ASSESSING NEPALESE FARMERS' PERCEPTIONS OF CLIMATE CHANGE, ITS IMPACTS, AND THEIR ADAPTATION OPTIONS IN LOWER MUSTANG

By

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DEDICATION

I would like to dedicate this piece of scholarly work to my late mother Mrs. Devaki Bom, my wife Sabbu Rana, and my beautiful daughter Saanvi RL Bom, who have brought happiness into my life.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF ABBREVIATIONS

Abbreviation	Description
ACAP	Annapurna Conservation Area Project
APR	Annual Percentage Rate
CBS	Central Bureau of Statistics
DFID	Department for International Development
DHM	Department of Hydrology and Meteorology
GHG	Greenhouse Gas
GEF	Global Environment Fund
GON	Government of Nepal
HDI	Human Development Index
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IRB	Institutional Review Board
LAPA	Local Adaptation Program of Action
MoE	Ministry of Environment
MCCICC	Multi-Stakeholder Climate Change Initiative Coordination Committee
NAPA	National Adaptation Program of Action
NASA	National Aeronautics and Space Administration
NCCKMC	Nepal Climate Change Knowledge Management Centre

NPC	National Planning Commission
NOAA	National Oceanic and Atmospheric Administration
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Program

ABSTRACT

In recent decades, about 80% of the farmers in Himalayan region of Nepal who depend on agriculture for survival have experienced both positive and negative impacts from climate change that challenge their abilities to sustain their livelihoods. In this context, this study evaluates the socio-economic and demographic characteristics that shape farmers' perceptions about climate-change, to identify the major impacts of climate change on Nepal's Lower Mustang agriculture, and to determine the barriers against and opportunities for adaptation initiatives that mitigate the impacts of climate change. Data were collected in several ways: farmers were surveyed, key informants were interviewed, and focus-group discussions were held. Secondary data included thirty-year (1987-2017) temperature and rainfall data of Jomsom and Marpha, two of four study sites in Lower Mustang to compare to the farmers' perceptions of climate change trends over the last three decades in the region.

Farmers perceive that temperatures are rising, there are unstable and unpredictable precipitation patterns, and snowfall has decreased over the last 40 years. These perceptions tend to align with the temperature and precipitation records for Jomsom and Marpha during that period. The major impact of climate change that has been perceived is that weather patterns are becoming increasingly favorable for vegetable farming. The attitudes of farmers and community leaders have grown to be supportive of environmental action and are perceived to have positively affected expectations about farmers' futures. Declining apple productivity at lower elevations, increasing insect

infestations and spreading diseases among crops, less hospitable conditions for livestock production, increasing frequency of flash floods, increasing soil erosion, and increasing debris flows are perceived to be some of the negative effects from climate change in the region. Farmers' adaptation strategies to the consequences of climate change in Lower Mustang include diversification of crops (vegetables, fruit, and fodder), increased use of insecticides and pesticides, gradual shifting of apple farming to more hospitable elevations, the introduction of disease-, pest-, and heat-resistant hybrid crops and livestock, and river water and rainwater harvesting. In addition to these efforts, mothers' groups in Lower Mustang have been instrumental in strengthening three key administrative arenas: financial management, environmental management, and the empowerment of women, which directly and indirectly enhances the adaptive capacities of female farmers in Lower Mustang.

The key barriers to adaptation of agriculture in Lower Mustang are governance and the socio-economic status of farmers. Minimal availability of public outreach and extension services, the lack of well-planned adaptation initiatives, poor flows of information, scant technical resources, limited budgets, and poor disaster-management are extant barriers to effective governance. Likewise, socio-economic factors – the ages, incomes, genders, castes, and ethnicities of farmers – impede the development of adaptation and resilience-building capacities. Despite these barriers, collaboration between local governments, the communities, and farmers seems to have significantly shaped adaptation initiatives and strategies in Lower Mustang.

1. INTRODUCTION

Climate change has become a growing concern for academics, scientists, managers, policy makers, and the public. Climate change refers to changes of the statistical averages, extremes, and seasonality of weather conditions at specific places, particularly the changing patterns of temperature, precipitation, and other regimes, regardless of their causes (Nature, 2018; IPCC, 2007). Scientific studies of climates and climate change are said to have originated with the work of the Swedish scientist Svante Arrhenius in the 1890s (Hoorn et al., 2010). However, public and academic discussions of climate change began in earnest in the late 1980s and early 1990s, when scientists first confirmed that global warming (i.e., rising global annual mean temperature) was occurring, and that Earth was warmer than any period since widespread record-keeping began in 1880 (Hoorn et al., 2010; Le Treut et al., 2007). Evidence compiled over the last few decades has led climate scientists to unequivocally conclude that contemporary global warming and subsequent regional climate changes are due principally to human activities (Leiserowitz, 2007) including emission of greenhouses gases to the atmosphere, widespread deforestation, and land-cover modifications (Lorenzoni and Pidgeon, 2006; Ishaya and Abaje, 2008). As a result, the globally averaged combined land and ocean surface temperature warmed 0.85°C [an estimate with greater certainly is that this is within a 0.65 to 1.06°C increase] over the period from 1880 to 2012 (IPCC 2013; Hansen et al., 2012). Globally averaged temperatures in 2017 were calculated to be 0.90°C (1.62°F) warmer than the baseline average (reflected by the 30-year period from 1951 to 1980) (NASA, 2018). Earth’s temperature is projected to increase by another 1.1°C to 6.0°C by this end of this century (Reidsma et al., 2010; IPCC, 2007) depending upon our responses to the growing crisis. Changes are apparent in the visibly diminishing snowpack and glacial ice around the world, and in the rising sea levels generated by ocean expansion due to warming (IPCC, 2013).

One of the important activities that has been and will be impacted by climate change is agriculture. Crop productivity has been reduced by either changing temperatures, changing precipitation patterns, or both (Lobell et al., 2011). Higher temperatures diminish yields and increase the growth of weedy plant species, insects, fungi, and other pests. At the same time, significant departures (floods, droughts, and seasonality of rainfall) from “normal” precipitation patterns have caused crop failures and decreased yields (Nelson et al., 2009). Variations in local climates have increasingly changed the frequency, severity, and spatial distribution of extreme events (such as droughts, floods, freezes, and hail) which have also impacted crop yields (Kimball et al., 2002; Ainsworth and Long 2005; Fischer et al., 2005). Not only are crops affected, but livestock farming is also impacted by climate change. There is robust evidence that livestock are affected when changing climates promote the spread of diseases and disease vectors that impact animals’ health and growth (Seo et. al, 2009). In the context of these changes and impacts, this study focuses on farmers’ perceptions of the occurrence and impacts from climate change on agriculture in Lower Mustang, Nepal, on the documented evidence of impacts from climate change on agriculture in the region, and on the social, cultural, and political barriers and opportunities for agrarian adaptation to the change.

1.1. Climate Change in Nepal

Nepal is a mountainous country located between China and India. It extends approximately 200 km from north to south and approximately 885 km from east to west. It has an area of 147,181 km^2. Nepal is rich in biodiversity. This diversity is distinct among regions due to the presence of three physical environments: snow-covered mountains in Nepal’s north (above 4000 m elevation), lower mountains and hills in its center (between 1000 and 4000 m), and the Terai (plains) (between 300 m and 1000 m) in its south (Figure 1).

Nepal contributes little fuel to global warming, but it is the fourth most vulnerable country in the world, according to the Climate Change Vulnerability Index (CCVI) (Maplecroft, 2011). Nepal bears (or will bear) the impacts of climate change despite its minimal contribution. Studies have indicated that the rates of warming, though variable across the mountainous region, average 0.06 °C per year for the upper Himalayan region (Shrestha, Gautam and Bawa, 2012). The climates of the entire country of Nepal are warming, averaging 0.027°C per year. With continued warming the temperature rise is projected to be between 3.0°C and 6.3°C by 2090 (Shrestha, 2014). These measurements are supported by the perceptions of the Nepalese who are aware that they are experiencing hotter and longer summer days (in terms of temperature) and shorter winters (Practical Action, 2009). Some areas of Nepal are also seeing increasing annual average precipitation rates, while the precipitation trends in other areas are decreasing (Pandey, 2015). For example, Shrestha et al (2012) and Macchi et al., (2015) have reported increased rainfall in the Himalayan region. Duncan et al., (2013) discerned decreased rainfall extremes and lower variability in lower elevations of Nepal. These studies are evidence that the extant global and regional climate projections may not accurately reflect the dynamic nature of Himalayan climates due to its complex physiography and weather patterns (Pandey and Bardsley, 2015).

Nepal's agriculture is determined primarily by the wet monsoon which generates approximately 80% of the country's annual precipitation during the months of June through September (Sigdel and Ikda, 2012). Recent studies have analyzed maximum-temperature trends in the Himalayan region and have revealed a constant warming at high-elevation regions. In turn, this has modified the monsoonal circulation and has created erratic (i.e., deviating from the patterns of the recent past) rainfall patterns over the region (Intgy, 2017; Sigdel and Ikda, 2012). The most apparent environmental impacts due to this unpredictable variation of rainfall timing and intensity are increased flash-flood events, enhanced soil erosion, emerging droughts, debris flows and landslides, and impacts to virtually every aspect of agriculture in the region, particularly to the effectiveness of irrigation in the Himalaya (Ingty, 2017; Shukla et al, 2018). Rising temperature has increased crop diseases and pests and has diminished the health of livestock. More frequent extreme weather can impact and constrain livestock productivity, particularly in highland regions like the Himalayas (Dhakal et al., 2013). The most visible indicator of warming temperatures is the recession of alpine glaciers which has and will have significant and increasingly disastrous impacts on downstream water supplies (Yao 2004; Barnett et al., 2005; Nogués-Bravo et al., 2007), as well as on biodiversity, and on personal livelihoods and local and regional economies (Xu et al., 2009). These impacts will generate dire consequences for Himalayan farmers due to declining production, decreased pastures and feed, and diminished trade of agricultural products, thus affecting the region's residents environmentally, economically, and socially (Uprety et al., 2017; Becken, 2013; Manandhar et al., 2011).

Several studies of Himalayan agriculture have been conducted in Nepal vis-à-vis climate-change perceptions, climate-change impacts, and adaptation and adjustments made by local communities and farmers. Most of these studies indicate that there are rapidly changing climates in the region (Shrestha et al., 2012; Turner and Annamalai, 2012) that are generating severe impacts on the social ecology (the interactive ecological relationships of social systems – particularly communities – with natural systems) of the region. Furthermore, studies have found that farmers have coped and continue to try to cope with changing climates through adaptation and adjustments (Bhatta, et al., 2015; Macchi et al., 2014). Adaptation efforts are principally based on farmers' perceptions of changes and the ensuing risks, and on their knowledge of the local environment generated from their personal experiences (Vedwan and Rhoades, 2001). However, agricultural impacts in countries like Nepal vary dramatically between households and between communities due to social inequalities, patterns of poverty, and disparities in access to resources and control over production. These inequities affect the availability and choice of adaptative actions.

To understand this problem, this research strives to undertake a deeper examination of the barriers and opportunities associated with several categories of personal, social, economic, and spatial attributes of farmers, and methods of governance of adaptation. The aspects evaluated are ethnic groups and castes (Homelin and Aase 2013), sex-based gender roles (Jerneck, 2017; Onta and Resurreccion, 2011), income (Jerneck, 2017), and age (Homelin and Aase, 2013). Ultimately, these characteristics guide the identification of the adaptation initiatives that are needed in one region of Nepal, Lower Mustang (Uprety et al., 2017; Becken, 2013). The main objective is to evaluate the socio-economic and demographic characteristics that shape farmers' perceptions about climate-change in their region, to identify the prospects of climate change's present and future impacts on Lower Mustang agriculture, and to determine the barriers preventing and the opportunities enabling adaptation efforts. Several specific research questions are elaborated and discussed below.

1.2. Research Questions

Public concern has influenced the development of formal climate-change policies and adaptation strategies in agriculture (Smith and Liebowitz, 2012). The traditional forms of coping and adaptation strategies are being improved gradually and innovations have been developed based on science and new agricultural technologies (Altier and Nicholas, 2017). These strategies are being implemented by farmers to avoid the impacts of climate change to the extent that their adaptive capacities and local circumstances allow (Altier and Nicholas, 2017; Burke et al., 2016; Moore and Lobell, 2014). Farmers employ both coping and adaptation strategies. Coping strategies are temporary solutions whereas adaptation strategies are long-term commitments in response to anticipated implications of climate change (Aryal et al., 2017; IPCC, 2007).

Farmers sometimes embrace adaptation measures promoted by policy makers and local, regional, or national governments. Otherwise they adopt personal, autonomous initiatives or projects (IPCC, 2007). Farmers' responses to these adaptation policies may vary by ethnicity, class, income, gender, age, individual experience, and local circumstances. This case study of farmers in Lower Mustang, Nepal is undertaken to examine the agricultural impacts of climate change, farmers' perceptions of the implications of climate change, adaptation strategies that farmers have considered and adopted, and the practical and imagined barriers preventing adaptations and the opportunities that adaptation may provide. Specifically, this study will answer three questions:

1. What are the important socio-economic and demographic factors that have affected farmers' perceptions of climate change during the last three or four decades? Are there significant differences among the spatial, socioeconomic, and demographic patterns of farmers perceptions in the region?

2. What do farmers perceive to be impacts that have already occurred due to climate change? What impacts do they expect to experience because of the apparent climate-change trends in the region? Are the levels of concerns among farmers statistically related to either the communities they reside in or their cohorts of social, economic, and other demographic classes?

3. What adaptation strategies have farmers initiated to mitigate the impacts of climate change in Lower Mustang? How do governance, ethnicity and/or caste, gender, income, age, and education influence farmers' adaptation choices in the region? Are there deterministic relationships between any of these characteristics and the barriers or opportunities for adaptation in Lower Mustang?

1.3. Conceptual Framework

A conceptual framework has been developed to logically connect and integrate the major concepts of this study (Figure 2). This framework is a structure that guides the analysis of data to answer the research questions.

Farmers' adaptation strategies are the intentional responses to climate-change impacts in Lower Mustang agriculture. These adaptations are mainly of two types that reflect local needs and local social conditions: unplanned and planned adaptations. Scholars argue that it is essential for unplanned initiatives be undertaken as soon as environmental stressors have been realized (Shukla et al., 2018; Measham et al., 2011; Eriksson 2009; Fussel, 2007). These unplanned adaptations are usually intended to last for only short periods of time. Strategies using more robust information about present and future climate-change impacts to evaluate the effectiveness, suitability, and adjustment needs of existing policies, practices, and infrastructure, are considered long-term (planned) adaptations (Lorenz et al., 2017; Fussel, 2007). Sometimes, both unplanned and planned adaptation actions occur simultaneously. This is usually influenced by local needs and local circumstances (Lorenz et al., 2017). Thus, it is necessary to use situationally designed adaptation strategies that reflect the local contexts, resources, and priorities of farmers and institutions involved in the adaptation process.

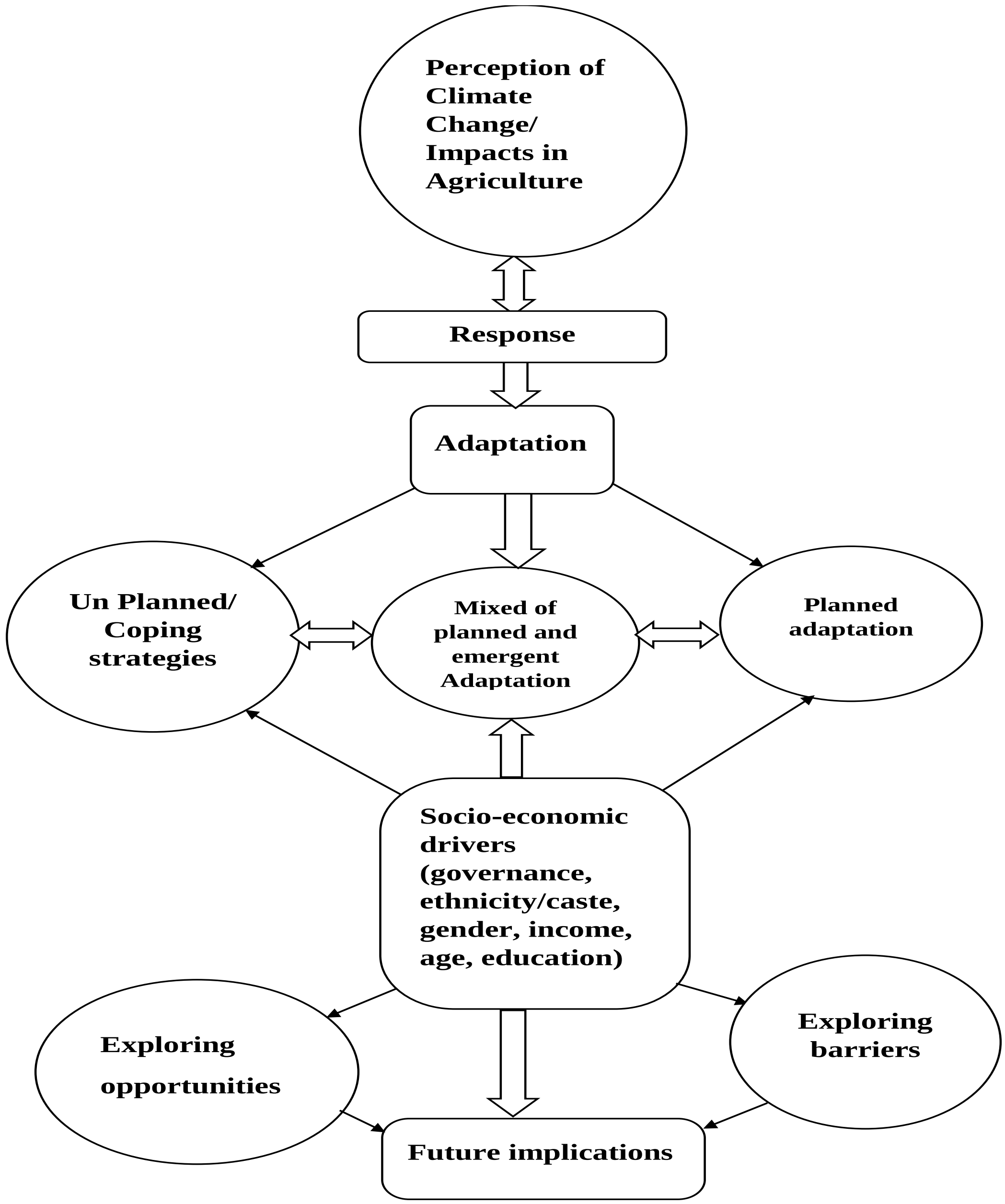

Figure 1. Conceptual framework

Planned and unplanned adaptation strategies are influenced by the production practices and resources of farmers, their financial management frameworks and financial stability, technological development, and government policies, programs, and resources used to initiate and complete climate-change mitigation plans (Lorenz et al., 2017). The effectiveness of mitigation efforts will also depend on the public's acceptance of plans and on their personal options, as well as the relative importance of social factors (such as ethnicity, governance, gender, income, and age) that either promote or make difficult adaptation, coping strategies, and adjustments (Adger et al., 2017). Therefore, this study is developed to discern whether social and personal factors are positively or negatively influencing agricultural adaptation in Lower Mustang, to enumerate the barriers and opportunities that are associated with these factors, and to assess the implications of these relationships.

1.4. Significance and Scope

This study reveals Nepalese farmers' perceptions of climate change in Lower Mustang district and the challenges that climate change generates for agriculture in the region. This study describes the present-day conditions of agriculture in the region, and catalogs farmers' stated strategies for adapting to and mitigating the challenges wrought by climate change.

There has been scant study of farmers' general perceptions of climate change in Lower Mustang. Few have examined the perceptions of evidence of impacts from climate change in Lower Mustang. An in-depth study of perceptions of climate-change indicators and the stated concerns about climate change should consider the effects that socio-economic and demographic characteristics of the farmers and their communities have on perceptions and concerns. This work, therefore, is intended to contribute to the body of literature that regards agrarian adaptation to climate change in the Himalaya.

Examination of local and community governance models that have traditionally shaped the livelihood and agriculture of Himalayan settlements is also scant in the research literature. Examining both local governments that are led by indigenous ethnic groups and the local elected officials in the communities of Lower Mustang will highlight the traditional and contemporary roles of governance in agrarian adaptation in the regino. Exploring and understanding the opportunities and barriers associated with community governance and agrarian adaptation can provide new insight to mold the theoretical considerations behind agrarian adaptations in the Himalaya.

The implications of gender roles, incomes, ages, and levels of education among farmers for agrarian adaptation is also scarce in the literature. In many parts of the developing world, patriarchy has dominated land ownership and decision making, but in Lower Mustang society is more matriarchal, and this makes the exploration of these relationships interesting, particularly in the face of the lacunae of agrarian-adaptation research here (Agricultural Management Information System, 2016). Ethnicities, genders, incomes, education-levels, ages, and community governance may be strongly linked and may interactively influence the adaptation initiatives undertaken or conceptualized in Lower Mustang agriculture. Thus, identification of the major barriers and opportunities pertaining to agrarian adaptation that are influenced by these factors in this region will provide a new perspective on climate change and agrarian adaptation. This study regards a diverse set of stakeholder groups and officials as key informants who collectively worked toward the common goal of the enactment of effective agrarian adaptation initiatives in Lower Mustang. It is hoped that the diversity of farmers and stakeholders included in this study will yield new information for scholars who are interested in the ways in which farmers' social, economic, and demographic characteristics might shape perceptions and mitigative actions to limit the impacts of climate change in the region.

1.5. Organization

This dissertation contains seven chapters, including this introduction. Chapter 2 provides an overview of the concepts of climate change, of the impacts of climate change on agriculture, and an evaluation of climate change adaptation policy interventions in Nepal. That chapter concludes with the description of the study area: Lower Mustang, Nepal. Chapter 3 discusses the scholarly literature and reviews the key concepts that guided the formulation of this study. Chapter 4 describes the methods of data collection and analysis used in this study. Chapter 5 describes the characteristics of the survey respondents and reports the survey-derived picture of farmers' climate-change perceptions and their views of the impacts that are likely to emerge in the region. Chapter 6 addresses the levels of concern that farmers have about the impacts of climate change, the adaptation and coping strategies implemented for farmers in Lower Mustang, and the key barriers to and opportunities created by farmers' adaptation initiatives in the region. Chapter 7 contains a summary of and conclusions of this study.

1.6. Limitations

It must be acknowledged that this study has limitations. The abbreviated temporal scope of this study due to limitations of time and financial resources, may have weakened some of the results. The sizes of samples for the cohorts covered in the study may have been insufficient to provide statistically robust data analysis. Furthermore, the survey data gathered and the data generated by the interviews and focus-group discussions in the field in the region is predominantly comprised only of the views of farmers of the area; the perspectives of the rest of the members (particularly those of significant and important demographic groups) of these communities may be either under- or unrepresented by this assessment, particularly in their views of climate change and adaptation matters.

1.7. Summary

Climate change is one of the greatest challenges humanity may have ever faced. To respond to this challenge, it is necessary to mitigate the impacts of climate change, particularly in climate-sensitive economic sectors like subsistence and commercial agriculture. This study focuses on adaptation because adaptation initiatives are gradually becoming more viable, convenient, and practical for farmers in developing countries. Most economically developing regions lack the resources and infrastructure to combat climate change through mitigation. Therefore, this study is focused on the perceptions and impacts of climate change and on the barriers and opportunities facing agrarian adaptation in Lower Mustang, Nepal. This research enhances our understanding of the adaptation strategies and policies of the present that could contribute to sustainable agriculture in Lower Mustang in the long-term.

2. CLIMATE CHANGE, IMPACTS ON AGRICULTURE, AND POLICY INTERVENTIONS IN ADAPTATION IN LOWER MUSTANG, NEPAL

2.1. Climate Change

To begin, it is necessary to distinguish between two concepts, weather and climate, to clarify the nature of the phenomenon referred to as "climate change." Weather and climate are related, but they are different in two ways: they each are used to characterize very different timeframes, and one is used to characterize the intensity of meteorological phenomena and processes, while the other reflects the long-term tendencies of weather patterns statistically and probabilistically. Weather is comprised of the experienced conditions and phenomena occurring in a region's atmosphere over short periods of time (measurable momentary conditions, hourly, daily, monthly, annually, etc.). Climate is a characterization of atmospheric patterns over relatively long periods of time (usually more than 30 years) (NASA, 2018). To discuss climate change, scientists tend to stochastically compare the long-term averages of daily weather conditions that provide expectations for future weather to the "recent" (30-year) patterns in order to determine whether current and near-future patterns are or are expected to be deviating from the long-term climate record of a region. According to Intergovernmental Panel on Climate Change (IPCC)'s fourth assessment report, climate change is the change of the state of the climate that can be discerned by changes compared to means, extremes, frequencies, and periodic variations that persist for extended periods, typically for decades or longer (IPCC, 2014). Climate change, however, should not be confused with "global warming," which is an upward trend in the monthly, annual, decadal, or century-long mean surface temperature of the entire Earth. Just as Earth has no "average weather," it also does not have a single climate (which, conceptually speaking, characterizes the distributions and states of temperature, moisture, and weather phenomena). Earth's surface is a mosaic of climates, some of which may be changing, and, if changing, may be changing in divergent conditions and at different rates due to various contextual factors. The United Nations Framework Convention on Climate Change (UNFCCC) regards climate change as changes to regional climates caused by either natural variability or by human activities that are altering the composition of Earth's atmosphere in ways that are observed, experienced, or measured over comparable time periods (UNFCC, 2014).

Over the past century, anthropogenic processes have altered Earth's energy budget and are considered by nearly all scientists to be the main drivers of global warming. Global warming has in turn has yielded changing climates, melting glaciers and permafrost, warming of oceans, and modifications to other natural systems (IPCC 2014). The main human activity promoting global warming is the emission of greenhouse gases (GHG) – principally CO_2, CH_4, N_2O, and CFCs – into the atmosphere. These emissions have dramatically increased the global concentration of atmospheric CO_2 from 275 parts per million (ppm) in 1850 to 410 ppm in 2019 (https://www.co2.earth/daily-co2); the highest concentrations in the atmosphere of the last half-million years (IPCC, 2014). This concentration is projected, assuming no mitigation of GHG emissions, to exceed 700 ppm by the end of this century (NOAA, 2018).

