- Study and identification of impacts of climate variability, such as invasive species, impacts on biodiversity and ecosystem will help to minimize the impact of climate change on overall biodiversity.

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APPENDIX

Appendix I: Questions for Key Informant Interview (KII)

1. Is there any variability of temperature and rainfall in Laprak in the past 10 years?
2. What do you think are the causes of climate change/ variability in your area?
3. What are the observed indicators of climate change/ variability in your area?
4. Can you describe any observable changes in climate patterns or weather events in your region over the past few years? How have these changes impacted your community or organization?
5. From your perspective, what are the most significant climate change-related issues or challenges facing your community or organization?
6. What do you think are the causes of climate change/ variability in your area?
7. Can you describe any observable changes in climate patterns or weather events in your region over the past few years? How have these changes impacted your community or organization?
8. How do you perceive the role of human activities, such as greenhouse gas emissions and deforestation, in contributing to climate change?
9. What are the key obstacles or challenges that your community is facing due to climate change and its impacts?
10. What are the local people's coping mechanisms used to reduce those impacts?
11. What are the main challenges and how do you think they can be improved?
12. In your opinion, what role can individuals, communities, and governments play in addressing climate change effectively?

Appendix II: Questions for Focused Group Discussion (FGD)

1. What comes to mind when you hear the term "climate change"?
2. Have you experienced or observed any changes in weather patterns or the environment that remind you of climate change?
3. What do you think are the local indicators of climate change/ variability in your area?
4. What are the main causes of climate change/ variability in your area?
5. Do you think these variabilities in climate affect your livelihood? If the answer is yes how?
6. What are the most common climate change impacts that affect your daily life or the lives of people in your community?
7. What steps do you believe individuals and communities can take to mitigate the effects of climate change?

Appendix III: Household Questionnaire

A. DEMOGRAPHIC INFORMATION

1.Name:	2.Municipality:			3.Ward:
4.Age:	5.Gender:			
6.Level of education:				
7.Length of residency in the area:				
8.What is the main livelihood activity?				
a.Agriculture & Livestock rearing	b.Business			
c. Gathering of NTFPs	d. Wage labor			
e. Service	f.Others			
9. Do you have your own land?				
a.Yes	b.No			
c. Borrowed land	d.Rented land			
e.Common Land	f. Others			
10.Annual income from herding:	a) >1 lakh	b) 1-2 lakh	c) 2-5lakh	d) <5 lakhs
11. Have you heard about the term "Climate Change"?	Yes		No	
12.If yes, what is the source of information?				
a. Formal education	b. Family & Friends			
c. Media	d. Others (specify)			

B. PERCEPTION OF CLIMATE INDICATOR

1. How do you perceive a change in the general temperature than 10 years before?	
a) Same as before	b) Colder than before
c) Hotter than before	d) Don't know
2. How do you perceive a change in the hottest season temperature than 10 years before?	
a) Same as before	b) Colder than before
c) Hotter than before	d) Don't know
3. How do you perceive a change in the hottest season temperature than 10 years before?	
a) Same as before	b) Colder than before
c) Hotter than before	d) Don't know
4. How do you perceive a change in the events of drought than 10 years before?	
a) Same as before	b) More frequent
c) Less frequent	d) More intensive
e) Less intensive	f) Don't know
5. How do you perceive a change in the events of drought than 10 years before?	
a) Same as before	b) More frequent
c) Less frequent	d) More intensive
e) Less intensive	f) Don't know
6. How do you perceive a change in rainfall amount in the rainy season than 10 years before?	

a) Same as before	b) Lower than before
c) Higher than before	d) Don’t know
7. How do you perceive a change in rainfall amount in the rainy season than 10 years before?	
a) Same as before	b) Lower than before
c) Higher than before	d) Don’t know
8. How do you perceive the change in the rainy season duration?	
a) Same as before	b) Longer than before
c) Shorter than before	**d)** Don’t know
9. How do you perceive the change in the dry season duration?	
a) Same as before	b) Longer than before
c) Shorter than before	**d)** Don’t know