Over the last century, fossil fuel (coal, oil, and natural gas) combustion to produce energy for industries, transportation, electricity, and heating and cooling of structures, has been the main forcing mechanism for rising CO_2 concentrations (NASA, 2018). Globally, power generation accounts about 23 billion tons of CO_2 emissions every year (Reddy, 2015). Among these fuels, coal is the least efficient in terms of the ratio of energy produced to CO_2 emitted: coal contributes 70% more CO_2 than natural gas per unit of energy (Reddy 2015). But increasing atmospheric concentrations of CO_2 and other GHGs is not only caused by emissions, it is also a function of the changing rate of CO_2 absorption and sequestration by metabolizing plants. Wide-spread deforestation caused by conversion of land for agriculture, industry, and livestock grazing, releases huge amounts of GHGs by burning of forests and by the reduced population of growing plants (which absorb CO_2 during photosynthesis) which naturally sequester carbon in the plants and soil during the cycling of carbon. Higher GHG concentrations cause the warming of Earth's atmosphere and this is reflected in the global average temperature: the January 2019 global land and ocean surface temperature was 0.88°C (1.58°F) above the 20th century average 14.8°C (58.6°F) (NOAA, 2019). The global change is not experienced equally everywhere, however, due to global atmospheric circulation patterns. Some regions may experience warmer temperatures, others may see little change, and others may see colder temperatures. There is also a changing diurnal pattern of temperature that is outside of the normal pattern of daytime heating and nighttime cooling: the frequencies of cold days and nights has decreased globally, and warm days and warmer-than-normal nights (i.e., increasing mean daily low temperatures) has increased (IPCC, 2013).

Temperature variance also influences the distribution of precipitation around the world. In terms of water, Earth is a closed system. The total volume of water on Earth changes little if at all. Water is redistributed within the hydrological cycle (atmospheric vapor (humidity), liquid, ice, terrestrial fresh water in lakes and rivers, snow- and icepack, permafrost, groundwater and soil moisture, confined aquifers, estuaries of fresh and salt water, and oceans and seas as salt water) and changes phase (as vapor, liquid, snow, or ice) due to changes in regional and seasonal temperature patterns. For example, precipitation over land in the mid-latitudes of the Northern Hemisphere has increased since 1901. Between 1901 and 2010, global mean sea-level rose by an average of 0.19 m (with a range of 0.17 to 0.21 m). The rate of sea-level rise since the middle of the 20th century has been greater than the average rate of the previous two millennia (IPCC, 2013). The impacts of global climate change have been observed in the patterns of extreme climatic events since 1950, including changes in the frequencies of intense rainfall events, floods, flash floods, droughts, flash droughts, heat waves, tropical storms, cyclones, and wildfires. Changing climates and the changing patterns of these phenomena yield a future that is riddled with greater uncertainty due to the loss in predictability that historically stable climate patterns provided. The uneven and changing distributions of settlements and economic activities in regions of the world, when combined with changing climates, means that there is no simple answer to questions about the ideal ways to prepare for change, what to expect in the near and distant future, and the locations that will be least or most affected. Everyone will be impacted either directly or indirectly and systems built on the foundation of a stable climate will be prone to disruption and failure.

2.2. The Impacts of Climate Change on Agriculture

Agriculture may be the economic activity that is most vulnerable to climate change. It is unavoidably dependent on seasonal weather conditions. In the time of accelerating climate change, global agricultural productivity has already been affected by two implications of shifting climates: the direct effects of changing temperature and precipitation patterns and the consequences of the changing patterns. The latter are the indirect effects propelling a changing distribution of pests and diseases, and changes in water budgets and soil moisture (Chaudhary et al., 2013).

Climate models have produced projections that link changing crop yields to CO_2 concentrations (Attavanich and McCarl, 2014; Perry et al., 2005;). Unlike, temperature and moisture content, there is generally little to no spatial variation of CO_2 in the atmosphere, so the relationship between crop yield and rising CO_2 levels is difficult to discern (Long et al., 2006). However, laboratory experiments have been conducted to test the relationship. These studies have found a positive, yet variable, relationship in wheat and rice, which seems to depend upon the region in which they are grown (IPCC, 2013). Carbon dioxide is an essential ingredient in photosynthesis and it also promotes fertility of soil, and therefore also crop yields (Ainsworth and Long, 2005; Long et al., 2006).

The combined effects of rising temperature and precipitation also alter productivity in most of the world's crops, to an extent (Schlenker and Roberts, 2009). Higher temperatures have been shown to increase yields of corn, winter wheat, and soya bean, yet decreases sorghum and cotton yields (Chen et al., 2004; Schelenker and Lobel, 2010). Increased of precipitation has been shown to negatively affect soya bean and sorghum yields (Attavanich and McCarl, 2014). Shifts in the intensity patterns of temperature and precipitation can benefit some crops in some places but can be detrimental for other crops in other places. Most crops do have thermal and saturation thresholds as well, when heat and moisture can negatively impact plants that have responded positively to lower levels.

In livestock ranching, traditional small-scale grazing operations that may be combined with crop farming tend to be more affected by rising temperatures than are industrial-scale operations (Nardone et al., 2010). Lower rainfall and increased frequencies of drought will diminish water supply, reduce pasture growth and the availability of forage, and when combined with rising temperature and greater sun exposure, can severely stress animals (Polley et al., 2013; Nardone et al., 2010). Rising temperature and increased aridity can increase livestock losses on rangelands (Steiner et al., 2018). Heat-related illness among animal stock can reduce food-intake and lessen milk, meat, and egg production (Silanikove, 2000). Heat waves have been found to have severe impacts on animal performance, illness rates, nourishment, metabolism, reproduction, and appetite, ultimately generating rising animal mortality rates (Mader et al., 2010). Increased rainfall intensity has been observed to increase soil degradation in pastures (Howden, Crimp and Stokes, 2008). Livestock disease can also be magnified in higher and wetter conditions as the ranges of disease vectors spread and migrate to fit their ideal climate conditions (Mendelsohan, 2000). Pest and disease outbreaks have reduced fecundity of livestock in many regions (Gale et al., 2009; Mu et al., 2014). Climate change has a complex impact on agriculture as it varies spatially and impacts spatially variable landscapes and economic activities. The result is played out regionally and can be examined more closely in many parts of the world. This study will focus its assessment on agricultural activities in an area in the Himalayan region of west-central Nepal.

2.3. Climate Change and Its Impacts on Himalayan Agriculture

Himalayan agriculture consists of rain-fed cultivation of apples, potatoes, maize, buckwheat, barley, and other minor millets, as well as livestock-rearing. The main characteristic of this system is integrated farming in which lower terraces are irrigated and upper terraces are precipitation dependent. Crops like rice, that need more water, are grown in lower terraces and crops like maize, that need less water, are grown in upper terraces. The uniqueness of this farming system is well established since it is small-scale, mixed, diverse, and is premised on an integrated relationship between crops, animals, forests, and the local environment.

Warming throughout the Himalayan region over the last few decades is an indication that the impacts of the coming changes will be more profound in the mountains due to the sensitivity and fragility of these environments (Sharma et al., 2009). Even small climate shifts are expected to have severe consequences to the region's ecological systems. Besides their biodiversity and their importance for the region's water supply, the mountains provide a wealth of ecosystem services to communities' downstream (Bhagawati et al., 201). Some studies focusing on climate change in the mountains of Nepal have found significant warming in higher elevations that has reduced snowpack and glaciers and increased the frequency of extreme events like landslides, droughts, and flash floods due to increased frequencies of intense precipitation, soil erosion, and debris flows (Gautam et al., 2010). All of these have strained agricultural activities in the highland regions (Dhakal et al., 2013).

The observed impacts of climate change in Himalayan region have included reduced crop yields, increasing pest infestations and disease outbreaks, and a surge in weedy species due to more frequent droughts and reduced water availability in some parts of the region (Palazzoli et al., 2015). Another apparent consequence of climate change is a purposeful elevational shift of apple farming due to warming at lower elevations (Manandhar, 2014; Shrestha, 2013). Recently, there was a delay in the onset of the wet monsoon in some parts of Himalayan region and it affected virtually all agricultural activities and caused confusion in the normal crop calendars (Eriksson, 2009). These impacts are expected to produce severe consequences for indigenous subsistence farmers living in more remote and ecologically fragile zones (UNFCCC, 2004).

Therefore, it is very necessary to understand the impacts of climate change based on the local conditions, topography, and geography of a region. To do this, the immediate and long-term impacts of climate change, especially in developing countries, should be addressed through local adaptation initiatives that strengthen agriculture and reduce the need for mitigation, the after-the-fact response to minimize losses. Some of the key policies pertaining to climate change and adaptation in agriculture in Nepal are briefly discussed below.

2.4. Climate Change, Adaptation, and Policy Interventions in Nepal

Global geopolitics of development aid has been instrumental in structuring the adaptation efforts in Nepal. The framing of Nepal as a ‘highly vulnerable’ country which needs international support to cope with climate change and its impacts, has been crucial to how donor aid is used in national and local adaptation initiatives. Some of the important climate change adaptation policies of Nepal are discussed below.

2.4.1. Nepal's National Adaptation Plans of Action (NAPA) 2009/2010.

Adaptation policies and programs have been structured in many countries to create institutions and infrastructure that can guide individual and collective responses to climate change. One of the efforts to support economically developing nations is the establishment of the United Nations Framework Convention on Climate Change (UNFCCC). This framework provides funding to developing nations through the United Nations (UN) and development agencies to develop and execute national adaptation plans of action (NAPAs). This international agreement is designed to help developing countries streamline their priorities to cope with changing climates and perturbations of biophysical resources (Eakin and Lemos, 2010). These plans follow a UNFCCC template and begin with vulnerability assessments that identify vulnerable populations and places and that catalog the risks posed for each country (Ayers and Forsyth, 2009; Denton et al., 2014). Once the most significant vulnerabilities are identified and mapped by each country's pertinent agencies, the assessment shifts to technical evaluations of infrastructural and institutional designs. These assessments involve national, regional, and local governments, as well as national, regional, and local non-governmental organizations (Biagini et al., 2014).

Nepal is among the least-developed countries in the world, where approximately 29 percent of the population lives in multidimensional poverty (National Planning Commission [NPC], 2018). The Human Development Index (HDI) for 2016 indicated that Nepal ranked 144th among 188 countries (HDI, 2016). Because of the level of impoverishment, Nepal qualifies to be a beneficiary under the UNFCCC to receive funding for adaptation initiatives of the most pressing sort from the Least Developed

Countries Fund (LDCF). The seventh session of the Conference of the Parties to the UNFCCC (COP7), held at Marrakech, Morocco in 2001, established the LDCF to support the world's poorest countries. Nepal received a grant of approximately US$20 million to design and execute its NAPA. The money was allotted from a joint venture of the UNDP, the DFID, the GEF-operated LDCF, and the Embassy of Denmark (UNDP, 2011). To receive funding from LDCF, Nepal's government approved its NAPA in September 2010, after 16 months of rigorous work and preparation. This NAPA is a national policy to address the implications of changing climates and to execute adaptation initiatives in vulnerable districts in three steps: a comprehensive preparation and dissemination of NAPA document, development and maintenance of the Nepal Climate Change Knowledge Management Centre (NCCKMC), and structuring by the NCCKMC of the Multi-Stakeholder Climate Change Initiative Coordination Committee (MCCICC) to implement the policy nationally.

After the initial development of NAPA, nine integrated projects were crafted to address the nation's adaptation priorities: development of community-based adaptation through integrated management of agriculture, water, forest and biodiversity sector; augmentation of adaptive capacity of vulnerable communities through improvements of the systems and increasing access to services for agricultural development; promotion of community-based disaster management to facilitate climate adaptation; enhancements of the monitoring and mitigating of glacial-lake outburst flows (GLOFs); improvement of forest and ecosystem management to supporting climate-adaptation innovations to protect public health; undertaking ecosystem management to enable climate-change adaptation; empowerment of vulnerable communities through sustainable management of water resources and development of sustainable energy systems; and the promotion of climate-smart urban development. To achieve the objectives of these projects in Nepal, US$350 million was needed. The NAPA's implementation framework focused on minimizing operating costs so at least 80% of the funding could be spent on grassroots-level adaptation initiatives.

Climate change in Nepal yields high risk, particularly in terms of biophysical impacts. It has comparatively poor infrastructure. It is an "underdeveloped economy," and has been experiencing rapid social, economic, and political changes (Nightingale, 2017). Other South Asian countries share similar challenges, but Nepal's adaptation programs are noteworthy for the extent to which each step in the process engages multi-stakeholder participation through the exercise of the NAPA (Dixit, 2010; GON/MoE, 2010). In fact, NAPA has prompted the development of new organizations throughout Nepal based upon institutional-design principles intended to foster extensive grassroots participation in adaptation activities and to link the various scales of governance (Ojha et al., 2016; Rutt and Lund, 2014).

Despite the achievements of NAPA, it has not been entirely effective or adequate, particularly in the agricultural sector. One critical assessment of the NAPA indicated that many limitations of the policy processes were used in the implementation of actions; one was a lack of prioritization for agrarian adaptation programs (Pandey and Bardsey, 2015). The policy lacked comprehensive analysis of reality in the 'situation analysis' portion of the NAPA; social-economic injustice was ignored in adaptation policy (Sharma, 2011). The NAPA lacked locally based knowledge of the issues and impacts mainly due to the poor representation of the locally knowledgeable players and stakeholders in the policy-making process (Pandey and Bardsley, 2015). Instead, central government staff of the Ministry of Environment (MoE) prepared the document in consultation with foreign experts hired by donor agencies to ensure that Nepal qualified for international financial support via the UFCCC. Fisher and Slaney (2013) indicate that it is difficult to evaluate progress made by NAPA, particularly due to limited local capacity to monitor actions. The prioritized districts in the NAPA were chosen more for convenience than because they had higher levels of vulnerability. Even the most vulnerable places (like the Mustang districts) have not been included as project sites. But most importantly, power and politics are generating negative outcomes in all aspects of adaptation programs, rather than merely being externalities that might require post-implementation management (Nightingale, 2017).

2.4.2. Nepal's Local Adaptation Plans of Action (LAPA) 2011.

Nepal's national government recognized the need to think beyond the NAPA to address the diverse experiences of climate variability throughout the country. Adaptation plans were needed for localities to mitigate the specific, local impacts of climate changes. After considering the opinions of civil organizations and experts, Nepal developed a Local Adaptation Plan of Action (LAPA) in 2011 and it became one of the first of the least-developed countries to do so. This policy is guided by National Climate Policy of 2011 and is based on the priorities set out in the NAPA. The main object of the LAPA is to support the most vulnerable populations in Nepal at the local level by creating and implementing locally specific adaptation plans and strategies. LAPA began with the identification of the rural municipalities, wards, and people who would be most affected by changing climates, then assess their adaptation needs, and finally prioritize adaptation options in local settings. LAPA would then be used to enlist and integrate local adaptation plans for action into a local-to-national planning process following the guidance of the Local Self Governance Act of 1999 (GoN, 2011). LAPA directed local stakeholders to identify the appropriate mechanisms for service-delivery agents and for funding channels to implement these local adaptation plans for action. Finally, the progress of LAPA would be monitored and assessed to ensure effective implementation of the policy and to determine cost-effective options for up-scaling local-to-national adaptation procedures and plans (LAPA, 2011).

When a Nepalese municipality develops a local adaptation plan of action, it must follow a multi-stakeholder engagement process to incorporate as much of the community as possible into decision-making in order to assess the entire spectrum of climate-change impacts. Climate-change adaptation plans should specifically address the immediate needs of the specific communities in order to build resilience. By contrast, sectorial development plans are service-oriented and cover a larger space and a larger, more diverse community (Regmi, 2014). Sectorial bias has been observed in empirical analyses of the preparation of these plans, and it seems to have been due to the influence of the organizations that facilitate preparation of adaptation plans (Regmi, 2014). In many cases, community adaptation-planning activities were very ambitious, and to complicate matters, it became more and more difficult to differentiate between the initiatives that were intended to be adaptive from those that were principally driven by development goals (Ojha et. al 2016).

A critical problem in the implementation of LAPA was a function of the absence of politically elected authorities between 1997 to 2016. This occurred due to internal conflicts in Nepal that prevented the formation of elected bodies representing urban and rural areas that would take the ownership of the local plans. Designing, implementing, and sustaining projects under LAPAs without functioning elected authorities was very challenging; government-nominated secretaries endeavored to build consensus among local leaders to enable implementation of LAPAs. Thus, the lack of government leadership has caused weak links in the vertical integration of policies from local to national levels (Bishwokarma, 2014).

Agrarian adaptation via LAPA initiatives are being implemented jointly by the Ministry of Agriculture Development, the UNDP, the FAO, and the government of Germany (Ministry of Agriculture, 2018). Their main aims and objectives are to make Nepal's poorest and most vulnerable farmers more resilient to the impacts of changing climates. They strive to promote new adaptive technologies, innovations, and knowledge development locally. They have focused on the challenge of drought through mitigation by encouraging non-traditional action, like practices that enhance groundwater storage, technologies for rain harvesting, and others. However, the consequential displacement of populations in parts of upper Mustang has not been given enough attention, even though it might be necessary eventually.

In the five years since the initial implementation of the LAPA framework in Nepal, it has proved to be a pragmatic approach to localize adaptation and to help climate change-vulnerable people to build resilience (Uprety, 2017). Nepal and its development partners, must continue to support evidence based LAPAs so they do not abandon such efforts at critical 'crossroads.' Because of the promulgation of a new constitution in Nepal in 2015, the use of the LAPA framework is needed now more than ever at the scales of the provinces and municipalities. More specific policies that enable agrarian adaptation to improve farmers' livelihoods and maintain food security are urgently needed in the mountainous, rural regions of Nepal.

From these lessons, it can be learned that Nepal's national and local policies (NAPA and LAPA, respectively) are focusing on empowering local governments to ensure effective climate-change adaptation. These policies seem focused on meeting the goals and objectives of the donor agencies rather than striving to make real impacts on the lives of affected groups of people. Critical evaluations of the implementation of these policies have judged them to be biased, suffering from a lack of prioritization of agrarian adaptation and from the absence of remedies of social-economic injustices in adaptation policies (Pandey and Bardsley, 2015). In this context, this study more deeply explores the roles of governance, gender, caste/ethnicity, income, and age to understand how these factors are shaping agrarian adaptation in Lower Mustang, Nepal. This important research goal is undertaken by exploring the impacts of climate change on the region's agriculture and by surveying farmers' short- and long-term adaptation strategies. Then, the role of local governance, gender, caste/ethnicity, income, and age of farmers are evaluated to determine the opportunities and barriers created by these socio-economic matters relative to farmers' adaptation initiatives in Lower Mustang, Nepal.

2.5. The Study Area: Lower Mustang, Nepal

2.5.1. Geographic Setting

Mustang is a remote Himalayan district in the northern part of west-central Nepal. The region abuts Tibet, China to its north, Manang District to the east, Dolpa District to the west, and Myagdi District to the south. Mustang is generally circumscribed by a box with its sides at 28º20’ N and 29º05’ N and 83º30’ E and 84º15’ E. The district is in the rain shadow of the Dhaulagiri Mountains to the west. The Annapurna ranges are to its east. Elevations in the district range from 2,000 m to 8000 m above mean sea level (asl). Mustang District is 3,573 km^2. Its population is approximately 13,452 (CBS, 2011).

Mustang is divided into two main regions: Upper Mustang (elevations in this part are approximately 4,100 m to 8,000 m asl) and Lower Mustang (approximately 2,000 m to 4,100 m asl) (Figure 2). Jomsom is the capital of Mustang District. Lower Mustang has more than 50 percent of the district’s total population (District Profile, 2016).

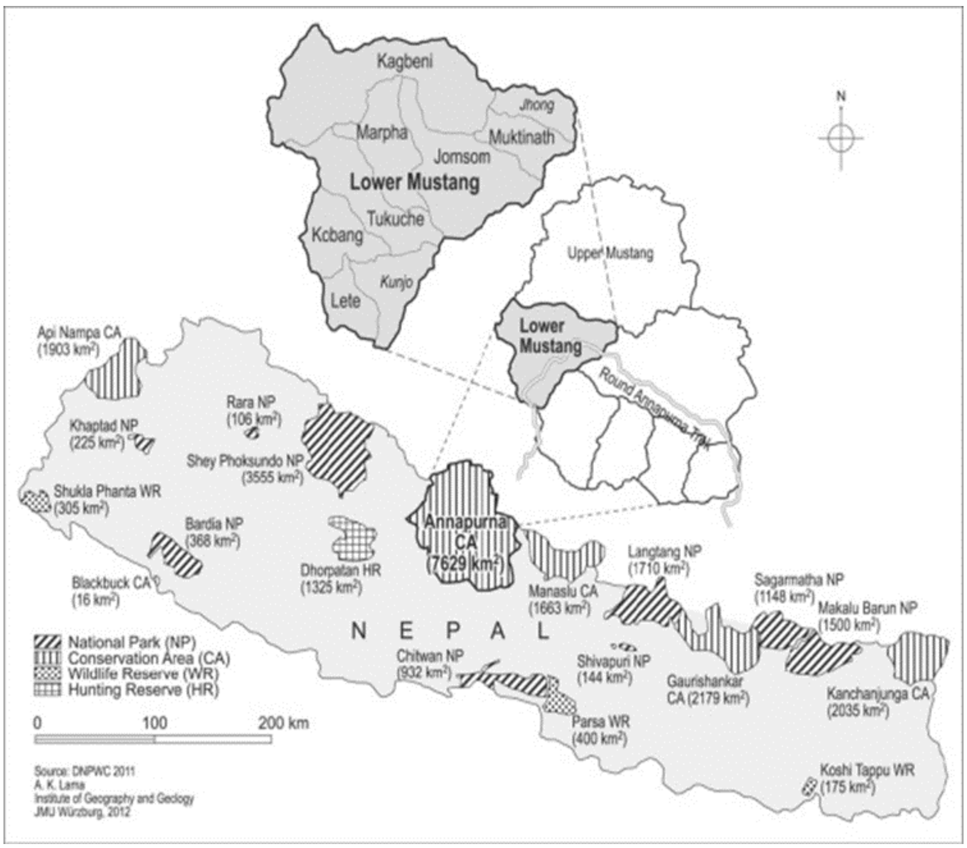

Figure 2: Study site map: Lower Mustang, Nepal (Source: AK Lama, 2012)

2.5.2. Climate and Socio-economic Conditions of Mustang, Nepal

The bio-climatic zones of Mustang district ranges from grassland to alpine tundra. The hottest month in Lower Mustang is August with an average maximum temperature of about 23°C degree and January is the coldest month with an average minimum temperature of -1.1°C (Table 1). The monthly average precipitation in Lower Mustang ranges from an average low of 2.07 mm in November to an average high of than 70 mm in July (Table 1). The average annual rainfall in the last three years 2015 through 2017 was about 315 mm (DHM Nepal, 2017). Over the last two decades, Mustang's temperatures and precipitation patterns appear to have changed. The region's average temperature has increased 0.13°C with fluctuation in annual rainfall and diminished snowfall (Aryal et al., 2014).

Table 1. Monthly average temperature and rainfall, Jomsom, Mustang 2015-2017 (Source: Department of Hydrology and Meteorology (DHM) Nepal)

Month	Average Minimum Temperature °C	Average Maximum Temperature °C	Average Monthly Rainfall (mm)
January	-1.1	10.30	40.37
February	0.3	13.73	7.83
March	2.6	14.97	45.63
April	4.1	18.83	37.17
May	8.1	20.70	21.73
June	11.4	22.90	35.60
July	13.4	22.60	71.00
August	14.0	23.00	24.13
September	11.7	22.13	20.20
October	5.6	18.90	8.07
November	2.2	15.90	2.07
December	-1.3	14.47	1.27
Year	2015-2017	2015-2017	Annual Average Total: 315.07

Lower Mustang is dominated by two ethnic groups: Thakalis and Gurungs. The Thakalis' origin in Lower Mustang is the "Thak Khola" region of the Dhaulagiri zone (in southern Mustang) which is located between Annapurna and Nilgiris Mountain on one side and Dhaulagiri on the other. Genetically, they are Tibeto-Monglian. Thakalis have several family clans. The most common are: Bhattachan, Sherchan, Guachan, Pannachan, Hirachan, Joharchan, Lalchan, and Tulachan. According to locals, this region was historically the site of a salt trade between the Thakalis and Tibetan merchants from China.

The Gurungs, the indigenous ethnic group in Lower Mustang, are concentrated in Kagbeni. They have lived in this area since at least the 18th Century, if not earlier. They are Tibeto/Mongolian as well. Their name, "Gurung", derives from the Tibetan word "grong," meaning "farmers" (Doherty, 1975). Thakalis and Gurungs practice Buddhism, Hinduism, and shamanism.

There are also few caste groups spread across Lower Mustang. The centuries-old caste system in Nepal has four main castes defined by their occupations and guided by views professed in Hinduism. These castes are Brahmans (priests), Chettri's (warriors), Vaishya (traders) and Sudra or "Dalits" (who do service-work – shoemakers, blacksmiths, tailors, etc.). These castes have their origins among Indo-Aryans. In Lower Mustang, the members of these castes seem to have migrated over the last several decades from the nearby districts and towns of Baglung, Myagdi, Dolpa, and Pokhara, as well as from Upper Mustang. Most have been primarily in search of employment. The most common Brahman/Chettri clans in Lower Mustang are Bista, Budhathoki, and Sharma. Some Bista are from the clan of Jigme Dorje Palbar Bista, who was the unofficial king of Mustang between 1964 and 2008. The most common family clans of

Dalits in Lower Mustang are the Vishwakarma, Damayee, Kami, Pariyar, Ghataney, Nepali, and Godamay.

The main sources of income in Lower Mustang are agriculture and tourism. Approximately 80% of Mustang's population depend on agriculture and this is supplemented with income from tourism. Mustang's climate is suitable for growing barley, potatoes, buckwheat, and apples (Manandhar et al., 2010). Common livestock in Mustang are yak-cow hybrids (jhopa or dzo) and horses, and both are used mainly for transportation of materials and food and for production of dung. The cows also produce milk. Goats, for meat, and sheep, for wool, are also raised. They are grazed in alpine meadows during summer and are stall-fed with grass, foliage, and crop residues during winter months. Livestock manure is an important component of the agro-pastoral system as it is essential for enriching soil fertility and recycling nutrients from forests and pastures through crop fields (Holmelin and Aase, 2013). The following chapter presents of review of the scholarly literature key concepts used in the study to reflect their relationship with adaptation in agriculture.