C. PERCEPTION ON IMPACTS OF CLIMATE CHANGE

1. Have you observed any climate variability-induced serious impact in the past 10 years?	a) Yes	b) No
2. Do you believe that climate change has an impact on biodiversity and ecosystems?	a) Yes	b) No
3. If yes, what impact do you perceive due to climate change on the biodiversity of your area?		
a) Introduction/ occurrence of invasive species	b) Decrease in the level of water in the lake/ pond	
c) Increased in the cover/ abundance of pasture land	d) Early flowering of plants	
e) Early singing of birds	f) Others	
4. Out of these perceived impacts on biodiversity in your area, which affects you the most and which affects you least?		
a) Introduction/ occurrence of invasive species		
b) Decrease in the level of water in the lake/ pond		
c) Increased in the cover/ abundance of pasture land		
d) Early flowering of plants		
e) Early singing of birds		
5. Have you observed any impacts of climate change on your agriculture and livelihood activities?	a) Yes	b) No
6. If yes, what are those impacts		
a) Decreased soil productivity	b) Increased livestock mortality	

c) Increased conflict over natural resources	d) Increased human diseases	
e) Increased problems due to transportation (increased mosquito number)	f) Others	
7. Out of these perceived impacts on agriculture and livelihood in your area, which affects you the most and which affects you least?		
a) Decreased soil productivity		
b) Increased livestock mortality		
c) Increased conflict over natural resources		
d) Increased human diseases		
e) Increased problems due to transportation (increased mosquito number)		
8. Have you observed any impacts due to the change in the climate indicators on your local weather and ecosystem?	a) Yes	b) No
9. If yes, what are those impacts you have observed?		
a) Increase/decrease in rainfall amount	b) Increase/decrease in intensity of hail storms	
c) Increase/decrease in the transition of seasons	d) Increase/decrease in rain-induced soil erosion	
e) Increase/decrease in spatial distribution of rainfall	f) Increase/decrease in frequency of lightning	
g) Increase/decrease in length of drought	h) Others	

10. Out of these perceived impacts on local weather and ecosystem in your area, which affects you the most and which affects you least?	
a) Increase/decrease in rainfall amount	
b) Increase/decrease in intensity of hail storms	
c) Increase/decrease in the transition of seasons	
d) Increase/decrease in rain-induced soil erosion	
e) Increase/decrease in spatial distribution of rainfall	
f) Increase/decrease in frequency of lightning	
g) Increase/decrease in length of drought	

D. PERCEPTION OF THE DIRECTION OF CLIMATE CHANGE IMPACTS

1. In your opinion what is the direction of change in the impacts of climate change than 10 years before?		
a) Introduction/ occurrence of invasive species	Increase	Decrease
b) Decrease in the level of water in the lake/ pond		
c) Increased in the cover/ abundance of pasture land		
d) Early flowering of plants		
e) Early singing of birds		
f) Introduction/ occurrence of invasive species		
g) Decreased soil productivity		
h) Increased livestock mortality		
i) Increased conflict over natural resources		
j) Increased human diseases		
k) Increased problems due to transportation (increased mosquito number)		
l) Decreased soil productivity		
m) Increased livestock mortality		
n) Increase/decrease in rainfall amount		
o) Increase/decrease in intensity of hail storms		
p) Increase/decrease in the transition of seasons		
q) Increase/decrease in rain-induced soil erosion		
r) Increase/decrease in spatial distribution of rainfall		
s) Increase/decrease in frequency of lightning		
t) Increase/decrease in length of drought		
u) Increase/decrease in the transition of seasons		