3. LITERATURE REVIEW

3.1. Perceptions of and Concerns about Climate Change

Human perception and concerns about the implications of climate change have profound importance for adaptation to and mitigation of the impacts of climate change at various scales and in different economic and social sectors. Research that examines the matter of climate-change perception can help governments create climate policies and can help pinpoint methods to motivate individual response to the ramifications of climate change, enabling more effective implementation of policies (Yu et al., 2013). Research on public perception of climate change has demonstrated that several factors influence the likelihood of recognition of the problem and the responses that people embrace (Chatrchyan et al., 2017; Steentjes et al., 2017; Demski 2017; Shi et al., 2016; Brugger et al., 2015; Capstick et al., 2015: Yu et al., 2013; Huda 2013; Aitken et al., 2011; Corner et al., 2011; Whitmarsh 2011). These studies show that, along with assorted climatic-variability indicators, age, education, income, gender, ethnic and cultural background, political orientation, personal experience, exposure to media, and personal knowledge about climate change influence the individual and public perceptions of and concerns about climate change (Shi et al., 2016; Brügger et al., 2015; Capstick et al., 2015: Yu et al., 2013; Huda 2013). Gallup polls conducted between 1989 and 2003 revealed that only 20 to 40% of respondents perceived climate change to be a major threat ((Lorenzoni and Pidgeon, 2006). Newer polls by Gallup between 2015 and 2018, showed that concerns had grown among Americans as up to 70% of respondents between 18 and 34, 62% of those between 35 and 54, and 56% of those older than 55 are now more concerned about the implications of climate change (Gallup Polls, 2018).

Disinterest among the elderly may be due to collective social denial, a process in which people subconsciously mute scientific evidence to avoid cognitive dissonance and to avoid the uncertainty-based fear of the future (Ruddell et al., 2012). Highly educated people are more likely to understand the scientific evidence that proves the occurrence of climate change and that is used to deduce its myriad impacts (Etkin, 2007). Furthermore, their views about climate change may also contrast with populations having less formal education since they are less likely to be employed in professions that will be directly and dramatically impacted by climate change, such as agriculture or fishing (Wolf and Moser 2011). Women, particularly in economically developing countries, experience a disproportionate burden from the implications of climate change. Due to their gendered roles in their societies, personal social and familial responsibilities are intertwined with weather and climate to the degree that climate change-induced shifts increase the difficulty of their work. Thus, in many communities, women are more likely to be more concerned about the issue than men (Crona et al., 2013).

Economic stability and income levels are found to affect perception and opinion about climate change. Many household surveys conducted in countries around the world demonstrate that the poor are more often more deeply impacted by the shocks caused by extreme weather events and environmental disasters and so their perception of and concern about climate change is higher than those of affluent communities who are better able to cope with impacts (Hallegate and Rozenberg, 2017). Personal experience also influences perspectives of the future. Those who were badly affected by extreme evens and dramatic changes in their environments are likely to be more concerned about climate change than those who have not experienced challenging conditions (Carmichael

2016). Political orientation reflects one's social philosophy and is conjoined with ethical and moral views. Everyone has some form of political attitude (whether they are engaged or disengaged), and much of the discourse surrounding societies' responses to the climate-change problem is influenced by individual attitudes. "Belief" in the science of and therefore the ramifications of climate change is highly dependent upon matters of trust. The public shapes its perceptions to reflect their perspectives relative to the political elites they have decided to trust. Party identity and affiliation and ideological orientation of the individual is highly correlated with their perspective on the threats posed by climate change (Carmichael, 2016).

Shi et al.(2016) indicate that knowledge about the causes of climate change is significantly related to public perception of climate-change risks. One may assume that a level of concern about climate change must be premised on knowledge about its potential impacts. But recent studies have revealed that knowledge about climate change has less effect on concerns about climate change than does the perception of one's level of risk (or likelihood of being impacted) (Shi et al., 2016). Another important factor influencing perceptions and concerns about climate change is media coverage of the issue and its impacts. Generally, the news media links external events to individual perception (Capstick et al., 2015). Since some may lack experience with climate change, if they have no political ties or relationship to scientific research about climate change, their perception of climate change must be filtered by the few conduits of information that they have, that are, most often, the media (Schäfer et al., 2014).

3.2. Importance of Adaptation in Agriculture

The importance of adaptation is growing (Shukla et al., 2018) and is recognized as a vital tool in response to changing climates (IPCC 2007; UNFCCC 2007). Adaptations are "sustainable actions or strategies that are implemented to reduce the vulnerability of natural and human systems to combat actual or projected impacts of climate change" (Janssena et al., 2009). Adaptation is the adjustment of either natural or human systems in response to actual, perceived, or expected changes or their effects, to moderate harm or to exploit opportunities that arise (IPCC 2007).

Communities' priorities and conditions dictate their choices of adaptation strategies. Some adaptation strategies are motivated by observations or by analyses of expected changes, and others are motivated by economic, social, environmental, or cultural conditions within communities (Fussel 2007). The severity of local environmental and socio-economic impacts influence adaptation strategies as well. To make climate-change adaptation successful in terms of political feasibility and social acceptance, public support and engagement is necessary (Moser and Pike 2015).

Critical to predicting climate change impacts on agricultural activities is discernment of the extent of the ramifications of the changes. This is particularly vital in developing countries, which have less capacity to cope with and adapt to disruptions. Farmers in developing countries have different adaptation objectives. The primary objectives are to secure food and to maintain their livelihoods, but due to limited resources and infrastructure, adaptation processes are constrained. Absent technology, low government support, poor transportation, and poor infrastructure impede adaptation and force farmers to rely on traditional adaptation models (Aryal et al., 2017).

Agricultural adaptations often require long-term shifts of agricultural activities, policies, regulations, and management practices. Farmers' goals and objectives (subsistence requirements, expected yields, need to subsist, and profit forecasts) also influence adaptation. Adaptation is a continuous process and is comprised of four major stages: signal detection, evaluation, decision-making and response, and feedback (Risbey et al., 1999). Agriculture's adaptation to shifting climates occurs within the context of other environmental, social, and economic processes (Milind and Risbey, 2000). Other important contextual influences include collective community motivations and coordinated actions, the effects of research-based policy decisions, changing and expanding communication networks, and exchanges of knowledge (Ayal et al., 2017). In this milieu, the provision of accurate and relevant information to farmers may help enhance their adaptive capacities (Tarnoczi and Berkes, 2010).

Some adaptation strategies used by farmers include adjusting sowing times, use of stress-tolerant crop varieties, and changing crops (Smit and Skinner, 2002). Similarly, local and regional adaptation practices may require changes to planting and harvesting dates and intensification of fertilizer use (Challinor et al., 2014). Other required adaptations may be the adoption of soil-erosion mitigation techniques, rotation of crops, increasing irrigation and drainage efficiency, business diversification, acquisition of crop insurance, the planting of trees to protect grasslands (Bizikova et al., 2014), adoption of pest- and disease-resistant varieties of livestock, relocation of grazing to elevations with better climate conditions (Manandhar et al., 2011). If implemented effectively, these strategies ultimately help farmers to reduce impacts to their lives and minimize the impacts of climate change. Thus, farmers committed to adaptation practices are likely to be more food-secure than those not adapting (Naskar et al., 2015).

Socio-cultural and economic adaptations are unique to local contexts. For instance, in mountains, farmers may create agricultural cooperatives to financially support small-scale farmers with loan programs designed for specific conditions. Farmers can use these loans to transition to different crop varieties or to buy insecticides and fertilizers.

Since the impacts of climate change are already evident in Nepal, adaptations are emerging. It is more cost-effective for farmers to start adaption now and it is feasible to do so immediately; the alternative is to rely entirely on mitigation of the losses (Manandhar et al., 2010). In this respect, people of the Himalayan region of Nepal need to increase their adaptive capacity. They can do so by strengthening local knowledge, acquiring newer technologies, exploring innovations, and changing their agricultural practices within their ecological and social systems. Strengthening the governance and governmental institutions, implementing new policies, and promoting the spread of effective adaptation processes across the region, can enhance individual farmers' adaptation capacities as well (Eriksson et al., 2009, Xu et al., 2014, Shukla et al., 2018). But the recognition of indigenous knowledge can also enhance adaptation and sustainability and complement individual and collective changes.

3.3. Local Governance and Adaptation to Climate Change

In recent years, especially in developing countries, local governments and concerned stakeholders have been creating policies and plans to mitigate the impacts of climate change (Preston et al., 2011), primarily because the impacts of changing climates are apparent and consciously experienced locally. Place-focused plans and policies that meet local needs are, therefore, of utmost importance. In many regions, municipalities design adaptation initiatives that aid the most vulnerable populations (Naess et al., 2005; Smith et al., 2009).

Agrawal (2008) states that municipalities and stakeholders have three important roles in this process. First, they identify and compile information about the impacts of climate change and evaluate the impacts relative to various sectors of life and the economy. Second, they mediate between individual and collective responses by identifying the vulnerabilities of each sector. And third, they facilitate delivery of resources to enable effective adaptation (Measham et al., 2011). Local bodies develop adaptation plans since little progress is being achieved at the national and international levels to mitigate GHG emissions. Therefore, local governments, non-governmental organizations, and stakeholders are looking for opportunities to be empowered to respond to climate change impacts to protect local communities. However, effective implementation of plans and policies made by local governments and other stakeholders depend on several factors, such as availability of resources, governments' priorities, adaptive capacity, and the actors involved in their networks of governance (Smith et al., 2009; Boydell, 2010; Dovers and Hezri, 2010).

3.4. Climate Change, Gender, and Adaptation

Social scientists have debated whether there is a gender dimension to climate change impacts and adaptations. Before addressing the relationship between gender and the implications of climate change, it is important to consider the relationships between humans and physical environments. Some have concluded that human-environment relationships are not gender-neutral (Dankelman 2010). They argue that women in remote regions of the world tend to interact more with the environment, and they are therefore disproportionately affected by environmental degradation (Dankelman, 2002). The Center for Science and Environment (1985) revealed that poor female villagers in developing countries suffer the most from environmental degradation and changing climate. Women are caught between the limitations of poverty, the impacts of environmental degradation, and their daily routines involving the acquisition of fuel, fodder, and water, and these tasks grow more difficult as ecological conditions worsen (Dankelman, 2002). There are two major representations of women's relationships with their environments. The first regards women to be vulnerable due to their dependence on the conditions of the environment. The second regards women as virtuous (i.e., more aware and careful) in terms of their treatment of the environment. Arora-Jonsson (2009) suggests that women in the Global South will be more severely impacted by climate change than will men. Most decision makers and implementers of policies in both the Global North and South are men (Arora-Jonsson, 2009). A recent study found that male-headed households use more adaptation methods than do female-headed households due to their abilities to access resources, greater property rights, larger social networks, and more highly developed personal communication skills (Ali and Erenstein, 2017).

Similarly, empirical evidence suggests that women experience poverty and deprivation differently than men do, so they can be differentially affected by shocks and environmental stressors (Goh, 2012). In the developing world, women tend to control fewer assets and have fewer rights than do men. Fewer assets and less access to capital and other resources increases the vulnerability of women (Goh, 2012). Cutter (1996) argues that women are more vulnerable due to their lower adaptive capacities, fewer opportunities for adaptation, and less access to information. This skew is more apparent in the Global South (Parasai and Shrestha, 2006). Moreover, rural women have higher levels of vulnerability than rural men due to their lower participation rates in institutional and economic dynamics and because rural women are also burdened by household responsibilities and parenting (Adger et. al., 2003).

An effective agrarian adaptation system is one in which technology is available to those who are most in need; to the poor and the most vulnerable: women. Women's situations may differ dramatically from men's and therefore there is a need for relevant technologies that fit users' individual circumstances; there should be full access to knowledge, information, and the technologies that enable adaptation (Uddin et al., 2014).

Women are also more virtuous in that they are likely to be more environmentally friendly and are they are usually more willing to take risks than are their male counterparts. Women are more prepared to change behaviors and are more inclined to support new policies and techniques to save or protect the environments around them (Arora-Jonsson, 2009). While assessing the impacts of climate change on agriculture and projecting the future conditions in terms of gender, it is critical to differentiate the impacts on women and men and to develop information that enables adaptation (Agarwal, 2010).

A person's adaptive capacity is dominated by social markers that influence access to and control over resources and the geographical contexts and limitations of daily activities. In this context, the scholarship addressing adaptive capacity and adaptation choices in agrarian settings in the Global South have focused on gender as the most important social marker and an important influence on a person's adaptability (Carr and Thompson, 2014). This literature focuses around three major themes that compound the implications of gender for adaptation. The first theme reflects the lack of women's participation in decision making (Dankelman and Jansen, 2010). Inequality in decision-making goes beyond selection of crops to plant and the timing of planting. It extends into the socially constructed roles that dictate one's ability to sell in markets and restricts personal mobility (Chaudhary et al., 2012; Djoudi and Brockhaus 2011). These decisions affect adaptation to climate change and shape agricultural outcomes; they are driven by male-dominated power structures, especially in the developing world (Carr and Thompson, 2014).

The second theme highlights the gendered disparities in access to land and land tenure (Quisumbing and Pandolfelli, 2008; Djoudi and Brockhaus, 2011). These disparities include the ability to purchase land and to access communally held or managed lands (Fletschner and Kenney 2011). These limitations have far-reaching consequences for agricultural productivity, which will, in most cases, diminish due to changing climates. Unequal entitlement to land affects agricultural outcomes and resilience, especially for women, and it will also impact their access to credit (Fletschner and Kenney 2011). Many small-holding farmers need credit to be able to purchase more climate change-resistant seeds and livestock varieties, agricultural tools, fertilizers, and other inputs. If women are denied such access, they will be more vulnerable than men (Ahmed and Fajber 2009).

The third theme focuses on the differential agricultural practices and crop choices that are driven by gendered roles demonstrating how the differences present different challenges and opportunities to different locations and in different environments (Ravera et al., 2016). These studies reveal that women often raise crops that are more sensitive to climate variability than do men. Since women are not usually the principal decision-makers in their households or communities, the resulting vulnerabilities created by differential climate impacts are often not addressed by indigenous or traditional adaptation strategies (Carr and Thompson, 2014).

The gap in the literature pertaining to conceptualization of gender is the power that masks questionable assumptions, for example the continued use of the categories of ‘‘men’’ and ‘‘women’’ in the context of gender vulnerability without empirical evidence to justify it. These prior assumptions that men are vulnerable, and women are more vulnerable to climate change are often relied upon without having evidence of vulnerabilities (Paavola and Adger, 2006; Reid and Vogel, 2006). Reliance on superficial categories may lead to results that fail to improve adaptation strategies.

3.5. Income and Agricultural Adaptation

The economic strength of farmers plays an important role in coping with and adaptation to environmental stress. In developing countries, farmers' wealth and finances are usually measured by their earnings from income-generating activities or by the number of livestock they own (Homelin and Aase, 2013). Resourceful farmers are likely to be less vulnerable to climate-change impacts due to their enhanced mitigation capacities (Deressa et al., 2009). Financial resources allow them to cope and adapt using more diverse and better technologies (Deressa et al., 2009). A recent study found that there is a direct relationship between income and the likelihood of implementing more adaptation strategies and methods (Ali and Erenstein, 2017).

If we take the example of Nepal, there are significant disparities in income, with average per capita income ranging from approximately USD 500 in some remote districts to over USD 2700 in Kathmandu, the capital of the country (NPC and United Nations Development Program [UNDP], 2014). The yearly average income of Nepali people also varies between castes and ethnic groups, with people from the Brahmin/Chhetri, Vaisya, Thakali, Gurung, and Sherpa earning considerably more than the Dalit groups (UNDP, 2014). This variable is vitally important for determining the patterns of farmers' personal adaptation initiatives, especially in the mountainous regions of Nepal.

3.6. Age and Adaptation in Agriculture

Generally, the age of farmers reflects their agricultural experience and expertise, both of which are important for mitigating the impacts of climate change. Studies in Ethiopia have shown a positive relationship between the number of years of experience in agriculture and the use of advanced agricultural technologies (Kebede et al., 1990). Experienced farmers are more likely to recognize the need to grapple with climate change and they are more likely to prevent or limit impacts by using technology (Maddison, 2006; Nhemachena and Hassan, 2007). Sometimes, however, there is an inverse relationship between age and adaptation choices, like adoption of soil conservation practices. A study by Shiferaw and Holden (1998) indicated that older farmers may be less willing to take the risks associated with new farming practices and technologies. A recent study found that younger farmers are more likely to practice soil conservation (Ali and Erenstein, 2017). Farmers younger than 35 used more innovative approaches and tended to adopt advanced agricultural methods (Ali and Erenstein 2017).

3.7. The Caste System and Adaptation in Nepal

The Hindu caste system that operated in Nepal is believed to have been started by Aryans in India around 1500 BC. The formal establishment of Nepal's Muliki Ain (National Legal Code) in 1854 promulgated Nepalese social hierarchy based on caste and ethnicity. Over the following century, the caste and ethnicity hierarchy determined individuals' social identities. Since Hindus comprise approximately 85% of the population today, the caste system profoundly influences several aspects of Nepali lives. The four caste divisions were the Brahman (comprised of priests and scholars), the Kshatriya or Chhetri (the rulers and the warriors), the Vaisya (merchants and traders), and the Sudra (laborers). Sudra is also known as Dalit and as the lowest caste, it included a few of the lowest ranked subgroups called "untouchables." Caste categories reflected wealth (or poverty), education, and health status of groups and dictated access to resources. Traditionally, the caste system prohibited land ownership among lower-caste members and their families. Though the caste system was formally outlawed in 1962, a study by Jones (2010) revealed that there are still barriers to land acquisition among the lowest caste in many parts of Nepal. They further revealed that Dalit were charged higher interest rates by upper-caste landlords and were prevented from having access to the most fertile and productive land; evidence that several institutional and cultural limitations persisted.

Regarding the ethnic groups in Nepal, political scientists Joshi and Rose (1966) classified the Nepalese population into three major ethnic groups defined by regions of origin: Indo-Nepalese, Tibeto-Nepalese, and indigenous Nepalese. The Tibeto-Nepalese group consists of several ethnic groups: Sherpa, Tamang, Rai, Magar, Limbu, Gurung, and Thakali, who define themselves as an ethnic group known locally as ‘janajati’ and indigenous people (Yadav et al., 2015). These Tibeto-Nepalese settled in northern Nepal, and, upon arrival, they were politically, socially, and economically marginalized by the Indo-Nepalese. Over the past few decades, however, these ethnic groups have acquired access to more resources and have become politically stronger in their region by consolidating their indigenous rights and by gaining greater access to resources than the Dalits. Thomas-Slayter and Bhatt (1994) observed that within rural Nepal, caste and ethnicity constitute the primary identifiers around which people, households, and communities come together for common action; to strategize collective agrarian adaptation, for example. Individual and collective adaptation initiatives undertaken by the most vulnerable lowest caste and ethnic groups may be hampered by deeply embedded cultural norms and values and by the inequalities that exist in Nepalese society (Ostrom, 2005; Jones, 2010). Because of these inequalities, especially in the mountains where conditions are already very harsh, Dalits may be suffering from the impacts of climate change because they are more vulnerable than are those that rank higher in the hierarchy of the region (Onta and Resurreccion, 2011). These deeply rooted inequalities and social barriers (such as untouchability) may have diminished the capacity of Dalits to adapt to changing climates since they must collaborate with people of higher castes to acquire the support and resources they need when they need them.

Historically, access to spaces of political power at the community level and the authority and autonomy associated with that access remained solely within the hands of the upper caste and well-established ethnic groups such as those residing in Mustang today. Although, no formal barriers exist to prevent the inclusion of members of lower castes in every collaborative agrarian initiative, the informal institutional environment ensures the absolute cultural hegemony of the upper castes in many local and national administrative proceedings regarding the resources and services provided by governments. In this context, beliefs of entitlement to social safety nets, such as credit and aid from national and international agencies and reluctance to support members of the community outside of specific castes, existed in western Nepal (Jones, 2010). These inequalities affected the efforts of low-caste people in their agrarian adaptation initiatives, determining how individuals react to climate stresses, variability, and change. Though outlawed in 1962, the caste system still pervades Nepalese culture, society, and economy (Jones 2010). With persistent inequalities Dalit men and women continue to bear the burden of discrimination and poverty in many parts of rural Nepal. This condition affects their adaptive capacities to combat climate variability, especially in their initiatives to adapt in order to sustain their livelihoods.

3.8. Summary

This chapter reviewed the scholarship to answer four questions: What are the factors that affect perceptions of climate change? What lessons can be culled from the scholarly literature about the roles of local governance, gender, caste/ethnicity, age, and income of farmers in adaptation strategies that seek to minimize the impacts of changing climates? Are there gaps in our understanding of the roles of governance, gender, caste/ethnicity, age, and income of farmers in mountainous, rural settings?

First, it can be said that local governance, gender, caste/ethnicity, age, and farmers' income are important determinants of local effectiveness of adaptation initiatives. Though socio-economic factors are interrelated and probably of equal importance, local governance seemed to be the most important since rural populations seem to be more dependent on local-government services. These services, however, are also affected by the local government's priorities and by their ability to provide such services in times of need.

Second, the roles of local governance, gender, caste/ethnicity, age, and farmers' incomes were not clearly delineated in the literature in terms of agrarian adaptation in mountainous, rural settings. At best there were only very generalized statements about these relationships. For example, the prevailing assumption that though men may be vulnerable, women are more vulnerable to changing climates, was often relied upon without evidence that clearly demonstrates these gendered dimensions of vulnerability (Paavola and Adger, 2006; Reid and Vogel, 2006).

In this context, a growing challenge in agrarian adaptation research is to identify and understand the sensitivities of different actors and social groups, the socio-economic and cultural barriers to adaptation, and the negative consequences that adaptation will have at the local level. Some of these variables may require an analysis of the role local governance, local social structures, ethnicity/caste, age, gender, and income in preventing local agrarian adaptation or impeding adaptation initiatives (Nielsen and Reenberg 2010). The next chapter discusses the methods of data collection and analysis used in this study.

4. METHODS

This study is planned so as to draw conclusions about three research topics: farmers' perceptions, the foundations of their perceptions, and the enabling or disabling contexts for adaptive responses. The first of these, farmers' perceptions, is examined to determine the important socio-economic and demographic factors that have affected farmers' perceptions of climate change in Lower Mustang and to determine if there are significant differences among the spatial, socioeconomic, and demographic patterns of farmers perceptions in the region. Secondly, the facets of farmers' lives will be examined by comparing the climate change-impacts perceived by farmers to the impacts likely to occur based on the region's climate trends and to analyze whether farmers' concerns are statistically related to the communities in which they reside or to their social and demographic cohorts, economics, or other characteristics. Finally, the understanding of the social, economic, and political contexts of adaptation will be achieved by identifying the climate change-adaptation strategies initiated by farmers, exploring how governance, ethnicity (or caste), gender, income, age, and education influence farmers' adaptation choices in the region and discerning whether there are deterministic relationships between these any of these characteristics and the barriers to or opportunities for adaptation in Lower Mustang. This chapter describes the methods of data collection and analysis were used to meet these objectives.

4.1. Data Collection Methods

To assess the relationships between the characteristics of farmers and farming methods and climate-change perceptions and adaptations, four field-conducted data collection methods were used: focus-group discussions, surveys of farmers, key-informant interviews, and secondary source data compilation. Four research sites (Kagbeni, Jomsom, Marpha and Tukuche) within the study area were visited between May and December 2018. The data collection methods and type of data collected are detailed below (Table 2).

Table 2. Data collection methods and data type

S.N.	Data Collection Methods	Data Type
1.	Rapid Rural Appraisal • Seven Focus Group Discussions conducted in four communities of Jomsom, Kagbeni, Marpha and Tokuche in Lower Mustang. • Group Interactions noted	• Explored the farmers' perceptions of climate change. • Identified major impacts of climate change in the agriculture of Lower Mustang. • Identified key barriers and opportunities to agrarian adaptation initiatives associated with socio-economic variables being studied.
2.	Farmers' Household Surveys • Survey Questionnaires developed • 200 Surveys conducted in four communities, fifty each from Jomsom, Kagbeni, Marpha and Tokuche in Lower Mustang.	• Collected respondents' socio-economic demographic data. • Collected respondents' perceptions, their level of concerns and threats of climate change and its impacts in the agriculture of Lower Mustang. • Identified common agrarian adaptation strategies. • Identified key barriers and opportunities associated with socio-economic variables being studied.
3.	Key Informant Interviews • Interview Questionnaire developed • 26 Key Informant Interviews conducted in the communities of Kagbeni, Jomsom, Marpha and Tokuche in Lower Mustang	• Collected key informant's individual experiences and knowledge on climate change and its impact on Lower Mustang's agriculture • Critically analyzed the key barriers and opportunities to agrarian adaptation initiatives associated with socio-economic variables being studied. • Triangulated the data collected from surveys and focus group discussions.
4.	Secondary Source • Meteorological data from the Department of Hydrology and Meteorology, Government of Nepal.	• Thirty-year (1987-2017), temperature and rainfall data of Jomsom and Marpha, two of four study sites in Lower Mustang, were collected to match the farmers' perceptions of climate change trend over the last three-four decades in the region

4.1.1. Focus-group Discussions.

Focus-group discussions are rapid assessment tools using pre-determined, open-ended questions designed to acquire qualitative data. The questions inquired about farmers' general knowledge about climate change and their perceptions of the impacts that climate change may have on agriculture in Lower Mustang District. These discussions enabled assessment of the impacts that local community governance (specifically the institutions that set agrarian-adaptation policies), farmers' incomes and funding sources, gender, and age have on agrarian adaptation in Lower Mustang. Focus-group discussions yielded information and data that otherwise may not have been revealed by the surveys and key informant interviews.

Before conducting focus-groups events, informal meetings were held with local leaders and farmers to identify farmers in the community that could be invited to participate. Both men and women farmers were contacted by local leaders, known as "Mukhiya," or by their messengers ("Katuwal") in person or by phone. This method of contact is a common practice in mountainous regions of Nepal when community discussions or public hearings are called.

Seven focus-group discussions were conducted in four communities in the study area: Jomsom, Kagbeni, Marpha, and Tukuche. Two of these included people of several different ethnicities (Thakali, Gurung, and castes (Dalit)). Three focus-groups were comprised exclusively of Dalit, and most present were female. The other two focus-

Figure 3. Participants of focus group discussion along with Mukhiya, Jomsom, Lower Mustang, Nepal (Source Field Visit, 2018)

groups included either all men (with varied ethnicities) or all women (Dalit, but of varied ethnicities). The groups ranged in size from 6 to 15 participants. I moderated each discussion but was aided by either the rural municipal chairman (Mukhiya) or by the women's-group chairperson. Discussions were focused on perceptions of climate change and impacts on agriculture, and on farmers' adaptation initiatives. The relationships of community governance, caste and ethnicity, gender, age, and income to agrarian adaptation initiatives were also discussed. Discussions were recorded and notations taken by a research assistant in a field log. Each discussion lasted approximately one hour.

Figure 4. Participants of focus group discussion, Marpha, Lower Mustang (Source: Field Visit, 2018)

Figure 5**. Participants of focus group discussion, Marpha, Lower Mustang (Source: Field Visit, 2018)**

4.1.2. Perception Survey.

A survey was designed to gather qualitative and quantitative data about farmers, their knowledge, experiences, observations, and adaptations. The survey contained four sections of questions regarding basic demographics and the three research questions. The four sections were: questions related to farmers' backgrounds and socio-economic information; questions related to farmers' experience, their knowledge, their understanding of climate change, and their awareness of potential impacts on agricultural activities and adaptation; questions pertaining to farmers' short- and long-term adaptation strategies and risk-mitigation measures; and questions about the influences of governance, gender, income, and age on adaptation and coping, and if and how they created barriers or opportunities for adaptation. Each section contained open-ended questions to encourage spontaneous responses and to reduce bias caused by restricted responses using pre-determined answers. The survey was designed in English, but it was translated into Nepali and administered in that form. Responses were compiled in Nepali and were then translated to English.

Field surveys of farmers in Lower Mustang were planned to use random sampling. Male and female farmers from Jomsom, Kagbeni, Marpha, and Kagbeni were selected from a voter register obtained from each municipality. If any randomly selected member was beyond contact, then they would be replaced by the next prospective participant. This process continued until the predetermined quota of 25 male and 25 female respondents was achieved for each community. This equal number of male and female respondents was intended to reduce bias based on sex and to be consistent and neutral and to enable comparability between communities when analyzing and interpreting the results of the surveys.

Figure 6. Surveying a dalit female in Marpha, Lower Mustang (Source: Field Visit, 2018)

Approximately 80% percent of Mustang's population of 13,452 (approximately 10,000) is engaged in agriculture (Agricultural Management Information System, 2016). To statistically represent this population, 200 farmers (100 male and 100 females) were surveyed to achieve a 95% percent confidence level and a 5%-10% margin of error.

Figure 7. Surveying a local farmer in Kagbeni, Lower Mustang (Source: Field Visit, 2018)

4.1.3. Key-informant Interviews

The third research method of data collection was to interview key-informants. These interviews were loosely structured conversations with key people in Lower Mustang to understand their perceptions of the real and expected impacts of climate change, as well as barriers and opportunities for adaptation among farmers in Lower Mustang (Secor, 2010).

Twenty-six key-informant interviews were conducted in Lower Mustang. Local leaders and other experts provided recommendations for informants and assisted with arranging interviews. Lower Mustang key-informants were those who have lived in or have served in the district for at least 10 years, were knowledgeable about agriculture in the district, were knowledgeable about the climatic and environmental conditions of the district and have served in leadership roles in the local communities. The informants selected included 8 from Jomsom, 7 from Tukuche, 6 from Marpha, and 4 from Kagbeni. Among them were four Mukhiyas (local leaders nominated by ethnic community members) and four government officials (representing the department of irrigation, the office of veterinary and livestock services, the office of soil erosion control, and the office of disaster management). Among the other key informants were four businessmen working in a local apple business, four mothers' group heads, four environmental science teachers (2 males and 2 females), three female Dalit representatives, a female ward secretary, and a conservation expert who represented the Annapurna Conservation Area Project (ACAP) in Lower Mustang, Nepal.

Each key informant provided their views and understanding of impacts of climate change on agriculture in Lower Mustang. They also opined on how local governing of policies and programs run by elected rural municipality chairs and the local community governance system led by Mukhiya assist or impede farmers in their agrarian adaptation initiatives. They shared their views about the effects of gender status, caste/ethnicity, age, and incomes on farmers' adaptation endeavors. In addition, these interviews provided background and context to complement the survey results and explained the coping and adaptation strategies used by farmers in Lower Mustang. Each interview was audio-recorded in Nepali and was later transcribed and translated into English for analysis and interpretation.

Figure 8. Key informant interview, rural municipality chairperson, Jomsom, Lower Mustang (Source: Field Visit, 2018)

4.1.1. Secondary Source Data

Secondary data such as meteorological data of Jomsom and Marpha, two of the four study sites, were gathered to determine the trends of temperature and rainfall in Lower Mustang. They were obtained from the Nepal Department of Hydrology and Meteorology. These data were collected to determine whether climatic indicators matched with farmers' perceptions of climate change in Lower Mustang.

Figure 9**. Key informant interview, mothers' group head, Tukuche, Lower Mustang, Nepal (Source: Field Visit, 2018)**

Figure 10**. Key informant interview, ward chair, Marpha, Lower Mustang (Source: Field Visit, 2018)**

4.2. Data Analysis Methods

Three data-analysis methods were used to analyze quantitative and qualitative data gathered in the field. These methods are descriptive statistics, non-parametric statistics, and content analysis. Descriptive statistics summarized the survey responses and enabled visualizations in frequency tables, and bar graphs.

Non-parametric methods were used to analyze categorical and ordinal data generated with Likert-scale questions to determine the significance of relationships among and between respondent groups. The Mann-Whitney U Test, the Kruskal-Wallis test, and the Chi-square test were the primary non-parametric statistics tests used. The Mann-Whitney U Test is commonly used to discern differences between two independent groups when the dependent variables are either ordinal or continuous but are not normally distributed (Laerd Statistics, 2018). The Kruskal-Wallis test assesses the significance of differences among groups of specific categories like the respondents' communities, income groups, age groups, and agricultural practices, enabling evaluation of the between-group differences and similarities in perceptions. The Chi-square test enables evaluation of the statistical associations between classes within respondents' communities, sexes, age cohorts, income classes, educational levels, and agricultural practices in terms of their concerns about the threats from regional climate change.

Finally, content analysis was conducted on the qualitative data collected from focus-group discussions, key informant interviews, responses to open-ended survey questions, and the author's field notes and observations. This technique classified texts into content categories, or themes, based on explicit coding rules (Weber, 1990; Bebel 2000). A code in a qualitative inquiry is most often a word or short phrase that symbolically assigns an essence-capturing attribute to a portion of qualitative data (Bebel 2000). In this study, three important themes were identified and analyzed. These themes are farmers' perceptions of climate change, climate change and its impact on Lower Mustang agriculture, and opportunities for and barriers to adaptation in Lower Mustang. The data collected under these themes were used to supplement the findings from the survey results, to interpret the strength of evidence, and to provide explanation when needed.

4.3. Institutional Review Board (IRB) Component of the Study

This study involves humans as research subjects, and therefore, a requisite detailed Institutional Review Board (IRB) proposal was developed and submitted to Texas State University IRB on March 13, 2018 for an expedited review. The IRB reviewed and approved the proposal on April 4, 2018. This approval allowed the researcher to conduct surveys, focus-group discussions, and key-informant interviews with the consent of each participant in Jomsom, Kagbeni, Marpha, and Tukuche of Lower Mustang, Nepal.

5. RESULTS AND DISCUSSION

The description of the results of data analysis begins with a summation of the socio-economic status and demography of the farmers who were surveyed in Lower Mustang, Nepal. Meteorological data gathered at Jomsom and Marpha, two of the four study sites, established the thirty-year (1987 to 2017) trend of temperature and rainfall in Lower Mustang. The analyses focused on the relationships between perceptions and the communities studied, and the sex, age, and agricultural practices of farmers. The results of testing using the non-parametric Mann-Whitney U test are discussed to highlight the statistically significant relationships. The Kruskal-Wallis test results are discussed to underscore the differences in perceptions between communities, cohorts, agricultural practices. The results of these analyses are supplemented with the information gathered through interviews and focus-group discussions and the results are discussed. The chapter concludes with a discussion of the ways in which Lower Mustang farmers' perceptions about climate change compare to the climate record (specifically indicators such as changes of temperature, rainfall, and snowfall patterns) of the last three decades.

5.1. The Socioeconomic Characteristics and Demographics of Farmers

Two hundred farmers (100 males and 100 females), twenty-five men and twenty-five women randomly selected in each of the four communities (Jomsom, Kagbeni, Marpha, and Tukuche) were surveyed (Table 3). The average number of years of experience among the surveyed farmers is 44.3 years; seemingly adequate to justify the assumption that they could have perceived climate change from their experiences in their communities. The other characteristics of the respondents derived from the surveys are discussed below.

Table 3. The distributions of survey respondents

			Respondents		Total
			Male	Female	
Community	Jomsom	Count	25	25	50
		% within Community	50	50	100
	Kagbeni	Count	25	25	50
		% within Community	50	50	100
	Marpha	Count	25	25	50
		% within Community	50	50	100
	Tukuche	Count	25	25	50
		% within Community	50	50	100
Total		Count	100	100	200
		% within Community	100	100	100

5.1.1. Ethnicities and Castes.

The composition of respondents' ethnicity and caste in Lower Mustang are: 70.5 % Thakalis and Gurungs, 19.5% Dalits, and 10 % Brahmans/Chettri. The distribution of respondents' ethnic and caste groups across communities in Lower Mustang communities were distinct in some ways. Jomsom, the headquarters of Mustang, is more diverse. Kagbeni is more homogenous. Marpha has more Dalits than the others. And Tukuche has the highest proportion of Thakalis, it is the cultural hearth and point of origin of the Thakalis.

5.1.2. Farmers' Households and Families

The tabulation of the respondents' household/family type in Lower Mustang indicate that there are 63% nuclear families and 37% joint/extended families, with an average of five family members per household. Marpha has the highest proportion of nuclear families (68%) and Tukuche has largest fraction of joint or extended families (42%) (Figure 11).

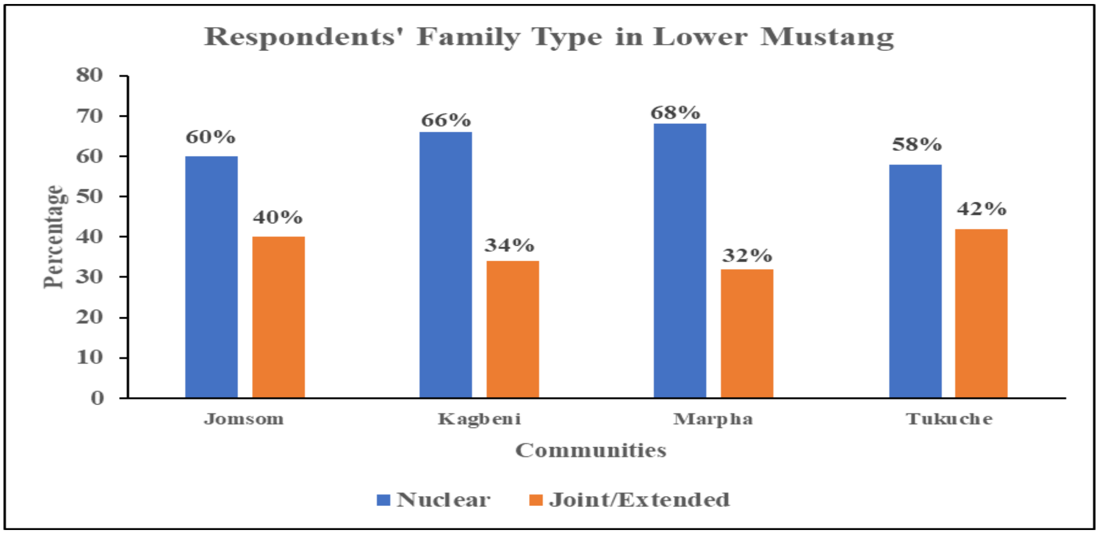

Figure 11. The distribution of respondents' family types in Lower Mustang

5.1.3. The Ages of the Farmers Surveyed in Lower Mustang

The tabulation of respondents' ages indicates that about 41% are elderly (51 and above), 35.5% of them are middle-aged (36-50), and about 23.5% are young adults (21-35) (Figure 4). Most Lower Mustang farmers are middle-aged and older. These groups have multi-decadal experiences from which they may have developed a perspective on change, and thus are more likely than most to be aware of changes in the region's climate and the impacts that climate change may have had on agriculture in Lower Mustang.

5.1.4. Farmers' Annual Incomes from Agriculture Production

The reported personal incomes of farmers indicate that at least half of respondents have annual incomes ranging from US$2,000 to US$4,999. The percentage of high-income (US $ 5000 and above) farmers is about 17% in Lower Mustang. Lower-income (less than $2000 per year) farmers comprise 23% (Figure 12). The upper-income group is comprised primarily of Thakalis and Gurungs. Dalits are members of the lower-income group. They are often supported by their families, who earn income as wage laborers in agriculture, manufacturing, and construction.

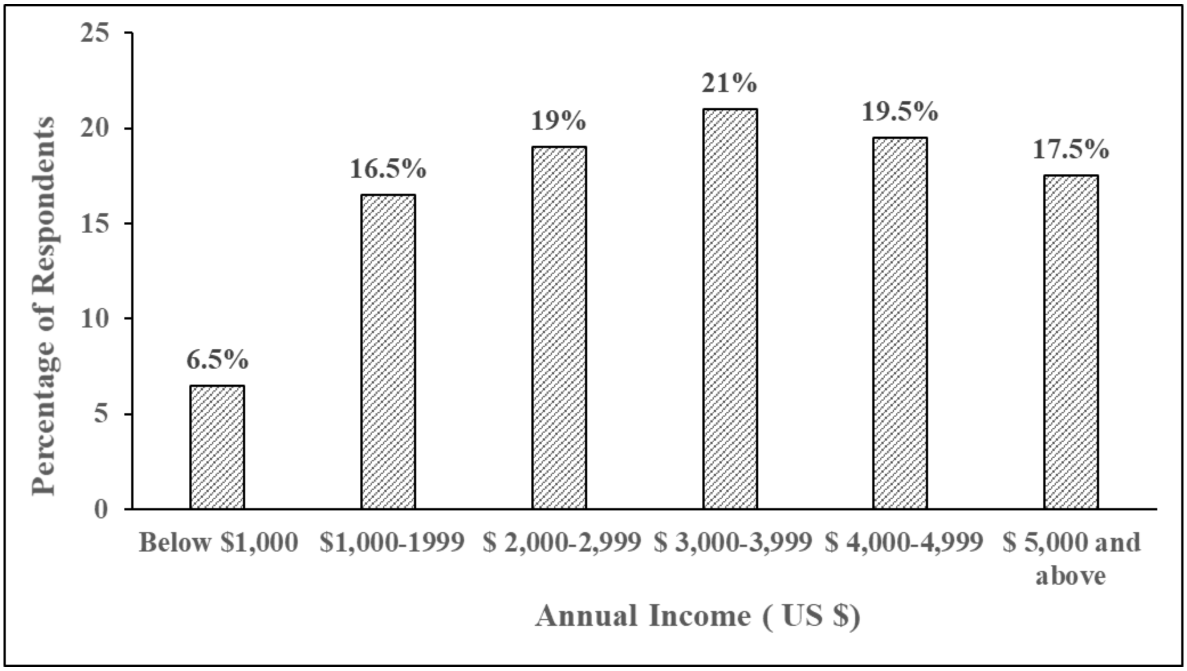

Figure 12. The distribution of respondents' annual income from agriculture

5.1.5. Sources of Family Income

Respondents' reported sources of family income indicates that only about a third of them depend solely on agriculture for their income (Figure 13). The other two-thirds supplement their agricultural incomes with other employment (such as work in the hotel and tourism industries, wage labor, off-shore work and remittance back to families, governmental employment, office work, and teaching (Figure 13). About 65% of Thakalis and Gurungs farmers have hotel and/or tourism businesses. And about 70% Dalits also worked in construction and agriculture as wage laborers. Most of those who are entirely dependent on agriculture are Thakalis and Gurungs. The group discussions revealed that these two groups usually operate large apple orchards, often earning as much as US $ 20,000 to US $ 25,000 annually.

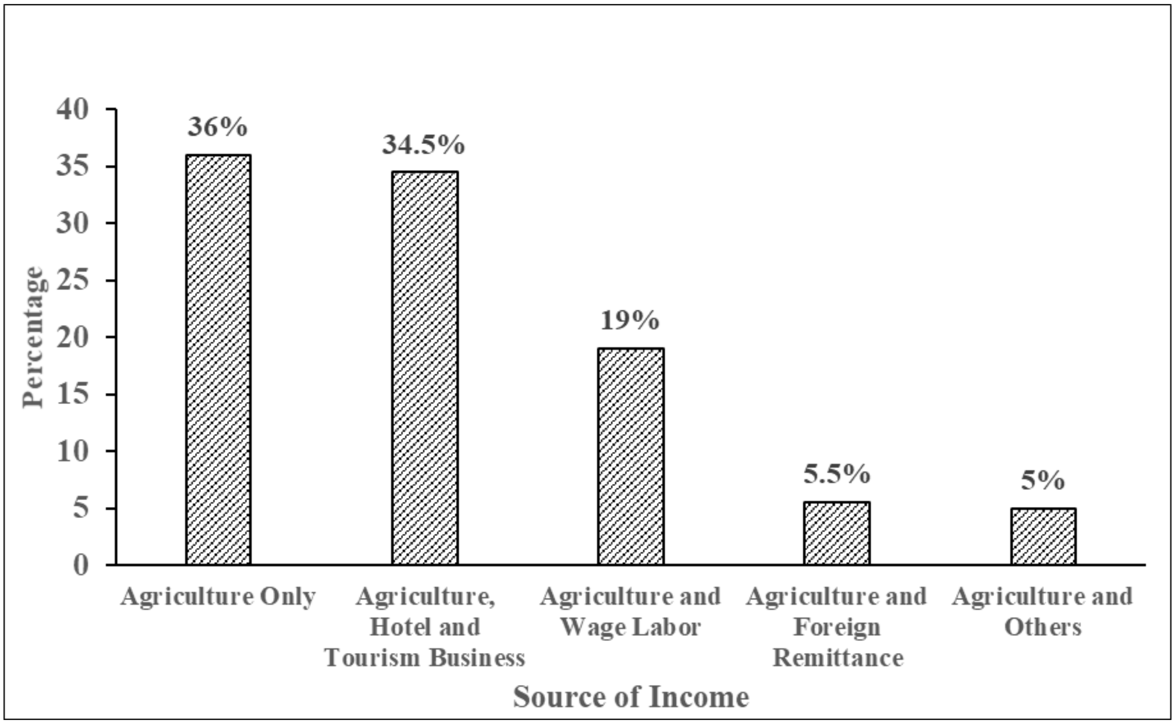

Figure 13. The distribution of respondents' sources of family income

5.1.6. *Farmers' Educational Attainment*

Approximately 70% of respondents had some education, while nearly a third had no formal education (though they had not attended school, some of them knew how to read and write) (Figure 14). Of those who had attended school, 22% had a primary education (grades 1 through 5), two-fifths had attended secondary school (grades 6 through 12), and only about one in twenty received a university degree (Figure 14). Most of the farmers had lower levels of education due in part to the remoteness of Lower Mustang which has had few public and private schools. Most of the Dalits, especially women, did not attend school due to their economic circumstances and the social barriers created by the notions of untouchability that plagued Nepal during the 19th and 20th centuries. Remnants of this caste-system principle can still be found in practice in Lower Mustang.

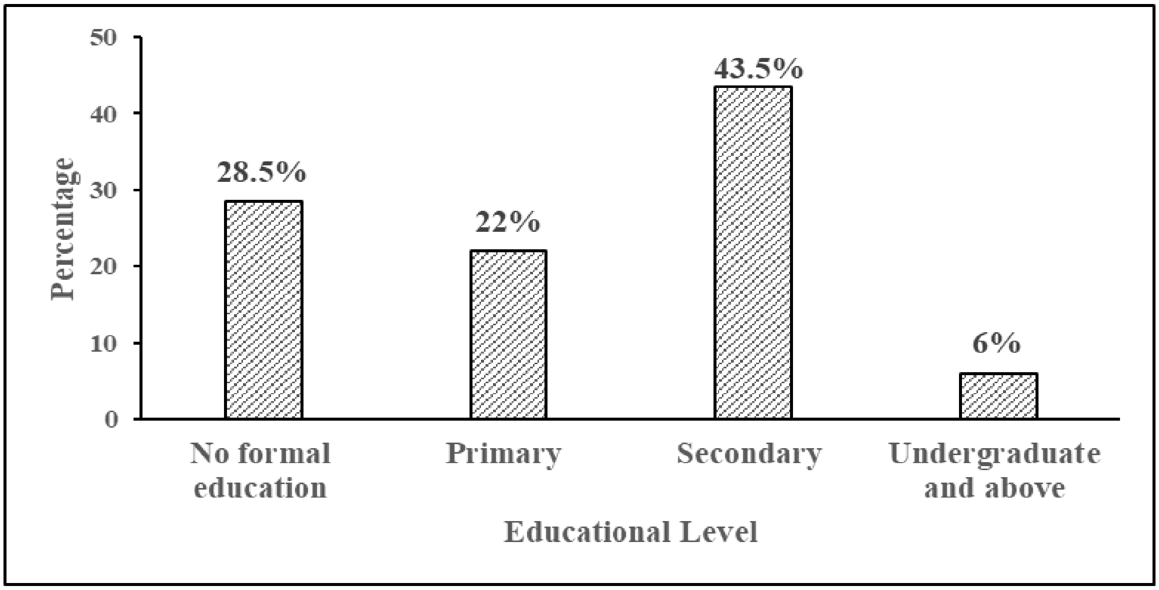

Figure 14. The distribution of respondents' educational attainment

5.1.7. The Array of Farmers' Crop Selections in Lower Nepal.

Nearly a third of farmers are engaged in cereal production, a third grow apples and vegetables, one fourth produce cereals, range livestock, and farm vegetables, and one fifth produce cereals, livestock, apples, and vegetables (Figure 15). Key informants' interviews and focus-group discussions revealed that farmers in the region are increasingly engaged in cash-cropping apples and vegetables. This is causing a shrinkage of acreages planted with more traditional crops like naked barley and buckwheat.

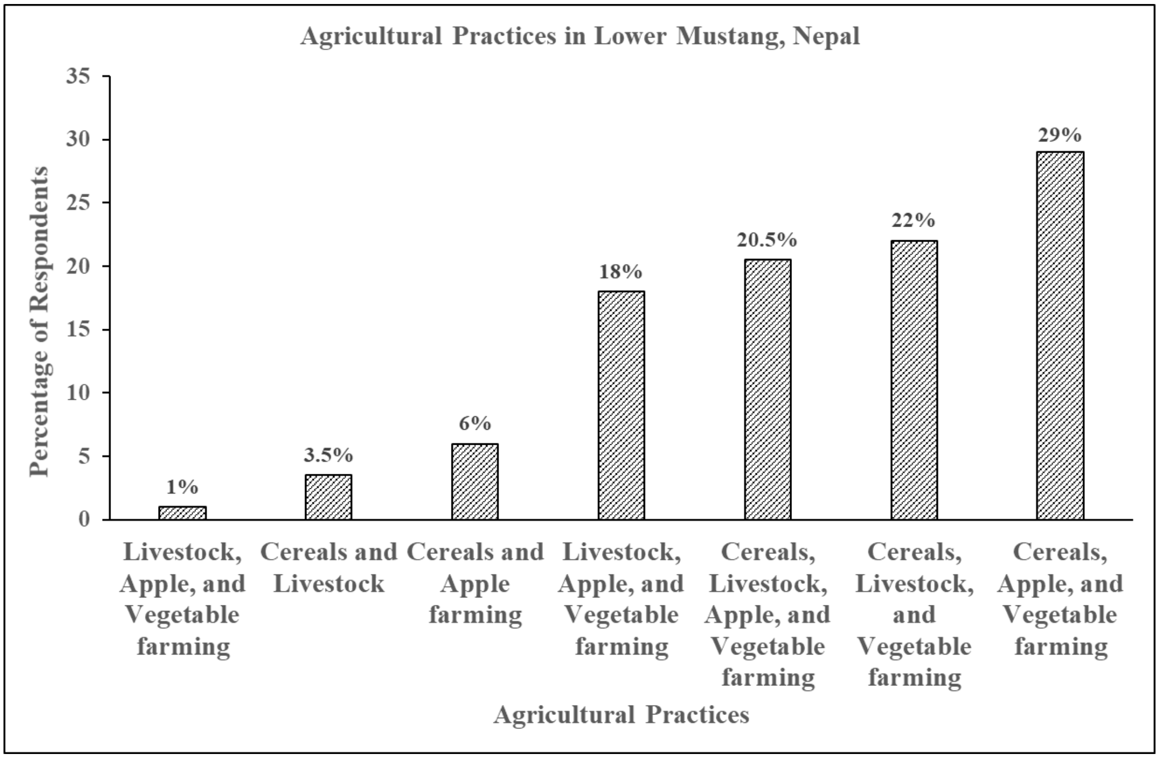

Figure 15. The distribution of respondents' agricultural practices

5.2. Views of Climate Change and Climate-change Information Sources

Farmers' perceptions of climate change, the frequency of their conversations about it and its impact in agriculture, and their sources of information are important influences that may affect their communities' adaptation and coping strategies. These issues are described below.

5.2.1. Farmers' Views of and Conversations about Climate Change.

Agriculture in mountainous Lower Mustang is likely to be affected most by changing temperature, rainfall, and snowfall regimes. Farmers were asked whether they believed climate change was impacting their agriculture and their communities. All respondents confirmed that climate change was already occurring in Lower Mustang and that it had begun occurring for the last 30 to 40 years. Nearly all respondents had engaged in discussions with others concerning the impacts that climate change was having on their agricultural practices, either doing so often (59%) or occasionally (40%). The frequency of farmers' discussions about climate change varied among the communities in the study (Table 4). Nearly seven in ten farmers in Kagbeni and Marpha said they often engaged in climate-change conversations, while the farmers of Jomsom talked about this problem less frequently (Table 4).

Table 4. The distribution of respondents' frequency of climate change conversation

			Frequency of Climate Change Conversation			Total
			Often	Sometimes	Never	
Community	Jomsom	Count	**20**	**30**	**0**	**50**
		% within Community	40%	60%	0.%	100%
	Kagbeni	Count	34	16	0	50
		% within Community	68%	32%	0%	100%
	Marpha	Count	34	15	1	50
		% within Community	68.0%	30.0%	2.00%	100%
	Tukuche	Count	30	19	1	50
		% within Community	60.0%	38.0%	2.0 %	100%
Total		Count	118	80	2	200
		% within Community	59%	40%	1%	100%

5.2.2. Sources of Information about Climate Change.

Knowledge of and understanding climate change often helps farmers to evaluate farming practices and to develop, adopt, and continue adaptation and mitigation. The farmers were asked about the sources from which they acquired information about climate change and the impacts on their communities. All farmers stated that they receive information about climate change via word-of-mouth and that this and their own experience were the two most important sources for them (Figure 16). Discussions with other farmers and with experts, and empirical, experiential evidence were the most important ways in which they developed an understanding of climate change and its impacts on Lower Mustang's communities. Other important sources for nearly half of farmers were public seminars, talks, and meetings.