PHOTOPLATES

Photo Plate I: Focus Group Discussion

A. Focus Group Discussion 1 done in Village 1(Phyapchee)

B. Focus Group Discussion 2 done in Village 2 (Gairigaudo)

C. Focus Group Discussion 3 done in Village 3 (Torando)

Photo Plate II: Key Informant Interview

D. Key Informant Interview 1 done with teacher

E. Key Informant Interview 2 done with elder person

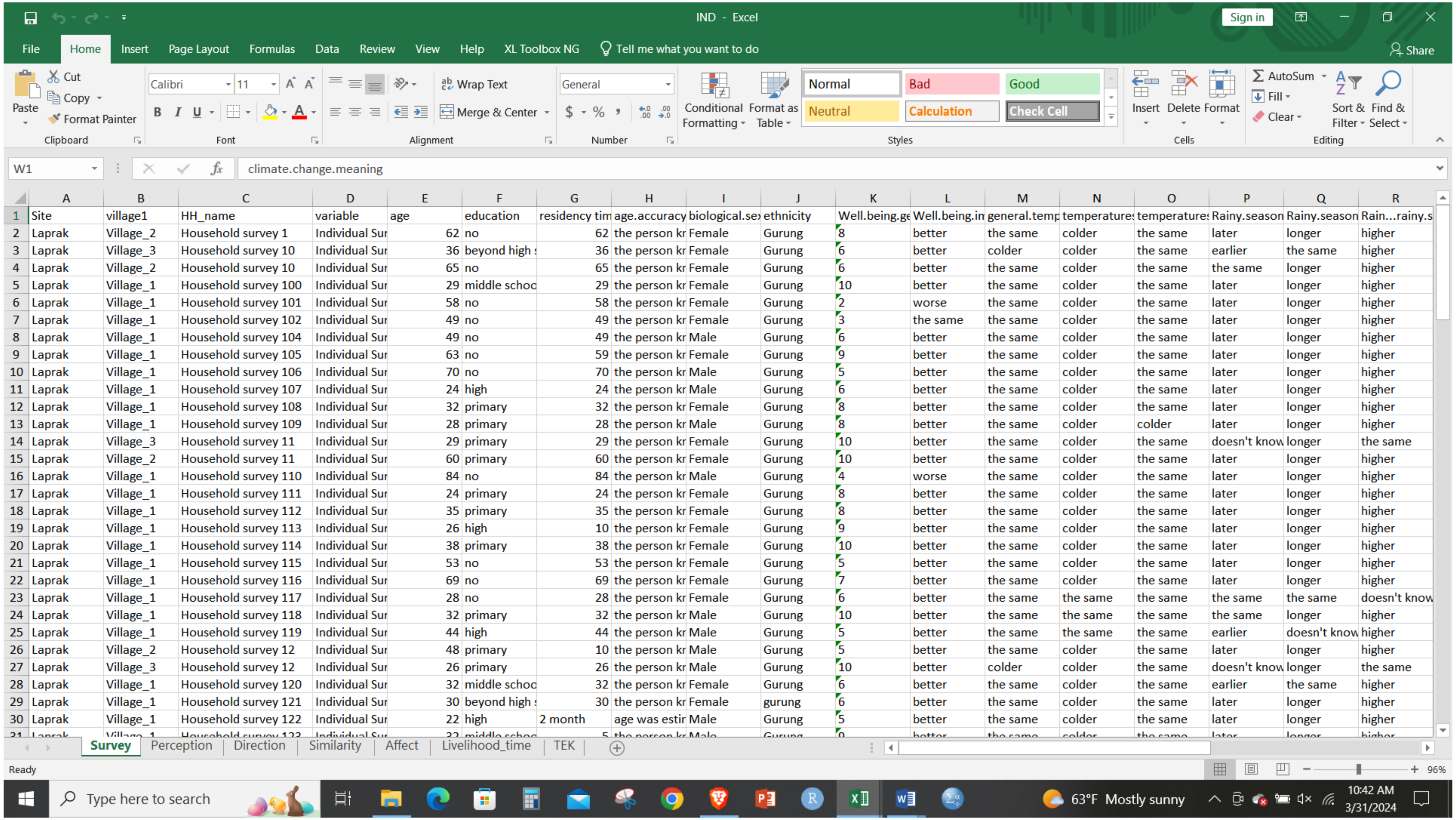
F. Key Informant Interview 3 done with herder

Photo Plate III: House Hold Survey

G. Household Survey 1

H. Household Survey 2

Photo Plate IV:



	Site	village1	HH_name	variable	age	education	residency tim	age.accuracy	biological.se	ethnicity	Well.being.ge	Well.being.in	general.temp	temperature	temperature	Rainy.season	Rainy.season	Rain...rainy.s
2	Laprak	Village_2	Household survey 1	Individual Sur	62	no	62	the person kr	Female	Gurung	8	better	the same	colder	the same	later	longer	higher
3	Laprak	Village_3	Household survey 10	Individual Sur	36	beyond high	36	the person kr	Female	Gurung	6	better	colder	colder	the same	earlier	the same	higher
4	Laprak	Village_2	Household survey 10	Individual Sur	65	no	65	the person kr	Female	Gurung	6	better	the same	colder	the same	the same	longer	higher
5	Laprak	Village_1	Household survey 100	Individual Sur	29	middle schoo	29	the person kr	Female	Gurung	10	better	the same	colder	the same	later	longer	higher
6	Laprak	Village_1	Household survey 101	Individual Sur	58	no	58	the person kr	Female	Gurung	2	worse	the same	colder	the same	later	longer	higher
7	Laprak	Village_1	Household survey 102	Individual Sur	49	no	49	the person kr	Female	Gurung	3	the same	the same	colder	the same	later	longer	higher
8	Laprak	Village_1	Household survey 104	Individual Sur	49	no	49	the person kr	Male	Gurung	6	better	the same	colder	the same	later	longer	higher
9	Laprak	Village_1	Household survey 105	Individual Sur	63	no	59	the person kr	Female	Gurung	9	better	the same	colder	the same	later	longer	higher
10	Laprak	Village_1	Household survey 106	Individual Sur	70	no	70	the person kr	Male	Gurung	5	better	the same	colder	the same	later	longer	higher
11	Laprak	Village_1	Household survey 107	Individual Sur	24	high	24	the person kr	Male	Gurung	6	better	the same	colder	the same	later	longer	higher
12	Laprak	Village_1	Household survey 108	Individual Sur	32	primary	32	the person kr	Female	Gurung	8	better	the same	colder	the same	later	longer	higher
13	Laprak	Village_1	Household survey 109	Individual Sur	28	primary	28	the person kr	Male	Gurung	8	better	the same	colder	colder	later	longer	higher
14	Laprak	Village_3	Household survey 11	Individual Sur	29	primary	29	the person kr	Female	Gurung	10	better	the same	colder	the same	doesn't know	longer	the same
15	Laprak	Village_2	Household survey 11	Individual Sur	60	primary	60	the person kr	Female	Gurung	10	better	the same	colder	the same	later	longer	higher
16	Laprak	Village_1	Household survey 110	Individual Sur	84	no	84	the person kr	Male	Gurung	4	worse	the same	colder	the same	later	longer	higher
17	Laprak	Village_1	Household survey 111	Individual Sur	24	primary	24	the person kr	Female	Gurung	8	better	the same	colder	the same	later	longer	higher
18	Laprak	Village_1	Household survey 112	Individual Sur	35	primary	35	the person kr	Female	Gurung	8	better	the same	colder	the same	later	longer	higher
19	Laprak	Village_1	Household survey 113	Individual Sur	26	high	10	the person kr	Female	Gurung	9	better	the same	colder	the same	later	longer	higher
20	Laprak	Village_1	Household survey 114	Individual Sur	38	primary	38	the person kr	Female	Gurung	10	better	the same	colder	the same	later	longer	higher
21	Laprak	Village_1	Household survey 115	Individual Sur	53	no	53	the person kr	Female	Gurung	5	better	the same	colder	the same	later	longer	higher
22	Laprak	Village_1	Household survey 116	Individual Sur	69	no	69	the person kr	Female	Gurung	7	better	the same	colder	the same	later	longer	higher
23	Laprak	Village_1	Household survey 117	Individual Sur	28	no	28	the person kr	Female	Gurung	6	better	the same	the same	the same	the same	the same	doesn't know
24	Laprak	Village_1	Household survey 118	Individual Sur	32	primary	32	the person kr	Male	Gurung	10	better	the same	the same	the same	the same	longer	higher
25	Laprak	Village_1	Household survey 119	Individual Sur	44	high	44	the person kr	Male	Gurung	5	better	the same	the same	the same	earlier	doesn't know	higher
26	Laprak	Village_2	Household survey 12	Individual Sur	48	primary	10	the person kr	Male	Gurung	5	better	the same	colder	the same	later	longer	higher
27	Laprak	Village_3	Household survey 12	Individual Sur	26	primary	26	the person kr	Male	Gurung	10	better	colder	colder	the same	doesn't know	longer	the same
28	Laprak	Village_1	Household survey 120	Individual Sur	32	middle schoo	32	the person kr	Female	Gurung	6	better	the same	colder	the same	earlier	the same	higher
29	Laprak	Village_1	Household survey 121	Individual Sur	30	beyond high	30	the person kr	Female	gurung	6	better	the same	colder	the same	later	longer	higher
30	Laprak	Village_1	Household survey 122	Individual Sur	22	high	2 month	age was estir	Male	Gurung	5	better	the same	colder	the same	later	longer	higher