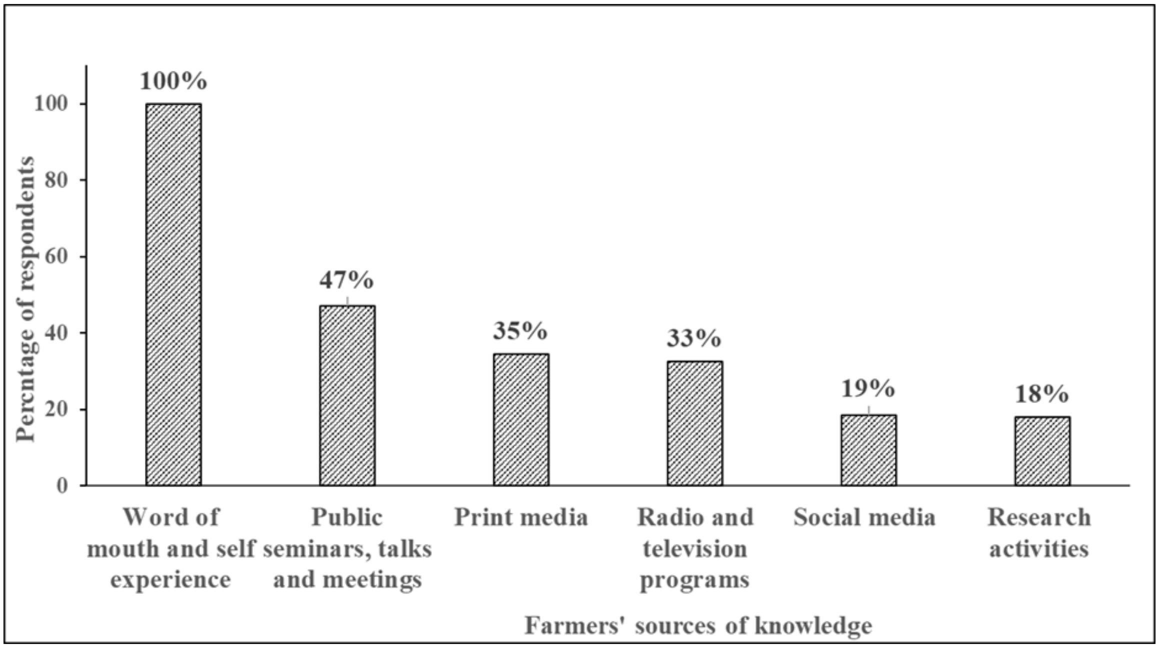

Figure 16. The distribution of respondents' sources of knowledge on climate change

About one-third indicated that national radio and television programs focusing on agriculture provided important information. Another third of the respondents, especially the youngest cohort (21-35) are informed about climate change and its impacts on social media via news links encountered in Facebook. Similarly, about a fifth of the farmers learn about climate-change issues from researchers who visit their communities to undertake climate-change studies. A few key informants also indicated that a book had recently been published in Nepali, *Prakriti ko Sandesh (*Nature's Message), (Series 1-3), by the Annapurna Conservation Area Project (ACAP), a non-government organization working in Lower Mustang. Simplified versions of this series of books are also included in the secondary-school (grades 8, 9 and 10) curriculum in Lower Mustang.

5.3. Farmers' Perceptions of Climate-change Indicators

Perceptions of climate-change indicators and their potential risks are prominent in the shaping of a natural-hazards policy and response system in any given geographical area (Brody et al., 2008). Farmers' perceptions of changes in their local environments are critical determinants of their responses to risks generated by climate change and influence their adaptation and coping strategies (Becken et al., 2013). To explore Lower Mustang farmers' perceptions about changing temperature, rainfall, and snowfall patterns over the last several decades, farmers were asked three questions: Has your area's temperature, rainfall, or snowfall increased over the last 30 to 40 years? Has your area's temperature, rainfall, or snowfall remained relatively constant over the last 30 to 40 years? and Has your area's temperature, rainfall, or snowfall decreased over the last 30 to 40 years?

5.3.1. Farmers' Perceptions of Temperature Change in Lower Mustang

More than 99 percent of farmers are convinced (73.5% strongly agreed and 26.5% agreed) that average temperature has increased in Lower Mustang over the last three to four decades. The distribution of this agreement in terms of the four communities, sex, age, income and agricultural practices are discussed below. The Statistical Package for the Social Sciences (SPSS) software was used for statistical analyses to determine whether there are significant relationships between these demographics and their perceptions of climate change in Lower Mustang.

5.3.1.1. Community perceptions of warming in Lower Mustang.

The communities in the study are located at different elevations: Kagbeni (2,810 m asl), Jomsom (2,743 m asl), Marpha (2,650 m asl), and Tukuche (2,590 m asl). But elevation apparently doesn't explain farmers' views of changing climate. Marpha's farmers (78% strongly agree and 22% agree) are more convinced that temperature has increased in Lower Mustang than are farmers in the other communities (Table 5). This may be because Jomsom, Kagbeni, and Tukuche are adjacent to the Kali Gandaki River which might moderate extremes in the warmer seasons. They are in spots where cool breezes off the river may seem to lower daytime heat, especially during summer. Marpha, by contrast, is farther from the Kali Gandaki River and the river may have little influence on its temperatures. Winds tend to be stronger at Jomsom, Kagbeni, and Tukuche, which may also result from the differential heating and cooling in these locations. Farmers of Kagbeni, however, are less strongly convinced that temperatures have risen (only 68% strongly agree) and this may indeed be due to elevation. The statistical tests, however, indicate that the differences between villages are not statistically significant ($p = 0.681$; this is greater than α of significance .05) (Table 5 and Appendix 1). We can conclude that perceived climate change is essentially consistent among these communities.

Table 5. Respondents' perceptions of rise in temperature in Lower Mustang by community

Perception	Level of Agreement		Community				Total
			Jomsom	Kagbeni	Marpha	Tuk uche	
Temperature has increased in Lower Mustang over the last 30-40 years.	Strongly Agree	Count	38	34	39	36	147
		% of all respondents in this category	25.9	23.1	26.5	24.5	100.0
		% of respondents in each community	76.0	68.0	78.0	72.0	73.5
	Agree	Count	12	16	11	14	53
		% of all respondents in this category	22.6	30.2	20.8	26.4	100.0
		% of respondents in each community	24.0	32.0	22.0	28.0	26.5
Total		Count	50	50	50	50	200
		% within temperature has increased over the last 30-40 years.	25.0	25.0	25.0	25.0	100.0

5.3.1.2. Perceptions of warming in Lower Mustang by sex.

Male farmers of Lower Mustang' are more convinced than female farmers that temperatures have changed in the region over these last several decades: 77% of males strongly agree and 23% agree and 70% of females strongly agree and 30% agree (Table 6). These differences may reflect the different residential mobilities over the lives of males and females in the study area. On average, male farmers tend to remain in Lower Mustang longer than females: males remain an average 49 years and females 39 years.

The Mann-Whitney U test, however, indicates that these differences are also not statistically significant (p=0.263) (Table 6 and Appendix 1).

Table 6. Respondents' perceptions of temperature increase in Lower Mustang by sex cohort.

Perception	Level of Agreement		Category		Total
			Male	Female	
Temperature has increased in Lower Mustang over the last 30-40 years.	Strongly Agree	Number	77	70	147
		% of all respondents	52.40	47.60	100
		% of each sex cohort	77.0	70.0	73.5
	Agree	Number	23	30	53
		% of all respondents	43.4	56.6	100
		% of each sex cohort	23	30	26.
Total		Number	100	100	200
		% of sample	50	50	100
		% of Total	50.	50	100

5.3.1.3. Perceptions of warming in Lower Mustang by age cohort.

An examination of the perceptions of temperature increases in Lower Mustang by age cohort reveals that more than 75% of those 36 years old or older strongly agreed that warming was occurring (Table 7). However, within the 66 and older age cohort, 85.7% strongly agreed and 14.3% agreed, a greater proportion than in the other groups. This might be explained by longer, more robust experiences. However, the Kruskal-Wallis test indicated that there were no significant differences in agreement between the age cohorts (p=.320) (Table 7 and Appendix 1).

Table 7. Respondents' perceptions of rise in temperature in Lower Mustang by age cohort

Perception	Level of Agreement		Respondents' Age Group 21-35	36-50	51-65	66 and above	Total
Temperature has increased in Lower Mustang over the last 30-40 years	Strongly Agree	Count	34	51	32	30	147
		% of all respondents	23.10%	34.70%	21.80%	20.40%	100.00%
		% within each age cohort	72.30%	71.80%	68.10%	85.70%	73.50%
	Agree	Count	13	20	15	5	53
		% of all respondents	24.50%	37.70%	28.30%	9.40%	100.00%
		% within each age cohort	27.70%	28.20%	31.90%	14.30%	26.50%
Total		Count	47	71	47	35	200
		% of the sample in each age cohort	23.50%	35.50%	23.50%	17.50%	100.00%

5.3.1.4. Perceptions of Warming in Lower Mustang by Types of Agriculture

Farmers' opinions about temperature changes in Lower Mustang may be influenced by the agricultural activities that they practice. Nearly 29 percent of farmers who grow cereal, apples, and vegetables strongly agree that temperature has increased in Lower Mustang (Table 8). Whereas 24.5% of farmers who grew cereals, raised livestock, and farmed vegetables strongly agreed and 17.7% of farmers who grew cereals, raised livestock, farmed vegetables, and grew apples strongly agreed (Table 8). Therefore, it may be inferred that farmers who grow apples and vegetables are most convinced that temperature has increased in Lower Mustang over the last 30-40 years.

Likewise, within categories of the arrays of agricultural practices we see some variation in confidence. Livestock rancher/apple grower/vegetable farmers unanimously agree strongly (i.e., 100%). Cereal grower/livestock ranchers are somewhat split in the strength of their certainty (85.7% strongly agree and 14.3% agree). The combination cereal farmer/livestock rancher/vegetable grower was less certain (81.8% strongly agree and 18.2% agree) (Table 5). But again, the Kruskal-Wallis test reveals that the differences are insignificant (p=.506) (Table 8 and Appendix 1).

Table 8. Respondents' perceptions of temperature increase in Lower Mustang by agriculture practiced

Perception	Level of Agreement		Agricultural Practices							Total
			Cereals and Livestock ranchi-ng	Cereals and Apple farm-ing	Livestock, Apple and Veg farming	Cereals Apple and Veg. Farm-ing	Cereals Live-stock and Veg. Faring	Livestock Apple and Veg Farmi-ng	Cereals Live-stock, Apple and Veg. Farming	
Temp. has increased over the 30-40 years	Strongly Agree	Count	6	8	27	42	36	2	26	147
		% of all respondents	4.10%	5.40%	18.40%	28.60%	24.50%	1.40%	17.70%	100.00%
		% of each practice	85.70%	66.70%	75.00%	72.40%	81.80%	100.00%	63.40%	73.50%
	Agree	Count	1	4	9	16	8	0	15	53
		% of all respondents	1.90%	7.50%	17.00%	30.20%	15.10%	0.00%	28.30%	100.00%
		% of each practice	14.30%	33.30%	25.00%	27.60%	18.20%	0.00%	36.60%	26.50%
Total		Count	7	12	36	58	44	2	41	200
		% of Total	3.50%	6.00%	18.00%	29.00%	22.00%	1.00%	20.50%	100.00%

5.3.2. Perceptions of Changes in Rainfall in Lower Mustang

To reveal Lower Mustang farmers' perceptions and confidence in those perceptions about changes in rainfall, three questions were posed: Has rainfall increased in Lower Mustang over the last 30-40 years? Has rainfall fluctuated (not remained constant) in Lower Mustang over the last 30-40 years? and Has the rainfall in Lower Mustang decreased over the 30-40 years? In response, 87% responded that they either strongly agreed or agreed that rainfall patterns have been fluctuating more, 11% were uncertain, and 1.5% strongly disagreed or disagreed. This is consistent with the findings of an empirical study conducted in Lower Mustang by Aryal et al., (2014). They determined that rainfall fluctuated over the last 30-40 years and contrasted with a period of scant rainfall prior to the 1980s. To examine agreement among farmers geographically and demographically, the responses were sorted by community, sex, age cohort, and the array of agricultural regimes. To evaluate the significance of differences the distributions were assessed with non-parametric statistical tests.

5.3.2.1. Communities' perceptions of changing rainfall in Lower Mustang.

In terms of confidence that there has been a change in rainfall patterns in Lower Mustang, there is a slight variation between communities. Jomsom farmers were in greater agreement (96% strongly agree or agree) than the others. Kagbeni farmers were slightly less so (92% strongly agree or agree), as were Tukuche (86%) and Marpha (74%) (Table 9). These are consistent with the information shared in both the focus-group discussions and key informant interviews. Many have concluded that rainfall has been quite variable in all Lower Mustang communities and it has been particularly unpredictable during the last 30-40 years. However, 26% of respondents in Marpha were not convinced either way, and 4% of farmers in Tukuche strongly disagreed or disagreed with this conclusion. The Kruskal-Wallis test revealed that the differences between communities *are* statistically significant (p=.005) (Table 9 and Appendix 1). More than half (56.5%) of respondents who were not convinced either way (i.e., neutral) were Marpha farmers (Table 9). This seems to indicate that farmers in Marpha haven't decided whether there are changing precipitation patterns.

Table 9. Respondents' perceptions of changes in rainfall patterns in Lower Mustang by community

Perception	**Level of Agreement**		**Community**				**Total**
			Jomsom	Kagbeni	Marpha	Tukuche	
Rainfall has fluctuated in Lower Mustang over the last 30-40 years	Strongly Agree/ Agree	Count	48	46	37	43	174
		% of all respondents	27.60%	26.40%	21.30%	24.70%	100.00%
		% within community	96.00%	92.00%	74.00%	86.00%	87.00%
	Neutral	Count	2	3	13	5	23
		% of all respondents	8.70%	13.00%	56.50%	21.70%	100.00%
		% within community	4.00%	6.00%	26.00%	10.00%	11.50%
	Disagree / Strongly Disagree	Count	0	1	0	2	3
		% of all respondents	0.00%	33.30%	0.00%	66.70%	100.00%
		% within community	0.00%	2.00%	0.00%	4.00%	1.50%
Total:		Count	50	50	50	50	200
		% of all respondents	25.00%	25.00%	25.00%	25.00%	100.00%
		% within community	100.00%	100.00%	100.00%	100.00%	100.00%
		% of Total	25.00%	25.00%	25.00%	25.00%	100.00%

5.3.2.2. Perceptions of changing rainfall by sex.

The relationship between perceptions of rainfall patterns over the 30-40-year period and the sex of the farmer reveals that males were in greater agreement (91% of males strongly agreed or agreed and only 83% of females did so) (Table 10). More female farmers (17%) were either neutral or they disagreed that rainfall patterns were changing; only 9% of males were neutral or disagreed about the rainfall patterns (Table 10). The Mann-Whitney U test indicates that there are significant differences (p=.045) between males' and females' perceptions of rainfall fluctuation in Lower Mustang (Table 10 and Appendix 1). Or to put it differently, males were more certain that rainfall has been fluctuating than were women.

Table 10. Respondents' perceptions of changing rainfall regimes in Lower Mustang by sex cohort

Perception	Level of Agreement		Sex		Total
			Male	Female	
Rainfall has fluctuated in Lower Mustang over the last 30-40 years -	Strongly Agree / Agree	Count	91	83	174
		% of all respondents	52.30%	47.70%	100.00%
		% within sex cohort	91.00%	83.00%	87.00%
	Neutral	Count	7	16	23
		% of all respondents	30.40%	69.60%	100.00%
		% within sex cohort	7.00%	16.00%	11.50%
	Disagree / Strongly Disagree	Count	2	1	3
		% of all respondents	66.70%	33.30%	100.00%
		% within sex cohort	2.00%	1.00%	1.50%
Total		Count	100	100	200
		% of all respondents	50.00%	50.00%	100.00%
		% within sex cohort	100.00%	100.00%	100.00%
		% of Total	50.00%	50.00%	100.00%

5.3.2.3. Perceptions of changing rainfall by age cohort.

The most certain set of farmers who are confident that rainfall is fluctuating in Lower Mustang is the cohort between 36 and 50 years old. That group comprised 32.2% of all respondents who strongly agreed or agreed that rainfall was changing. They are followed by the group between 51 and 65 (26.4%) and those between 21 and 35 years old (23.6%). Within these cohorts, however, those 51 to 65 years old were most strongly certain (strongly agreed or agreed) (97.9%) that rainfall has fluctuated in Lower Mustang (Table 11). The Kruskal-Wallis test indicates that there are significant differences in strength of confidence (agreement or disagreement) within the age groups (p=.023) (Table 11 and Appendix 1). Age groups have different perceptions of the rainfall regime; for instance, the 36- to 50-year-old farmers expressed an enormous amount of uncertainty (60.9% were neutral, neither agreeing nor disagreeing that there were changes occurring and rainfall was less predictable) (Table 11).

5.3.2.4. Perceptions of changing rainfall by agricultural practice.

Cereals-apple-vegetable farmers are the most confident farmers (31% strongly agreed or agreed) about their perception of a changing and unpredictable rainfall regime. Among all groups, the livestock-apple-vegetable farmers were in complete agreement with each other: 100% indicated that they strongly agreed or agreed that rainfall patterns have and are changing. This group was followed in terms of strength of conviction by the cereal-apple-vegetable group (93% strongly agreed or agreed). The Kruskal-Wallis test found no significance in the differences of perceptions of rainfall patterns however (p=.098) (Table 12 and Appendix 3). Farmers conducting different agricultural production operations share their perceptions with those in other regimes.

Table 11. Respondents' perceptions of changing rainfall regimes in Lower Mustang by age cohort

Perception	Level of Agreement		Respondents' Age Group				Total
			21-35	36-50	51-65	66 and above	
Rainfall has fluctuated over the last 30-40 years	Strongly Agree / Agree	Count	41	56	46	31	174
		% of all respondents	23.60%	32.20%	26.40%	17.80%	100.00%
		% within age cohort	87.20%	78.90%	97.90%	88.60%	87.00%
	Neutral	Count	4	14	1	4	23
		% of all respondents	17.40%	60.90%	4.30%	17.40%	100.00%
		% within age cohort	8.50%	19.70%	2.10%	11.40%	11.50%
	Disagree /Strongly Disagree	Count	2	1	0	0	3
		% of all respondents	66.70%	33.30%	0.00%	0.00%	100.00%
		% within age cohort	4.30%	1.40%	0.00%	0.00%	1.50%
Total		Count	47	71	47	35	200
		% of all respondents	23.50%	35.50%	23.50%	17.50%	100.00%
		% within age cohort	100.00%	100.00%	100.00%	100.00%	100.00%
		% of total	23.50%	35.50%	23.50%	17.50%	100.00%

Table 12. Respondents' perceptions of changes in the patterns of rainfall in Lower by agriculture practiced

Perception	Level of Agreement		C, LR	C, AF	C,VF	C.AF,VF	C,LR,VF	LR, AF,VF	C,LR, AF, VF	Total
			Agricultural Practices							
Rainfall has fluctuated over the last 30 to 40 years -	Agree /Strongly Agree	Count	5	8	32	54	37	2	36	174
		% of all respondents	2.90%	4.60%	18.40%	31.00%	21.30%	1.10%	20.70%	100.00%
		% within group	71.40%	66.70%	88.90%	93.10%	84.10%	100.00%	87.80%	87.00%
	Neutral	Count	1	4	4	4	6	0	4	23
		% of all respondents	4.30%	17.40%	17.40%	17.40%	26.10%	0.00%	17.40%	100.00%
		% within group	14.30%	33.30%	11.10%	6.90%	13.60%	0.00%	9.80%	11.50%
	Disagree / Strongly Disagree	Count	1	0	0	0	1	0	1	3
		% of all respondents	33.30%	0.00%	0.00%	0.00%	33.30%	0.00%	33.30%	100.00%
		% within group	14.30%	0.00%	0.00%	0.00%	2.30%	0.00%	2.40%	1.50%
Total		Count	7	12	36	58	44	2	41	200
		%	3.5%	6%	18%	29%	22%	1%	20.5%	100%
C = Cereals, LR = Livestock Ranching, AF = Apple Farming, VF = Vegetable Farming										

5.3.3. Farmers' Perceptions of Changes in Snowfall Patterns.

The survey participants were asked: Has snowfall increased, remained constant, or decreased in Lower Mustang over the last 30-40 years? In response, 75% strongly agreed and 25% agreed that annual snowfall amounts have decreased. To dig deeper into the patterns of this perception of snowfall patterns the responses were further analyzed in relation to communities, sex, age cohort, and the agricultural activity practiced by respondents.

5.3.3.1. Communities' perceptions of changing snowfall patterns.

The distribution of farmers' perceptions of snowfall amounts in Lower Mustang by the categories of communities of farmers' in Kagbeni (2,810 m asl), Jomsom (2,743 m asl), Marpha (2,650 m asl) and Tukuche (2,590 m asl) are described below.

The respondents in Jomsom (84% strongly agreed and 16% agreed) have slightly more confidence that snowfall has decreased than farmers in the other communities (Tukuche – 80% strongly agreed and 20% agreed; Marpha – 70% strongly agreed and 30% agreed; and Kagbeni – 66% strongly agreed and 34 % agreed) (Table 10).. Communities at higher elevations usually receive more snow. The results follow this trend, however Jomsom may also be influenced by its local environment, not just its elevation. The Kruskal-Wallis test shows that there are no significant differences between the rates of agreement ($p= 0.131$) (Table 13 and Appendix 3). The perception that snowfall has decreased is virtually equivalent across these communities.

Table 13. Respondents' perceptions of decreasing snowfall in Lower Mustang by community

	Level of Agreement		Community				Total
			Jomsom	Kagbeni	Marpha	Tukuche	
Snowfall has decreased in the last 30-40 years.	Strongly Agreed	Count	42	33	35	40	150
		% within Community	84.0%	66.0%	70.0%	80.0%	75.0%
	Agreed	Count	8	17	15	10	50
		% within Community	16.0%	34.0%	30.0%	20.0%	25.0%
Total		Count	50	50	50	50	200
		% within Community	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	25.0%	25.0%	25.0%	25.0%	100.0%

5.3.3.2. Perceptions of Changing Snowfall Patterns by Sex

How does their sex influence farmers' perceptions of the long-term change in snowfall patterns in Lower Mustang? The statistics suggest that males are more confident that snowfall has decreased over the last several decades. Of the 150 respondents who strongly agreed with this view, 56.7% were male and 43.3% were female. Among males, 85% strongly agreed and 15% agreed; among females, 65% and 35% (Table 14). The greater strength of agreement among males could reflect their longer residence times in Lower Mustang. Though both agreed that snowfall decreased, the non-parametric Mann-Whitney U test indicated that there is a significant difference in their levels of agreement as p=.001 (Table 14 and Appendix 1).

Table 14. Respondents' perceptions of decreasing snowfall in Lower Mustang by sex cohort

Perception	Level of Agreement		Category: Sex		Total
			Male	Female	
Snowfall has decreased in Lower Mustang over the last 30-40 years.	Strongly Agree	Count	85	65	150
		% of respondents	56.70%	43.30%	100.00%
		% within sex cohort	85.00%	65.00%	75.00%
		% of Total	42.50%	32.50%	75.00%
	Agree	Count	15	35	50
		% of respondents	30.00%	70.00%	100.00%
		% within sex cohort	15.00%	35.00%	25.00%
		% of Total	7.50%	17.50%	25.00%
Total		Count	100	100	200
		% of respondents	50.00%	50.00%	100.00%
		% of Total	50.00%	50.00%	100.00%

5.3.3.3. Perceptions of changing snowfall patterns by age cohort.

The group that most strongly agreed that they perceived that snowfall has decreased in Lower Mustang over the last 30-40 years is the group of respondents between 36 and 50 years old. That they comprised a higher percentage (34.70%) of the respondents who strongly agreed was mainly due to them constituting a larger percentage of the surveyed farmers. However, the group that contained the highest proportion (77.10%) of members who strongly agreed (as opposed to those who agreed) is 66-and-older age group (Table 15). The Kruskal-Wallis test reveals that differences in the perceptions of the members of these age cohorts is not statistically significant (p=.965) (Table 15 and Appendix 1).

Table 15. Respondents' perceptions of decreasing snowfall in Lower Mustang by age cohort.

Perception	Level of Agreement		Respondents' Age Group 21-35	36-50	51-65	66 and above	Total
Snowfall has decreased in Lower Mustang over the last 30-40 years	Strongly Agree	Count	35	52	36	27	150
		% of respondents who strongly agreed	23.30%	34.70%	24.00%	18.00%	100.00%
		% of members of age group	74.50%	73.20%	76.60%	77.10%	75.00%
		% of Total	17.50%	26.00%	18.00%	13.50%	75.00%
	Agree	Count	12	19	11	8	50
		% of respondents who agreed	24.00%	38.00%	22.00%	16.00%	100.00%
		% of members of age group	25.50%	26.80%	23.40%	22.90%	25.00%
		% of Total	6.00%	9.50%	5.50%	4.00%	25.00%
Total		Count	47	71	47	35	200
		% of respondents in age group	23.50%	35.50%	23.50%	17.50%	100.00%
		% of Total	23.50%	35.50%	23.50%	17.50%	100.00%

5.3.3.4. Perceptions of changing snowfall patterns by agriculture practiced.

Farmers who produced cereals, apples, and vegetables were a slightly larger plurality (27.3 %) of all farmers who strongly agreed with the belief that snowfall amounts have been decreasing over the last three to four decades. However, among those who strongly agreed, it was farmers who produced specific combinations of products that expressed different levels of confidence. For example, 100% of the rancher/apple grower/vegetable farmer group strongly agreed, and 85.7% of the rancher/cereal farmer strongly agreed (Table 16). The Kruskal-Wallis test indicated that there were no significant differences between the groups, however ($p=.805$) (Table 16 and Appendix 1).

Thus, farmers engaged in different sets of agricultural activities are similar in their agreement that snowfall has been diminishing in Lower Mustang.

Table 16. Respondents' perceptions of decreasing snowfall in Lower Mustang by agriculture practiced

Perception	Level of Agreement		Agricultural Practices							Total
			C, LR	C, AF	C,VF	C.AF, VF	C,LR,VF	LR, AF,VF	C,LR, AF, VF	
Snowfall has decreas-ed in the last 30-40 years	Strongly Agree	Count	6	8	28	41	32	2	33	150
		% of respondents who strongly agree	4.0%	5.3%	18.7 %	27.3 %	21.3 %	1.3%	22.0 %	100.0%
		% agricultural practice group	85.7 %	66.7 %	77.8 %	70.7 %	72.7 %	100.0 %	80.5 %	75.0 %
	Agree	Count	1	4	8	17	12	0	8	50
		% of respondents who agree	2.0%	8.0%	16.0 %	34.0 %	24.0 %	0.0%	16.0 %	100.0%
		% agricultural practice group	14.3 %	33.3 %	22.2 %	29.3 %	27.3 %	0.0%	19.5 %	25.0 %
Total		Count	7	12	36	58	44	2	41	200
		% of Total	3.50 %	6.00 %	18.00 %	29.00 %	22.00%	1.00%	20.50 %	100.%
		C = Cereals, LR = Livestock Ranching, AF = Apple Farming, VF = Vegetable Farming								

5.1. Perception of Climate-change Impacts on Agriculture

Farmers' perceptions of the impacts of climate change on agriculture, in both positive and negative terms, influence adaptation planning and coping strategies to mitigate against loss and to take advantage of emerging opportunities. To understand the major impacts experienced among them, farmers were asked to select from a list of impacts that might have impacted them. The key responses and other information gleaned from focus-group discussions and key-informant interviews are discussed below. The perceived impacts of climate change are categorized as positive and negative impacts, and these are also described below.

5.4.1. Perceived Agricultural Benefits of Climate Change

Ninety-nine percent of farmers expressed the view that Lower Mustang has diversified its vegetable farming in the last 30-40 years, and they felt that this indicates that climate change is having beneficial impacts on the region's agriculture, particularly its vegetables (Figure 17). Vegetables are normally grown at elevations of 3000 to 3800 (m asl). In the past, Lower Mustang vegetable production was limited to potatoes and cabbage. A warming climate has enabled the production of tomatoes, cauliflower, carrots, peas, cucumbers, beans, and many other vegetables in Lower Mustang. They are regarded as the cash-crops of the region (a complete list of vegetables grown in Lower Mustang developed from the surveys, interviews, and discussions can be found in Appendix 4). By 2018, the diversity of vegetables in Lower Mustang had considerably increased as a result of the development of new road connections that began in 2006, linking Lower Mustang with nearby districts and major Nepalese cities like Pokhara and Kathmandu. In addition to an increasingly favorable climate to grow vegetables, access enhanced farmers' markets and provided opportunities to explore new varieties of vegetables; it motivated them to diversify their vegetable crops.

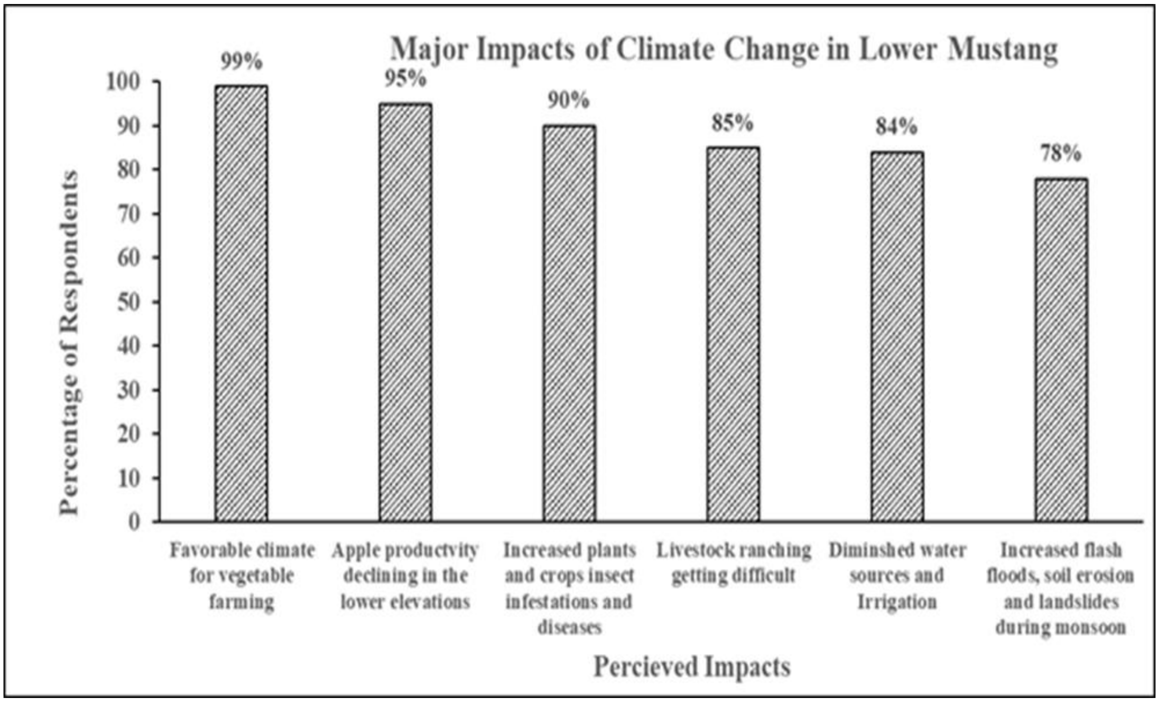

Figure 17. Respondents' perceived impacts of climate change in Lower Mustang

Another positive impact of climate change voiced by focus-group participants is an increasingly positive attitude about adaptation and improved adaptive behaviors among farmers. Farmers are now more concerned about climate change and its impacts in agriculture, and they are learning to adapt in their own ways and are changing their relationships with their environments. One example has been observed on the banks of the Kali Gandaki River in Lower Mustang, where the public, in concert with women's groups, has started planting trees (a local species of pine) to stop soil erosion and to prevent landslides; their work is complementing the efforts of governmental agencies.

5.4.2. Perceived Negative Agricultural Impacts of Climate Change

The farmers' survey also indicates that there are several changes that may have negatively impacted the Lower Mustang agriculture (Figure 17). Ninety-five percent of farmers have perceived a decline in apple production at lower elevations of Lower Mustang. Ninety percent believe that insect infestations and plant diseases are increasing.

Eighty-five percent believe that ranching is becoming more difficult. Eighty-four percent perceived that water supplies were diminishing, and irrigation water was less abundant. And 78% believe that flash floods are more frequent and more severe, that soil erosion is intensifying, and that there are more landslides during monsoon (Figure 17). These impacts will be discussed further below relative to climate-change indicators; aspects like rising annual temperatures, fluctuating rainfall, and decreasing snowfall in Lower Mustang.

5.4.2.1. Perceived Impacts of Rising Temperature in Communities

To evaluate the accuracy of farmers' perceptions of changing patterns of temperature in Lower Mustang, the actual average monthly maximum and minimum temperatures of Jomsom and Marpha meteorological stations in Lower Mustang were determined using data collected from the Department of Hydrology and Meteorology, Nepal. After discerning the trends of the average maximum and minimum temperatures from 1987 to 2017, it can be concluded that the belief that temperatures have slowly increased over the last 30-40 years is confirmed by the empirical record (Figures 18 and 19).

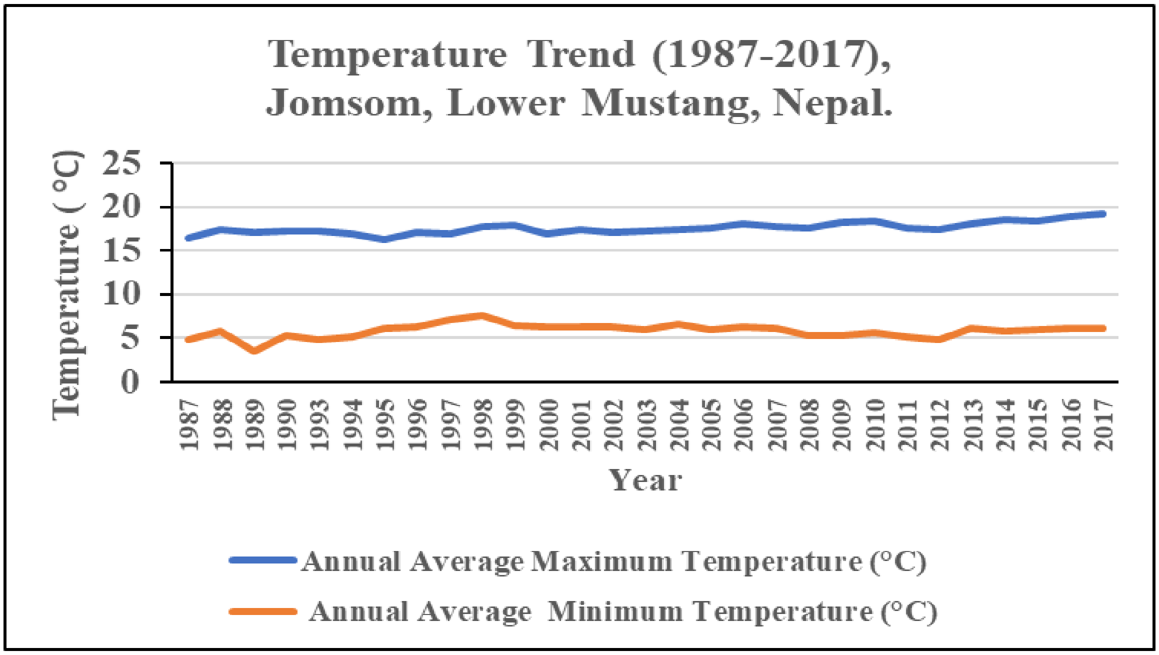

Figure 18. Temperature graph (1987-2017) for Jomsom, Lower Mustang (Data Source: Department of Hydrology and Meteorology, Nepal)

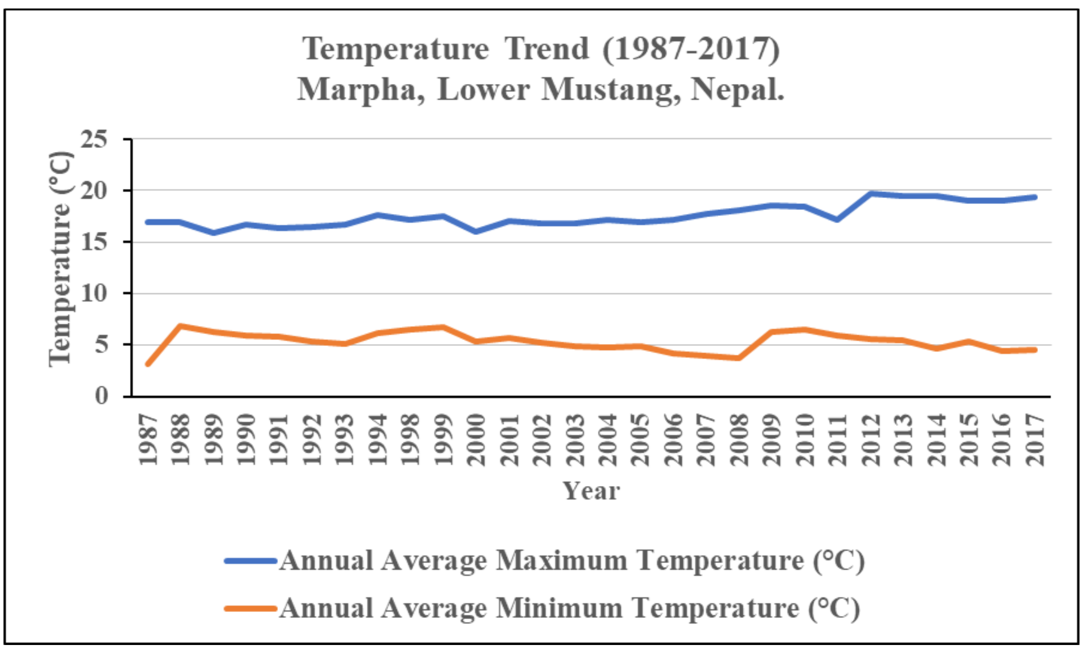

Figure 19. Temperature graph (1987-2017) in Marpha, Lower Mustang. (Data Source: Department of Hydrology and Meteorology, Nepal)

The five-year temperature average in Jomsom increased from 1987 to 2001: from 17.1°C to 17.3°C. The five-year average increased from 17.5°C in the 2002 to 2006 period to 18.5°C during the 2012 to 2017 period (Table 17). The standard deviation for maximum temperatures ranges from 0.2 to 0.44, and the coefficient of variation (cV) ranges from 2.9% to 17%, indicating that the variation of maximum temperatures during the study period was not significant. Similarly, the 5-year average of minimum temperature rose from 4.8°C in the 1987 to 1991 period to 6.7°C in the 1997 to 2001 period. It decreased a bit over the next decade but increased to 6.06 °C by the 2012 to 2017 period. Empirically, the trend of average of maximum temperature matches with Lower Mustang farmers' perceptions.

Table 17. Jomsom temperature trend in five-year intervals (1987-2017)

Year	Average Temperature °C (Maximum)	Standard Deviation (σ)	Coefficient of Variation (cV)	Average Temperature °C (Minimum)	Standard Deviation (σ)	Coefficient of Variation (cV)
1987-1991	17.1	0.34	0.022	4.8	0.75	0.17
1992-1996	17.2	0.44	0.029	5.6	0.82	0.14
1997-2001	17.3	0.32	0.02	6.7	0.16	0.029
2002-2006	17.5	0.2	0.013	6.25	0.4	0.073
2007-2011	17.9	0.34	0.021	5.54	0.49	0.1
2012-2017	18.4	0.31	0.019	6.06	0.14	0.027

The five-year averages of maximum temperatures in Marpha average rose by 0.5°C from 1987 to 2001 and have since increased by almost 2°C by the 2012 to 2017 period. The standard deviation of the 5-year interval maximum mean temperatures was 0.49 by 2001 but became more variable over the next 3 periods. The coefficient of variation of the maximum-temperature averages ranged from 2 % (1987-1991) to 4.9%

(2012-2017), a statistically insignificant amount. However, farmers perceptions of rising temperature align with the 5-year trends (Table 18).

The impacts of the changing climates as perceived by local farmers, focus-group participants, and key informants are discussed below.

The most apparent impact of warming of climate in Lower Mustang seems to be felt in apple farming. With increasing temperatures, the lower elevations of Lower Mustang are slowly becoming inhospitable for apple orchards. Therefore, farmers are slowly shifting apple farming to higher elevations (Figure 17). Apple farmers believe

Table 18: Marpha temperature trend in five-year intervals (1987-2017)

Year	Average Temperature °C (Maximum)	Standard Deviation (σ)	Coefficient of Variation (cV)	Average Temperature °C (Minimum)	Standard Deviation (σ)	Coefficient of Variation (cV)
1987-1991	16.5	0.4	0.02	5.5	1.28	0.26
1992-1996	16.9	0.48	0.035	5.4	0.43	0.096
1997-2001	17	0.49	0.032	5.8	0.62	0.11
2002-2006	17.1	0.32	0.021	4.5	0.4	0.1
2007-2011	18.3	0.81	0.049	5.5	1	0.2
2012-2017	18.98	0.5	0.03	4.7	0.56	0.12

that rising temperatures have promoted infestations by insects and diseases, and that these have degraded the quality and size of apples.

One of the key informants, a 73-year-old farmer, said:

> *The common insects and diseases in Lower Mustang driven by warming climate are the Zizina Moth, Woolly Apkid, Paply Bark (fungus) Scab, Root Rot, Uwa-Root Rot (virus). These diseases and infestations have not only affected apple farming but also cereal crops and vegetables in the region. We are scared that there may not be apple farming in Lower Mustang 20-30 years down the road.*

Rising temperatures in Lower Mustang are also impacting water resource. In this regard, a 57-year old key informant working for the office of agriculture and extension services told me:

> *About 20 to 30 years ago, there were several water springs and streams along the Kali Gandaki River corridor in Lower Mustang that would infiltrate moisture into nearby agricultural lands. But in the recent decade, due to the rise in temperature, almost all these water springs and streams have dried and if this process continues, Lower Mustang might have to face long spells of drought in the future*.

Rising temperatures are also perceived to be impacting livestock ranching, which is becoming increasingly difficult in Lower Mustang. One impact is heat stress in cattle. A key informant working for the district's livestock services said:

> *During summer months, cattle – such as Jhopa* (a cross of yak and local cow), *cows and mountain goats – are frequently suffering from stomatitis* (a viral disease that affects lips, gums, tongue, and/or dental pad with appearances of blisters on the inner surfaces of the mouth) *in recent years.*

The other impacts include decrease in grazing lands and scarcity of grass. These concerns were also expressed by survey and focus-group participants. Focus-group discussions also revealed that heat-stress has also increased the number of abortions occurring in local *Lulu* cows over the last two decades.

5.4.2.2. Perceived impacts of changing patterns of rainfall.

To evaluate the accuracy of farmers' perception of rainfall patterns in Lower Mustang, rainfall data from Jomsom and Marpha meteorological stations were acquired from Nepal's Department of Hydrology and Meteorology. After graphing rainfall amounts from 1987 through 2017, it is apparent that farmers' perceptions of rainfall (that the annual patterns are inconsistent, unpredictable, and have been changing over the last 30-40 years) is borne out by the empirical data (Figure 20 and Figure 21).

The annual rainfall amounts in Jomsom averaged in six five-year increments reveals that the amount of rainfall in the last five year (2012-2017) has increased up to 358.8 mm, but rainfall has been inconsistent during the year period, and this is reflected in the coefficients of variation for the six periods which ranged from 11 to 38% (Table 19).

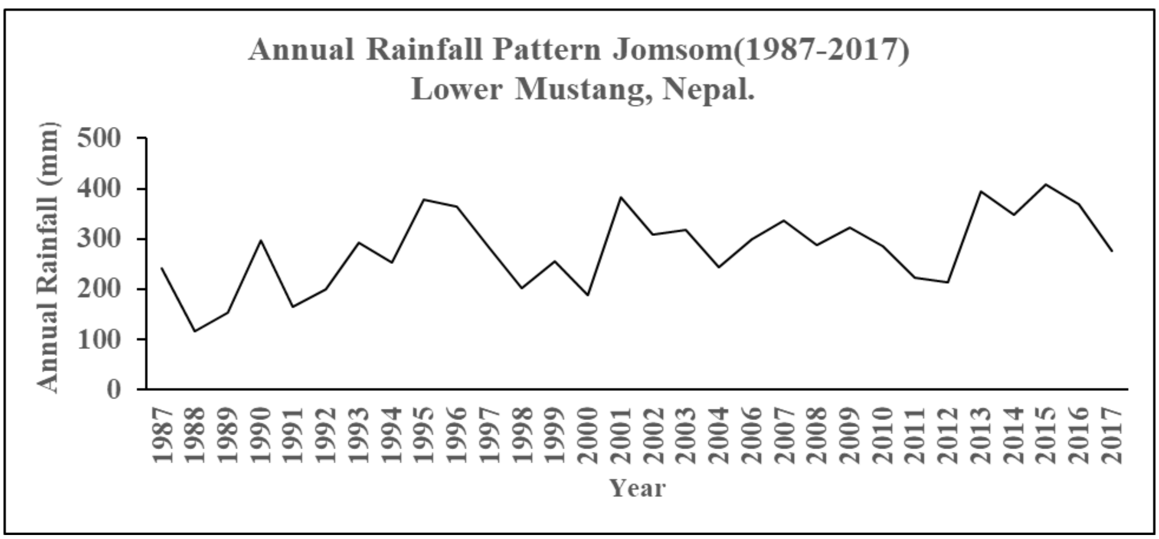

Figure 20. Rainfall in Jomsom, Lower Mustang (1987-2017) (Data Source: Department of Hydrology and Meteorology, Nepal)

The five-year average annual rainfall record in Marpha indicates that five-year rainfall totals have increased from 394 to 419 mm in 1997-2001. The standard deviation **(σ)** is as great as 106 but rainfall has been inconsistent over the study period. The variation from period to period was great as indicated by cV, which ranged from 15 to 28% (Table 20).

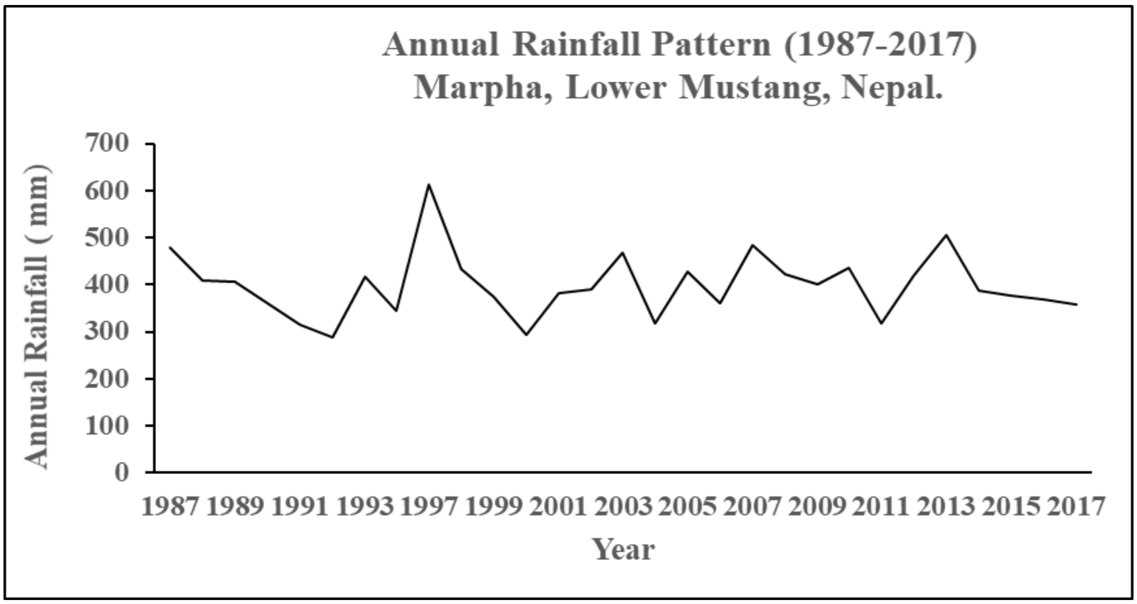

Figure 21. Rainfall in Marpha, Lower Mustang (1987-2017) (Data Source: Department of Hydrology and Meteorology, Nepal)

Table 19. Jomsom five-year interval rainfall trend (1987-2017)

Year	Five-year Average Rainfall (mm)	Standard Deviation (σ)	Coefficient of Variation (cV)
1987-1991	194.2	65.75	0.38
1992-1996	297.6	67.3	0.25
1997-2001	261.6	69.23	0.29
2002-2006	335.5	31.5	0.11
2007-2011	266.54	41.3	0.17
2012-2017	358.8	46.5	0.14

Table 20. Marpha five-year interval rainfall trend (1987-2017)

Year	Five-year Interval Average Rainfall (mm)	Standard Deviation (σ)	Coefficient of Variation (cV)
1987-1991	394.2	54.8	0.15
1992-1996	349.4	52.8	0.18
1997-2001	418.9	106.6	0.28
2002-2006	392.4	52.6	0.15
2007-2011	412.32	54.12	0.14
2012-2017	402.2	49.8	0.13

The implications of the precipitation trends are clear from the assessment of these empirical data (Tables 20 and 21). Temporal patterns of precipitation appear from the trends to be chaotic and unpredictable. Farmers' perceptions that rainfall has varied quite widely over the last 30-40 years in Lower Mustang is reflected in the rainfall record.

There are numerous impacts on agriculture caused by the irregular and fluctuating rainfall in Lower Mustang. Most of the survey respondents, key informants, and focus-group participants agree that unpredictable intense downpours are generating an increasing number of flash floods every year especially during the monsoon (May through July). Flash floods have damaged irrigation canals and have damaged cereal crops, apple harvests, and vegetable yields. One key informant working at Soil Conservation Office, described on event:

> *In July 2015, a very intense rainstorm in Lower Mustang induced a very strong flash flood and damaged irrigational canal, cereal crops and vegetables, many farmers suffered a big loss.*

A participant in a focus group added: "these flash floods eroded topsoil, caused landslides and damaged agricultural lands and constrain livestock movements."

Another form of precipitation that often accompanies heavy rainfall in Lower Mustang is hail. A focus-group member described the problem:

> *Before fifteen to twenty years ago, we never experienced hail. In the recent years, we frequently experience hail during monsoons; they have damaged our crops and vegetables, damaged flowering apple trees, and affected other agriculture activities in Lower Mustang.*

5.4.2.3. Perceived impacts of decreasing snowfall in Lower Mustang.

Survey participants, key informants, and focus-group discussants agree that snowfall has dramatically decreased in Lower Mustang over the last 30 to 40 years. A 75-year-old survey participant said:

> *Three to four decades back, they used to have snow accumulations as high as 1 feel now it seems like a fairy tale. The snowfall now is very low and unpredictable in terms of time and amount.*

The trend of decreasing snowfall has affected the quality and productivity of apples. One apple farmer, a key informant, stated:

The amount of moisture provided by snowfall is insufficient to meet the needs of the trees during the initial stage apple fruit growth during winter months.

Focus-group discussion also revealed a perception that decreasing snowfall seems to have also affected the growth of grass on grazing lands during winter months in Lower Mustang.

5.2. Summary

Most of the farmers in Lower Mustang believe that there has been a slow rise in temperature, fluctuations in rainfall amounts and unpredictable patterns, and decreasing snowfall amounts in Lower Mustang over the last 30-40 years. These perceptions tend to align with temperature and rainfall data collected at Jomsom and Marpha between 1987 and 2017. Marpha farmers strongly agreed with the statement that temperatures have risen, and the rate of agreement was greater than for any other community. Male farmers were more certain of this fact than were females. The middle-aged and elderly (people older than 36 years) were more certain that were younger farmers (ages 21 to 35). With regard to perception of fluctuating rainfall patterns in Lower Mustang, the most convinced of all communities were the same groups: the farmers of Marpha, male farmers, and middle-aged and elderly farmers. However, there were no significant differences in perception between farmers grouped by agricultural practices concerning a changing pattern of rainfall. In terms of perceptions of diminishing snowfall across Lower Mustang, farmers in Jomsom were more certain than in other communities, males were more strongly convinced, and the elderly (older than 51 years of age) were most certain of this fact. Farmers producing cereals, apples, and vegetables were the most strongly convinced of diminishing snowfall.

Lower Mustang's farmers have observed the impacts of climate change. The most significant impact they have experienced are the increasingly favorable conditions for growing vegetables. Negative effects observed by farmers include declining production of apples in lower elevations, increasing frequency of infestations of insect pests, greater problems with diseases in plants and livestock, and diminishing water supplies due to warming. Fluctuating rainfall (irregular timing of storms and sometimes significantly increased rainfall rates in storms) has produced a rise in flash-flood frequency, soil erosion, landslides, and have damaged irrigation canals. Decreasing snowfall has primarily affected apple production across the region.

The next chapter discusses farmers concerns of the threats and impacts of climate change to the agricultural practices of Lower Mustang. Adaptation and mitigation efforts to prepare for, adjust to, and minimize damages from climate change will also be discussed. As will an assessment of the potential opportunities from and barriers to adapting to climate change.

6. THE LEVELS OF CONCERN, ADAPTATION, AND THE OPPORTUNITIES AND BARRIERS TO CHANGING AGRICULTURE IN LOWER MUSTANG

This chapter discusses the results of the surveys, focus groups, and interviews that pertain to farmers' concerns about climate change, their adaptation initiatives, and the opportunities for and barriers against change in agriculture practices in Lower Mustang. Each of these themes will be examined in terms of farmers' demographic characteristics and agricultural practices.

6.1. Concerns About the Impacts of Climate Change

To understand the concerns of farmers and their perceptions of the threats to agriculture of climate change in Lower Mustang, questions were posed to survey participants using a five-point Likert scale (Appendix 2). Approximately 27% were highly concerned and felt highly threatened, 57% were concerned and threatened, 12% were neutral, and 4 % were not concerned and not threatened. Responses in the interviews of key informants and focus-group discussions helped to analyze this distribution: the higher levels of concern and increasing threat are responses to the perceptions of the recent past – decreasing quality of apples, lowering productivity of orchards, increasing frequency and severity of disease outbreaks and insect infestations, and increasing flash flooding during monsoon. The most important concerns were about apple growing: a key informant who works for the Marpha Horticultural Center indicated that the lower-elevation communities (like Lete and Ghasa at 2200 m asl) used to have many apple farms in 1990s, but today apple farming is nearly extinct in these areas primarily due to warming that has occurred over the last four decades. Further analysis within sex, age, income, and level-of-education cohorts, and in terms of agricultural practices are discussed below. The results of the non-parametric chi-square test results are assessed to identify the statistically significant relationships between feelings of concern and these categories.

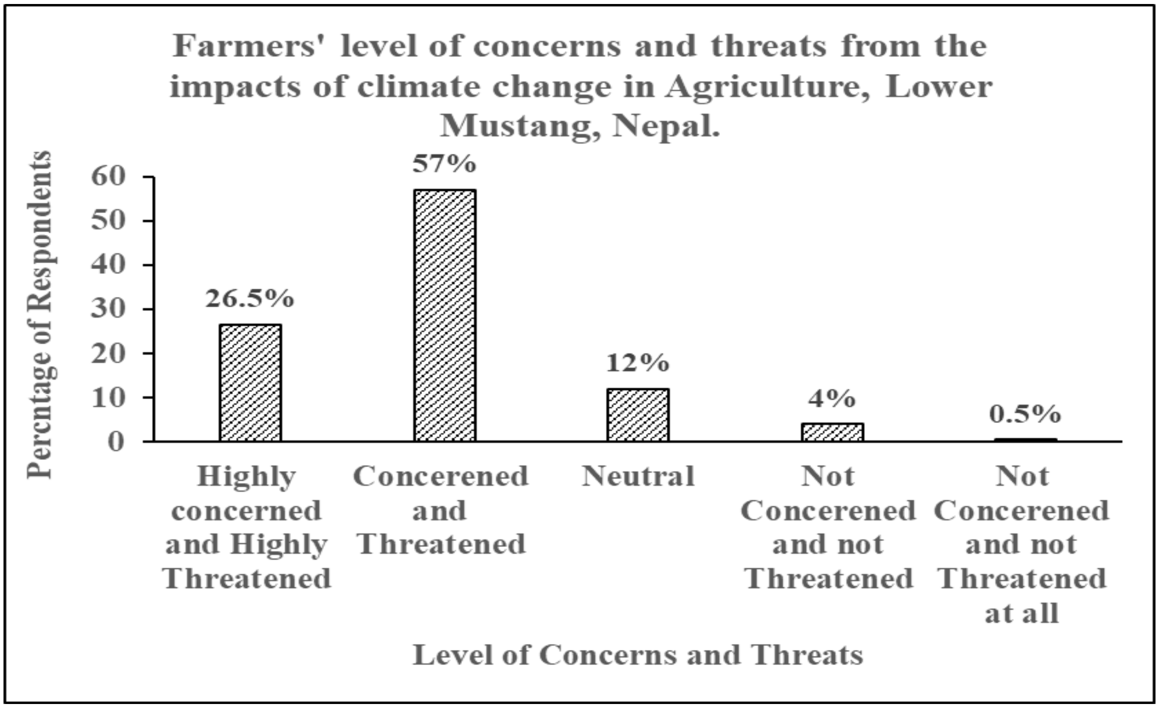

Figure 22. Farmers' level of concerns and threats from the impacts of climate change in agriculture

6.1.1. Concerns About the Impacts of Climate Change by Sex.

The distribution of farmers' levels of concerns about the impacts of climate change over the last 30-40 years were differentiated by respondents' sex. Of those who were "highly concerned and highly threatened," more were female than male (Table 17). Similarly, females comprised a larger portion of the "concerned and threatened" group (Table 17). One can conclude that the women surveyed are slightly more concerned and threatened than were the men. The chi-square test, however, showed that the proportional differences were not significant (p=.566) (Table 21 and Appendix 1). Therefore, men's and women's levels of concerns and perception of threat from climate change were statistically speaking no different (Table 21).

Table 21. The distribution of respondents' level of concerns and threat from the impact of climate change by the categories of sex

Level of Concern and Threat		Sex		Total
		Male	Female	
Highly Concerned and Highly Threatened	Count	24	29	53
	% within level of concern and threat	45.30%	54.70%	100.00%
Concerned/Threatened	Count	54	60	114
	% within level of concern and threat	47.40%	52.60%	100.00%
Neutral	Count	14	10	24
	% within level of concern and threat	58.30%	41.70%	100.00%
Not Concerned/Not Threatened	Count	5	3	8
	% within level of concern/threat	62.50%	37.50%	100.00%
Not Concerned and Not threatened at all	Count	1	0	1
	% within Level of concern and Threat	100	0.00%	100.00%
Total	Count	100	100	200
	% of sample of each sex	50.00%	50.00%	100.00%
	% of Total	50.00%	50.00%	100.00%

6.1.2. Concerns About the Impacts of Climate Change by Age

Farmers' responses to level of concerns and threats by age group were similarly analyzed. The component of the groups of respondents who were "highly concerned and highly threatened" and "concerned and threatened" that is the largest is the middle-aged group (ages 36 to 50): 32.1% and 35.1%, respectively (Table 22). However, the youngest

Table 22. The distribution of respondents' level of concerns and threat from the impact of climate change by age

Level of Concern and Threat		Respondents' Age Group				Total
		21-35 years	36-50 years	51-65 years	66 years and above	
Highly concerned and Highly Threatened	Count	16	17	11	9	53
	% within Level of concern and Threat	30.20%	32.10%	20.80%	17.00%	100.00%
Concerned and threatened	Count	22	40	33	19	114
	% within Level of concern and Threat	19.30%	35.10%	28.90%	16.70%	100.00%
Neutral	Count	4	11	3	6	24
	% within Level of concern and threat	16.70%	45.80%	12.50%	25.00%	100.00%
Not Concerned and Not Threatened	Count	4	3	0	1	8
	% within level of concern and Threat	50.00%	37.50%	0.00%	12.50%	100.00%
Not Concerned and threatened at all	Count	1	0	0	0	1
	% within level of concern and Threat	100%	0.00%	0.00%	0.00%	100.00%
Total	Count	47	71	47	35	200
	% of sample within each age group	23.50%	35.50%	23.50%	17.50%	100.00%

age group (ages 21 to 35) comprised the largest of those who were "not concerned and not threatened" and "not concerned and not threatened at all," but the number of farmers in those categories was very small (Table 22). Chi-Square results indicate that there is no statistical significance to these within-group differences (p=.266) (Table 22 and

Appendix 3). Thus, age is not an influence on the expressions of concern and perception of threat among those surveyed.

6.1.3. Concerns About the Impacts of Climate Change by Income.

Income differences were analyzed in the same fashion. The results reveal that the poorest two groups (earning less than US $1,999) and the middle-income families (earning between US $4,000 and $4,999 annually) were more highly concerned and felt more threatened than they were concerned and threatened by climate change (Table 23. While the other lower-middle income and upper income groups had greater proportions of their sample sets in the "concerned and threatened" category. Chi-square results show that there is no statistically significant difference between the levels of concern and perceived threat and the income groups (p=.597) (Table 23 and Appendix 1). Income is not a factor that is directly related to perception of climate change threat.

6.1.4. Concerns About the Impacts of Climate Change by Education Level

Education-levels were similarly discerned to evaluate their relationship to concern and perception of threat posed by climate-change impacts. The majority of farmers in Lower Mustang who were highly concerned and highly threatened by climate change were those farmers with secondary education (Table 24). Similarly, this group comprised the largest portion of the "concerned and threatened" and "neutral" groups. Chi-Square results indicate, however, that there is no statistical significance between the views of farmers at different levels of educational attainment (p=.850) (Table 24 and Appendix 1). Education also does not have a statistically predictive role in explaining farmers' levels

Table 23. The distribution of respondents' level of concerns and threat from the impact of climate change by income

Respondents' Level of Concern and Threat		Annual income from Agriculture						Total
		Below US $1000	US $1000-1999	US $ 2000-2999	US $ 3000-3999	US $ 4000-4999	US $ 5000 and above	
Highly Concerned and Threatened	Count	5	10	7	10	12	9	53
	% within Level of concern and Threat	9.40%	18.90%	13.20%	18.90%	22.60%	17.00%	100.00%
Concerned/ Threatened	Count	6	16	21	26	21	24	114
	%within Level of concern and Threat	5.30%	14.00%	18.40%	22.80%	18.40%	21.10%	100.00%
Neutral	Count	1	6	7	4	5	1	24
	% within Level of concern and Threat	4.20%	25.00%	29.20%	16.70%	20.80%	4.20%	100.00%
Not Concerned/Not Threatened	Count	1	0	3	2	1	1	8
	% within Level of concern and Threat	12.50%	0.00%	37.50%	25.00%	12.50%	12.50%	100.00%
Not Concerned and Not Threatened at all.	Count	0	1	0	0	0	0	1
	% within Level of concern and threat	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Total	Count	13	33	38	42	39	35	200
	% of sample within each income group	6.50%	16.50%	19.00%	21.00%	19.50%	17.50%	100.00%

of concern with climate change, and it doesn't explain feelings of fear of the consequences.

Table 24. The distribution of respondents' level of concerns and threat from the impact of climate change by highest educational level

Level of concern and threat		Respondents' Highest Level of Education				Total
		No formal Education	Primary	Secondary	Undergraduate and above	
Highly concerned and Highly Threatened	Count	12	9	28	4	53
	% within Level of concern and threat	22.6%	17.0%	52.8%	7.5%	100.0%
Concerned and Threatened	Count	34	27	47	6	114
	% within Level of concern and threat	29.8%	23.7%	41.2%	5.3%	100.0%
Neutral	Count	8	5	9	2	24
	% within level of concern and threat	32.70%	16.40%	47.30%	3.60%	100.00%
Not Concerned/Not Threatened	Count	3	3	2	0	8
	% within level of concern and threat	37.5%	37.5%	25.0%	0.0%	100.0%
Not Concerned and Not Threatened at all	Count	0	0	1	0	1
	% within level of concern and threat	0.0%	0.0%	100.0%	0.0%	100.0%
Total	Count	47	71	47	35	200
	% of sample in each group	28.5%	22.0%	43.5%	6.0%	1 00.0%

6.1.5. Concerns About the Impacts of Climate Change by Agricultural Practiced.

Finally, the perceptions that produce concern and the feeling of being threatened were compared by groupings of farmers producing specific sets of products. The tabulation results indicate that the largest group of farmers who were "highly concerned and highly threatened" was comprised of those who grew cereals, apples, livestock, and vegetables. The largest group of those who were "concerned and threatened" were those who grew cereals, apples, and vegetables (Table 25). Chi-square testing indicates that there are statistically significant differences in their level of concerns and threats among agricultural-practice groups (p=.002) (Table 25 and Appendix 1). Thus, it appears that the types of agriculture practiced in Lower Mustang influence the perceptions of threat and levels of concern.

6.2. Agricultural Adaptation Efforts in Lower Mustang

Around the world, adaptation policies and strategies are being implemented to reduce the anticipated impacts of climate change. In the agricultural sector, it is believed that these strategies become more effective, and consistent with farmers' preferences, if farmers proactively participate in public meetings and workshops especially during the pre-implementation phase of such strategies (Khanal et al., 2018).

Before considering the adaptation strategies and initiatives of key farmers in Lower Mustang, it is important to discuss farmers' awareness of and participation in public meetings and workshops on climate change adaptation strategies in agriculture. Two dichotomous (yes/no) questions were posed to farmers: Are you aware of any public meetings or workshops conducted by government and non-government agencies? and

Table 25. The distribution of respondents' concern and threat by their agricultural practices

Level of Concern and Threat		Agricultural Practices							Total
		C, LR	C, AF	C,VF	C.AF, VF	C,LR, VF	LR, AF,VF	C,LR, AF, VF	
Highly Concerned and Highly Threatened	Count	1	3	7	13	13	1	15	53
	% within concern and Threat	1.9	5.7	13.2	24.5	24.5	1.9	28.3	100.0
Concerned and Threatened	Count	4	4	21	40	27	1	17	114
	% within Level of concern and Threat	3.5	3.5	18.4	35.1	23.7	0.9	14.9	100
Neutral	Count	2	1	5	4	3	0	9	24
	% within Level of concern/ Threat	8.3	4.2	20.8	16.7	12.5	0.0	37.5	100.0
Not Concerned and Not Threatened	Count	0	4	2	1	1	0	0	8
	% within Level of concern and Threat	0.0	50.0	25.0	12.5	12.5	0.0	0.0	100.0
Not Concerned and Not threatened at all	Count	0	0	1	0	0	0	0	1
	% within Level of concern and Threat	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0
Total	Count	7	12	36	58	44	2	41	200
	% within concern and Threat	3.5	6.0	18.0	29.0	22.0	1.0	20.5	100.0
C = Cereals, LR = Livestock Ranching, AF = Apple Farming, VF = Vegetable Farming									

Have you attended any public meetings or workshops conducted by government and non-government agencies? About 54% of the farmers stated that they were aware of governmental and non-governmental meetings or workshops in their community. But only 47% of the farmers attended meetings or workshops. Among those who attended public meetings or workshops 52% were male and 48% female. Majority of participants informed that these meetings were held in convenient locations i.e. town halls. They also informed that the description about the aim of the meeting program was easy to comprehend. Likewise, Farmers participating in meetings informed that the descriptions of the potential impacts of climate change in the agriculture was somewhat clear however, the level of discussion on issues and policy alternatives to agrarian adaptation across were discussed less than desired. These results suggest that there should be out-reach efforts to inform farmers of the availability of these opportunities, and efforts to promote attendance at meetings that can help farmers minimize the expected impacts of climate change in their agricultural activities. Despite low levels of participation, farmers' in Lower Mustang have established adaptation initiatives and developed coping strategies.

6.2.1. Pesticide and Fertilizer Use in Lower Mustang.

Most (88%) of the farmers in Lower Mustang have been using various kinds of pesticides and inorganic fertilizers to contain insect infestations and diseases in cereals, vegetables and apple farming as their coping mechanism (Figure 23). The most common pesticides used for cereals and vegetables are deltamethrin and carbofuran, and dimethoate (Rogor), cypermethrin (Super-cyper) and the inorganic fertilizer urea for apples as recommended by the Office of Agricultural Extension services (this was stated by an agricultural-extension officer, one of the key informants). Farmers believe that these pesticides are only a temporary solution. The agricultural extension officer said that they have begun to develop an integrated pest management (IPM) system as a more sustainable approach. One example of IPM system was described for apple trees: Identify the pest problem as either a single plant-multiple pest syndrome or a single plant-single pest syndrome, then follow these four steps.

1. Inspect farms to screen for infestations of apple plants;
2. Inspect susceptible plants daily, inform farmers of any infestations or disease problems, and communicate methods of controlling problems.
3. Determine whether there are any natural enemies or natural predators on the farms that can be used to control infestations: for example, the ladybird beetle (family *Coccinellidae*) is a predator of many insects.
4. If the infestation is beyond control, insecticides (like Rogor and Supercyper) can be used as a last resort on affected apple plants or on the entire farms to control problems like apple scab. These steps have effectively controlled pests (according to the agricultural extension officer in Lower Mustang).

6.2.2. Shifting Apple Farming to Higher Elevations.

The most common apple varieties grown in Lower Mustang are: Royal Delicious, Richa Red Delicious, Golden Delicious, Royal Delicious and Red Gold (Figure 24). A warming climate has promoted unfavorable conditions for the growth of

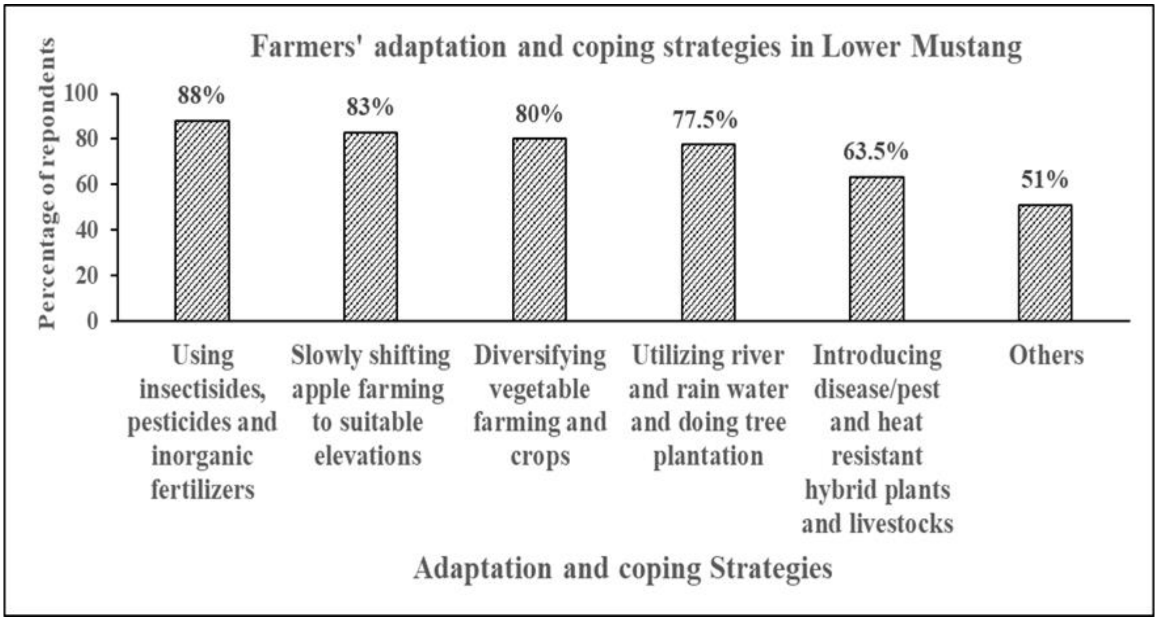

Figure 23. Farmers' adaptation and coping strategies in Lower Mustang

these varieties and the productivity have declined. Warming has increased insect and disease infestations and has also decreased snowfall at lower elevations. About 83% of farmers believe that apple farming in Lower Mustang is slowly "elevating" (shifting to higher elevations where the climate conditions seem to be favorable – i.e., cooler summers and winter snowfall is comparatively higher). A key informant mentioned:

> *As an adaptation strategy, initiative or a collaborative effort, farmers in Lower Mustang are in the process of forming an "Eco-grow Initiative" through a cooperative in Jomsom, where they expect to grow as many as 16,000 apple plants on 20 hectares of land within next 2 or 3 years. This is on leased lands provided by the government near the base of Nilgiris Mountain.*

Focus-group participants also indicated similar projects were underway elsewhere: farmers in Kagbeni have a similar project known as "Hyata Thang," which

Figure 24. Apple farm in Lower Mustang (Source: Upendra Bom)

aims to grow apples on 20 to 30 hectares of land; and Marpha has a project known as "Marpha Shyang Fola," which involves new apple orchards on 5 to 6 hectares.

6.2.3. Diversification of Crops and Vegetable Farming.

About 20 to 30 years ago, Lower Mustang agriculture was limited to growing potatoes and cabbage as their main vegetable crops. As the region's climate was warming and is favoring the growth of other vegetables, about 80% of the farmers surveyed indicated that they are diversifying their vegetable crops for their personal use and for sale. Among the notable vegetables that are now grown in Lower Mustang are hybrids of tomato, cauliflower (Figure 25), carrot, green pea, cucumber (Figure 26), onion, bean, and other leafy green vegetable plants (e.g., spinach and green cabbage (Figure 27). These vegetables are viewed as the new cash crops of the region, and they have become alternative sources of income for both small- and large-holding farmers. To meet off-season demands, farmers have greenhouses (Figure 28). In addition to regular naked barley and buckwheat, farmers have also begun to grow maize and green mustard (Figure 29) in some parts of Lower Mustang in order to discourage weed and promote grasses in agricultural fields for livestock fodder. This is an alternative strategy to combat the decline of natural grazing lands and meadows in Lower Mustang.

Figure 25. Cauliflower harvested in Jomsom, Lower Mustang (Photo: Upendra Bom)

Figure 26. Cucumber plants in Jomsom, Lower Mustang (Photo: Upendra Bom)

Figure 27. Hybrid cabbage in Tukuche, Lower Mustang (Photo: Upendra Bom)

Figure 28. Greenhouse in Marpha, Lower Mustang (Photo: Upendra Bom)

Figure 29. Mustard in Marpha, Lower Mustang (Photo: Upendra Bom)

6.2.4. Irrigation and Tree Plantations

With diminishing water supplies and decreasing availability of irrigation water, about 78% of survey respondents expressed the need to use water from Kali Gandaki and to harvest rain as a long-term adaptation strategy. Some focus-group discussants said:

Some farmers who can afford to are already boring water from the main Kali Gandaki River to irrigate agricultural farms and apple orchards.

Likewise, a key-informant apple farmer noted:

There was no need to bore water from the Kali Gandaki River until the last decade, since streams and creeks in the upper valleys in most parts of Lower Mustang had enough water to irrigate down-stream apple and vegetables farms. But now water from these sources is slowly decreasing and irrigation canals are frequently damaged by flashfloods and landslides during monsoon; farmers are boring water from the Kali Gandaki River in some parts of Lower Mustang to meet their water demands.

Since boring water from the Kali Gandaki River is very expensive, only rich farmers can do it. Therefore, most farmers are turning to rain-water collection ponds (Figure 30), collected water can be used especially during the drier winter and spring seasons when precipitation is comparatively low. Some key informants also stated that drip irrigation systems can also be introduced and experimented with to irrigate vegetables and apples farms across Lower Mustang. Farmers have also started planting trees on the banks of the Kali Gandaki River as a part of their adaptation strategy to create a greener environment that may help control soil erosion and landslides (Figure

31), in addition to gabion retaining walls along riverbanks and in the valleys. A key informant said:

> *The Office of Soil Conservation in coordination with local municipality and Annapurna Conservation Project Area (ACAP) have introduced a new approach to environment conservation. We provide some incentives to those who join their tree plantation efforts in proportion to the number of saplings they plant.*

Various mother-groups, youth clubs and local farmers have committed to the campaign; now previously bare hills are boasting lush green cover. Officers believe that the project will help to control soil erosion and eventually enable locals to earn livelihoods from forest resources.

Figure 30. Snow and rain-water collection pond in Kagbeni, Lower Mustang (Photo: Upendra Bom)

Figure 31. Pine tree plantation (local name "Bhotey Sallo") along the bank of the Kali Gandaki River, Lower Mustang (Photo: Upendra Bom)

6.2.5. Introduction of hybrid plants and livestock.

Farmers in Lower Mustang have begun introducing hybrids of cabbage and potatoes in Lower Mustang as an adaptation strategy to combat the impacts of warming climate. One of the key informants, an apple farmer, said that farmers are also using hybrid apple seeds and incorporating grafting techniques in apple trees to increase the taste of the fruit and to enhance the trees' productivity. Farmers have also considered planting apple varieties that would need less chilling to ripen, that would mature earlier, that would be drought tolerant, and varieties that are more resistant to infestations and diseases. Farmers are also rearing hybrid Jersey cows (Figure 32) to replace local "Lulu" cows to meet their dairy needs.

Figure 32. Jersey cow shed in Kagbeni, Lower Mustang (Photo: Upendra Bom)

6.2.6. Mothers' Group and adaptation activities in Lower Mustang

Mothers' groups (locally known as "Aama Samuha"; "Aama" means mother) have become popular in rural mountainous regions of Nepal, including Mustang, since the 1990s (Thakali, 2012). Over the last thirty years, these groups have been instrumental in three key administrative arenas: financial management, environmental management, and empowering women.

In terms of financial management, savings and credit cooperatives run by the mothers' group are very common in Lower Mustang. These cooperatives provide loans to low-income farmers who file proposals for agricultural activities. These loans allow farmers to invest in the agricultural activities that they desire. Referring to one such scheme, a mothers' group head in Tukuche, Lower Mustang, said:

> *Our agricultural cooperative organization provides loans of between US $1,000 and US $5,000; loan interest APR is up to 14 %. Loans are provided to small-holding farmers based on their proposals. We have been providing loans for proposals that prioritize vegetable farming, poultry farming, and goat farming. We create committees of 5 to 9 people (comprised of both males and females) in each locality. Based on their recommendations, we disburse loans to members of women's groups who apply*.

In addition, these cooperatives provide loans to low- and middle-income farmers for investment in apple-juice factories, packaging of dried apples and apricots, or production of massage oil, essentially to enable diversification of their incomes and increase their adaptive capacity in terms of household finances.

Mothers' groups play an important role in local environmental management. One venture described in a focus-group discussion was a Lower Mustang mothers' group who frequently engaged in tree planting on the area's barren hills and along the Kali Gandaki River. In the long run, they intend to increase humidity and rainfall, prevent landslides and mass wasting, and stem soil erosion. The result has been that hills are now covered in lush green vegetation. The mothers' group also engages in clean-up of agricultural lands in their communities by burning dry leaf litter and crop residues several times a year. In recognition of successful environmental conservation projects, the institutions and organizations working on environmental management and conservation in Lower

Mustang (the Office of Soil Conservation and Annapurna Conservation Area Projects (ACAP), for instance) have started to foster participation of women in their planning and programs.

The third important role of the mothers' group in Lower Mustang is empowering women in local affairs. To encourage self-reliance and independence and to prepare them for employment, the mothers' group conducts training and skill-enhancement workshops every three months. These workshops are open to women of all ages and any caste or ethnicity. Some of the most popular workshops are pickle-making and apple-wine brewing. Since Lower Mustang is an increasingly popular tourist destination, some mothers' groups have been offering hospitality management courses for girls and women. Training has helped women diversify incomes through self-employment and other jobs. Further, the mothers' group offers informal classes for middle-aged and elderly women about their rights and responsibilities. These efforts by the mothers' group have directly and indirectly enhanced women's adaptive capacity among farmers in Lower Mustang.

6.2.7. Other adaptation and coping strategies in Lower Mustang.

Among the other adaptation and coping strategies in Lower Mustang, about 51% of respondents indicated that they acquire loans to run small-scale agricultural operations, to deploy indigenous insect- and disease-control techniques, to buy modern tools, and to conduct land rituals and prayers once a year.

Among indigenous (or traditional) coping strategies to control insects and disease in plants, the most common practice is the spreading of wood-fire ashes on affected plants and the use of organic fertilizers (e.g., cow dung, goat manure and organic wastes) to increase soil fertility. Likewise, some farmers who can afford to are using modern agricultural tools, like the hand-tractor (Figure 33), instead of traditional manual ploughing using “Jhopa” (a livestock crush of yak and cow) as their adaptation strategy. They can save time for other agricultural activities. Among farmers who conduct land rituals or prayers, many believed that whenever there are natural disasters and calamities that affect their agricultural crops and lands, their god is angry. To please their god, farmers request a *Lama* (local priest) to perform land rituals and prayers that are commonly known as “Bhumi Puja,” calling this a spiritual approach to adaptation.

Figure 33. Hand-Tractor in Marpha, Lower Mustang (Photo: Upendra Bom)

6.3. Opportunities in Adaptations in Lower Mustang

The opportunities in agricultural adaptation in Lower Mustang in relation to role of governance, gender, age income, and education are elaborated and discussed below.

6.3.1. The Role of governance.

There are two forms of local government in each community in Lower Mustang: one is an elected government that is headed by a rural-municipality chair; the other is a traditional-community government that is led by a "Mukhiya", who is nominated by local indigenous-ethnic community members like the Thakali and Gurungs. The co-existence of these two forms of governments is uncommon in other parts of Nepal. Both governments have defined roles in support of farmers' adaptation initiatives and coping strategies, but the elected local government has a greater responsibility than does the community led government. The responsibilities of the elected government include providing subsidies, loans, and resources (for instance, inorganic fertilizers, seeds, or pesticides) to farmers; providing extension services; and conducting workshops in coordination with district agricultural and livestock services. In one case, for instance, a district agricultural officer dictated that "All plastics used in greenhouses and all agricultural tools (like a hand tractor) are eligible for a 50% subsidy." Local governments, in coordination with the district irrigation and disaster-management office, have roles in creating irrigation projects, and repairing and maintaining damaged canals. An officer at the irrigation and disaster management office stated

Every year we have around estimated budget of about 3 million (US $), currently we have 76 projects in pipeline and 30 have been completed in the last five year. These completed projects would help irrigate 900 hectares of agricultural lands across Lower Mustang.

Government and non-government stakeholders are equally responsible for implementing agrarian adaptation policies under a Local Adaptation Plan of Action (LAPA, and federal plans and policies like the National Adaptation Programs of Action (NAPA). One such national-level project, as informed by an agricultural officer, is the "Prime Minister Agriculture Modernization Project (PMAMP) initiated in 2016.

The project aims to specialize the production system based on concentrated efforts at various stages ranging from production to processing and marketing. It has envisioned a holistic system of specialized production by linking it with science, industry, modernization and diversification. The ministry has a target of running the project for the next 10 years, under which the ministry will expand the blocks, zones and super zone gradually every year. Under this project, agricultural land in various parts of the country is or will be categorized based on productivity. In each district, a specialized production area will be determined and classified under four categories such as Pocket (10 hectares), Block (100 hectares), Zone (500 hectares) and super zone (1000 hectares) based on their productivity. On this front Mustang District is trying to be designated as Block for apple growing and eventually become zone receive more budget to make this project implement effectively.

The role of the community government led by a "Mukhiya" has become more limited over the years. It is mainly responsible for settling local disputes among farmers, maintaining discipline, law, and order, and for managing the irrigation system, which includes the creation of a roll-call calendar in which farmers are scheduled to receive water from the main irrigation canal for irrigation of their farms. A local messenger, the "Katuwal", is responsible for informing each community in Lower Mustang of decisions by the "Mukhiya". The survey revealed that only about 60% of farmers were satisfied with the services provided by either the rural municipal government or the community government.

6.3.2. Gender roles and adaptation in Lower Mustang.

About 90% of the farmers taking part in the survey believe that gender roles are very important in household decision-making regarding adaptation initiatives. This is especially the case among indigenous women of Thakali and Gurungs in Lower Mustang where women assert greater control over assets and property. One Mukhiya, a key informant, said:

> *Despite traditional patriarchal system in many parts of Nepal, society in the Mustang district is more gender-neutral; men and women farmers have equal say in decision making, whether it is buying or selling lands, collecting money from vendors, or buying new agricultural tools or machines.*

Almost all monetary transactions are made by women, and the presence of women in agricultural fields is vital. Over the years, these changing gender roles have begun to influence caste groups like the Brahmans/Chettri's and Dalits in Lower Mustang, as well. mothers' group can still engage more in the region and keep on empowering women.

6.3.3. Age and adaptation in Lower Mustang

More than 80% of farmers belonging to the middle-aged group (36-50) said that they have positively contributed to adaptation initiatives in Lower Mustang. These contributions include transferring knowledge to younger generations, holding workshops, and training. They also believe that their years of experience in agriculture have helped guide the government officers who are new to Lower Mustang. One informant said:

The younger generation needs to learn from the older generations, and at the same time, elderly people need a lot of attention to their health.

Similarly, an officer in the agricultural extension services indicated that younger farmers (21-35) and middle-aged farmers (36-50) were slightly more inclined to use new technology in their adaptation initiatives. For example: Younger generation were inclined to use Hand tractors, but the older generation believe that they do not plough as deep and not deep enough to mix the layers of soil whereas the traditional form of ploughing using “Jhopa” achieves this.

6.3.4. The role of income in Adaptation practices in Lower Mustang.

About 80% of farmers taking the survey stated that income plays a very important role in determining their adaptation initiatives. Most of them said that if their incomes were substantially higher and yielded greater profits, they would be able to invest in these three areas: increased vegetable farming by leasing government or private fallow lands, increased apple distilleries and factories to manufacture apple cider, apple juice and apple wine that reflect local flavor profiles, and more organic composting pits that could be used to increase fertility and eventually increase agricultural productivity. Likewise, some focus-group participants stated:

> *If we had more income and profits, we would be able to hire agricultural workers to complete all our agricultural activities in time*.

This demonstrates that income is a very important factor influencing farmers' adaptation strategies and the move to more resilient and sustainable agricultural activities in Lower Mustang.

6.3.5. Roles of education and training and Adaptation in Lower Mustang.

More than half of farmers feel that the education system and training services have huge roles in the dissemination of accurate and reliable information about climate change and its impacts on agriculture in Lower Mustang (Figure 34). An agricultural services officer stated:

> *We have agricultural extension services that provide training and we conduct workshops. In fiscal year 2017/2018, we taught 34 farmers about apple farming and the impacts of climate change on agriculture in Lower Mustang.*

Several environmental science teachers in public schools in Lower Mustang who were among the key-informants group said:

> *We have started teaching courses on climate change and adaptation in agriculture starting grade six.*

They also indicated that they have begun introducing additional curricula developed by ACAP beginning in grade eight. These focused on the impacts of climate change in the Annapurna region (which includes Lower Mustang). Therefore, education and training are key methods to improve adaptation. These programs may not only help current farmers but may also enable future farmers to combat climate-change impacts.

6.4. Key Barriers or Constraints to Adaptation Initiatives in Lower Mustang

There are several barriers or constraints that affect farmers' adaptation strategies and initiatives in Lower Mustang. They can be categorized as either governance-derived barriers or socio-economic barriers experienced by farmers. These are more fully elaborated below.

6.4.1. Governance-related barriers.

The most important barrier or constraint on adaptation initiatives as perceived by 79% of farmers surveyed is the lack of public outreach and government extension services pertaining to climate-change adaptation and impacts on agriculture (Figure 34). A representative of the Annapurna Conservation Area Project in Jomsom, Lower Mustang said:

> *We conduct awareness campaigns, trainings and workshops that disseminate information to farmers and other stakeholders in the region, focusing on the ways to mitigate the impacts of climate change. But these workshops are very limited in frequency, there are only five to seven workshops each year. This relatively small number has been dictated primarily by the country's limited budgets.*

An officer from the Irrigation and Disaster Management office said something similar:

> *We do few workshops for and meetings with our users' group; once or twice a year in Lower Mustang. We disseminate information on water demand, the impacts of climate change, and its impacts on agriculture, among other things. We have about 40 users' groups for 76 irrigation projects. We need more workshops and training sessions that pertain to climate change in Lower Mustang, its impact on agriculture, and the irrigation system of Lower Mustang.*

A key informant representing the Office of Veterinary and Livestock Services in Jomsom said:

We have been conducting basic workshops and training for livestock ranchers that can last from one to three days long. In a single year we conduct about 5 to 6 one-day training sessions and workshops, and about 3 to 4 three-day workshops. But workshops that specialize on the topic of climate change and its implications for livestock and would improve the dissemination of clear and concise information to livestock farmers are very few or non-existent.

The instances discussed above are indications that there are not enough workshops or public-outreach programs offered through governmental and non-government agencies to educate the farmers of Lower Mustang. Therefore, farmers must use their own knowledge and experiences (which may be limited or not at all adequate) to plan and implement adaptation initiatives.

Approximately 75% of farmers taking the survey believed that there are no concrete adaptation plans pertaining to climate change and agricultural adaptation in Lower Mustang, Nepal (Figure 34). One key informant said:

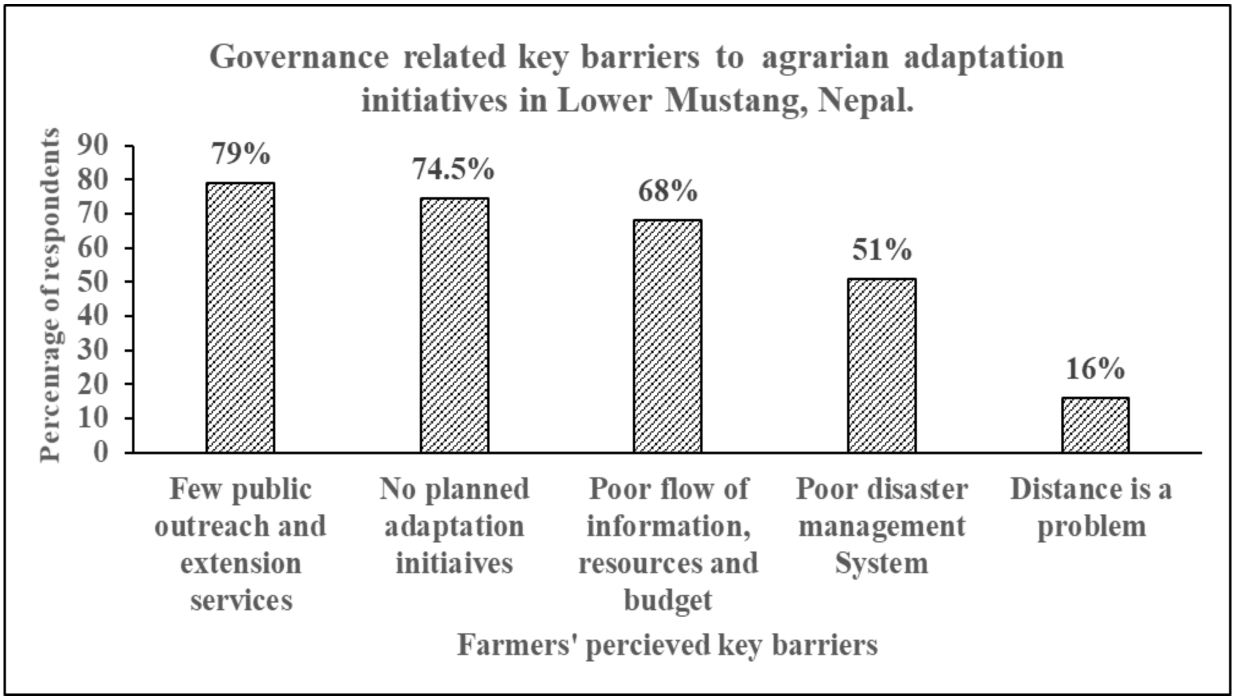

Figure 34. The distribution of the perceptions that farmers' perceived governance-related barriers

> *We do not have long-term sustainable agrarian adaptation plans in Lower Mustang initiated by either the national government or local stakeholders to fight against climate-change impacts. And even the Local Adaptation Plan of Action (LAPA) is very weak in its implementation*.

Not having concrete plans for adaptation is a key barrier for farmers to achieve their personal adaptation goals and objectives in a systematic and orderly way. Governments actions and services are currently oriented toward the solution of farmers' issues temporarily. One of the reasons for the poor performance rating from government stakeholders in the opinion of 70% of farmers is that there is poor information flow and a lack of resources and budgets. Some emergency deliveries to farmers are even delayed and cancelled because of this. Approximately 51% of the respondents believe that Lower Mustang's disaster management system is very weak (Figure 34). Particularly during monsoon season when intense rainfall causes flash floods and landslides. Farmers complained that Lower Mustang has no "emergency centers" to communicate the potential dangers of natural hazards or extreme events to the public. The networks of local stake holders are very weak. The majority of farmers in the focus groups said there are no suitable, publicly funded, cold-storage facilities for harvested produce in the region and there are no well-managed evacuation centers (that would optimally be on higher ground and in open spaces). Farmers have limited space in their homes for storage of livestock feeds, like hay grass. A post-disaster management plan that provides governmental compensation for farmland- or livestock-losses is seldom available to farmers.

Sixteen percent of farmers said their other perceived barrier to adaptation was distance (Figure 34). They collectively stated that the remoteness of Lower Mustang generated distances of separation that were difficult to surmount to get government-provided resources because they required a half-day of travel (to district headquarters and back) to conduct any administrative work or to take livestock to veterinary clinics. It is essential for important stakeholders (such as the national and local government and non-government agencies) to prioritize their goals and efforts to provide services in a timely to address the barriers.

6.4.2. Socio-economic barriers.

The most important socio-economic conditions that are barriers to farmer adaptation initiatives are income, educational achievement, age, caste, and sex (Figure 35). Of greatest concern is household income. More than 60% farmers surveyed expressed that recently their incomes from agriculture has been insufficient for them to invest in the adaptation initiatives that are planned for. Farmers must seek loans or improve their incomes with additional work from other sources like working at hotels, or as wage laborers, or on adaptation initiatives. Some low-income farmers said that, at times, their incomes were not enough to buy pesticides or inorganic fertilizers.

More than 50 percent of respondents perceived that their formal-educational attainments were a key barrier to adaptation initiatives (Figure 35). Most of these were farmers with no formal education or a very limited primary education. These farmers said they have become reliant on educated people who can formally apply to governmental and non-governmental agencies across Lower Mustang for loans, subsidies, funding, financial support, and resources. A key informant said that they have also limited opportunities to attend formal (governmental and non-governmental) workshops and training sessions related to climate change and agricultural adaptation.

Another barrier was perceived by about 30% of surveyed farmers: their age. Most were elderly farmers aged 65 and above. They said their health after 60 years became a problem for their adaptation activities: they could not spend enough time in their fields. Without exception, there were few farmers over 65 (male or female) active in the fields to harvest cereals, to weed grasses, to spray chemicals, or to water vegetables. Some younger farmers, between the ages of 21 and 35, complained that their ages and their agricultural experience did not meet the criteria to attend the few training sessions and workshops conducted. A few elderly farmers mentioned that, despite extensive

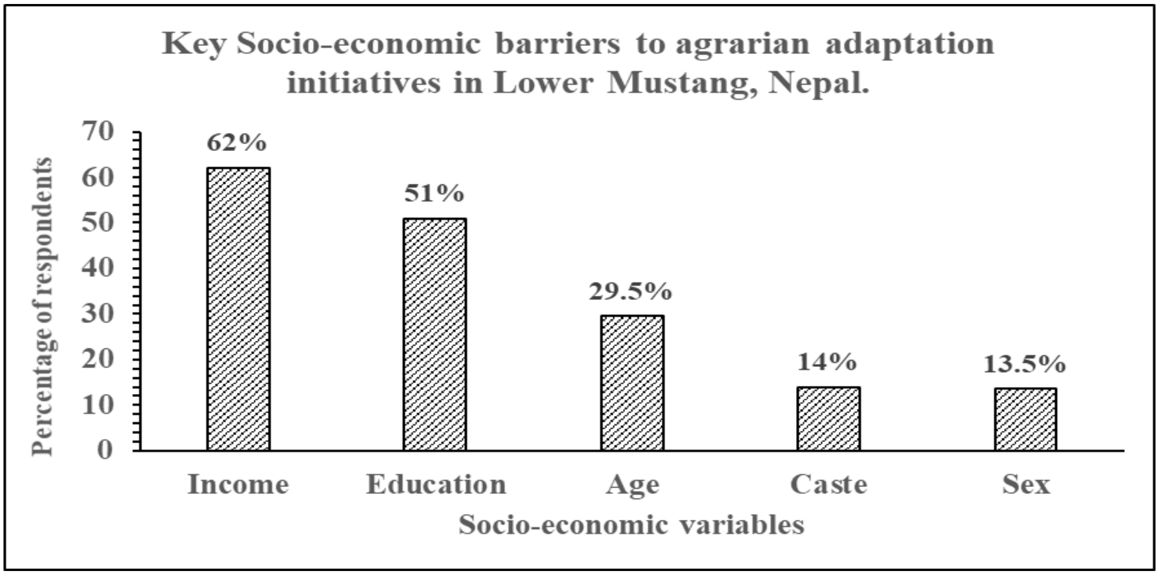

Figure 35. The distribution of farmers perceived socioeconomic barriers in Lower Mustang

experience and knowledge in agriculture, they were rarely given the opportunity to participate in local policy planning for agrarian adaptation initiatives in Lower Mustang.

The farmers' caste was also seen to be a barrier by 14% of farmers, who said their caste is still a problem for their adaptation actions. It was learned in the focus-group discussions that most of these farmers are Dalits. According to them, Dalits continue to be denied opportunities that include participation in training sessions and workshops and receiving agricultural resources and services in a timely fashion. Adding to this, a key informant, a Dalits, said:

Our caste was a huge problem until 15 to 20 years ago. In private and public settings, we were treated as untouchable by the upper castes and ethnic groups. But in recent years, especially after the inception of the newly promulgated constitution in 2015 which strictly bans any form of caste-based discrimination, cases of caste-discrimination have become rare, but these still can occur, particularly at the personal level.

Similarly, being born a girl was a problem for about 14% of farmers who they said they were barred from going to school just because they were girls. And today, they are facing problems because of it. A Dalit woman, a key informant, said

our parents had a perception that it was waste of time and money to spend on a girl's education; she would later get married and live with her husband in a distant place.

Likewise, a few Dalit women in a focus-group said:

Just because we are woman, whether from upper or lower castes, we are sometimes simply denied participation in training and workshops about agriculture adaptation.

But these cases are very rare in Lower Mustang.

This gives one a sense that being girl or women is still a problem. Few women specially from lower castes can take advantage of opportunities for growth, development, education, or adaptation in Lower Mustang.

6.5. Discussion

Previous studies (Aryal et al., 2018, Ingty, 2017; Uprety et al., 2017; Pandey, 2016; Manandhar, et al., 2011, Dahal, 2006) pertaining to perceptions of climate change and its impacts on the livelihood of Himalayan region were based either on generalizations of the perceptions of the subjects studied or on climatic variability of the study areas founded on meteorological data. By contrast, this study introduces a new perspective into the understanding of climate change perceptions discourse by comparing the degree of agreement of farmers perceptions of climate change indicators (like rising temperature, an unstable rainfall regime, and decreasing annual snowfall totals) with their characteristics: the communities in which they live, their sex, their age, their incomes, and the types of agricultural in which they engage.

Barely studied on the perception climate change impacts are the farmers' perceptions of change based on these demographic variables. Therefore, this study adds to the climate change perception literature by reflecting how people's levels of concerns and perceptions of the threats that will arise from climate change can vary among these cohorts and are influenced by their environments and by the social structures within which they act.

Regarding the discourse about vulnerability in the climate-change adaptation literature focused on communities in high mountain regions, this study contests other conclusions that rural women in the developing world are universally more vulnerable to climate change (Goh 2012; Paavola and Adger 2006; Reid and Vogel 2006). In this study, women of the indigenous Thakalis and Gurungs ethnic groups in Lower Mustang appear to have comparatively better access to assets and capital and higher participation rates in agricultural enterprises via mothers' group activism and agro-based cooperatives. These resources enrich and strengthen their adaptive capacities, enabling them to become less vulnerable to the region's climate change.

Several studies (Khanal et al., 2018; Shukla 2018: Ingty 2017; Preston et.al. 2011; Regmi, 2014; Aryal et al., 2014; Ishya and Abajey 2008) of climate change adaptation in the developing world, including the Himalayan region, have failed to consider the influences of local governance, gender, caste/ethnicity, age, income, and education in climate-change adaptation strategies. This study has explored how rural municipality- and indigenous community-based governances share their responsibilities to develop effective agricultural adaptation in the region despite their limited budgets and resources. The study also highlighted gender roles (i.e., both ethnic men and women equally involved decision in making process) in buying and selling of land or buying new agricultural tools or technology. Female often engaged in more monetary transactions than males. Decision making processes are dominated by males in many societies, particularly where patriarchy has stronger influence but it is not in the case of Ethnic communities in Lower Mustang where female play an important role in their household decisions. The role of age in adaptation is much less often studied than are income and education. This study further incorporates farmers' perspectives on how age is contributing to or affecting their adaptation efforts.

The social barriers and stigmas in relation to climate change adaptation initiatives in relation to rural communities in Nepal are scant in literature (Khanal et al., 2018; Shukla 2018; Ingty 2017; Dhakal 2011; Regmi 2014; Aryal 2014; Gautam 1993). This study has, therefore, attempted to add facts about climate-change adaptation in the Himalayan literature by exploring the social and cultural barriers to adaptation that may have negative consequences on farmers' adaptation efforts at the local-level. One example in this study, regards the lower caste Dalits, who even today face difficulties collecting information and accessing local government resources. Also, being female and being denied access to education complicates adaptation efforts as they are reliant on educated people to get them the help and resources they need.

6.6. Summary

The results of the survey, key-informant interviews and focus-group discussions suggest that farmers in Lower Mustang are concerned with and feel their agricultural activities are threatened by the impacts of climate change. The farmers seem to be more concerned and threatened because they are aware that apple farming in lower elevations is slowly disappearing. Most farmers consider apples to be their cash crop, but they feel that down the road they may not get a financial return on their investments. Such concerns and perceived threats are slightly stronger among farmers in Marpha than in other communities. Female farmers are also more concerned and threatened than are the males. Among the farmers between 36 and 50 years old were somewhat more concerned and threatened than were other age groups. Among income-defined groups, the lowest and middle-income groups were concerned with climate change and threatened by it because of their vulnerable financial position or inability to meet their basic needs. The levels of concern and perception of threats were not significantly different among the groups of farmers engaged in different agricultural practices since there was a significant number of neutral responses among the farmers who grew cereals, ranched livestock, grew apples, and farmed vegetables.

The farmers' coping strategies to deal with the threat of increasing plant infestations is to using pesticides and inorganic fertilizers to increase crop production. Farmers have also begun to introduce disease and pest and heat resistant hybrid plants and hybrid livestock in lower elevations. The adaptation strategies to decreasing apple productivity in lower elevations, include slowly shifting apple farming to more suitable elevations by forming cooperatives in each community in Lower Mustang. On the positive side, diversification of crops has become an alternative adaptation strategy to overcome the losses from growing apples. To meet water demands, farmers have begun pumping Kali Gandaki River water and have also started harvesting snow and rainwater to irrigate their lands. They have begun tree plantations throughout Lower Mustang to prevent soil erosion and to control flooding. Other adaptation strategies include introduction of new agricultural tools, applying indigenous pest and disease control, and introducing hybrid crops and livestock.

Elected municipal governments led by a "chairman" and community governments led by "Mukhiya" are vital to providing resources and services to support farmers' adaptation initiatives. The roles of farmers' incomes, their education and training via outreach programs, their age and experience in agriculture were considered important factors that created opportunities that may help sustain farming and strengthen farmers' adaptation initiatives in Lower Mustang.

The key barriers to adaptation of agriculture in Lower Mustang are fundamentally about governance and the socio-economic conditions of farmers. Farmers perceived that there several important governance barriers: there are few public outreach and extension services; there are no well-planned adaptation initiatives; there is a poor flow of information, resources, and budget; and there is a poor disaster-management system across Lower Mustang. Likewise, farmers' incomes and education attainment levels were the most important personal socio-economic barriers. For some farmers their age, caste, and sex have constrained their adaptation initiatives to an extent. The final chapter will summarize this study, discuss the policy and adaptation recommendations, and express the conclusions of the study.

7. SUMMARY AND CONCLUSIONS

7.1. Summary

This study has found that the most important indicators (of the elements of climate) of climate change in Lower Mustang over the last several decades seem to be the rising temperatures, variable and unpredictable rainfall patterns, and decreasing snowfall (Pandey, 2016; Aryal et al., 2014; Malla 2008). We can conclude from this work that the socio-economic, cultural, and demographic characteristics of the people and their communities in Lower Mustang seem to influence farmers' perceptions of climate change. The different perceptions of climate change among the farmers from different communities seem to have been formed or influenced by the environmental conditions in which they live.

For example, according to a key informant, the Kali Gandaki River has less influence on Marpha's thermal conditions than in the other communities, so residents of Marpha may feel the warming more than residents of other communities. The surveys undertaken here have shown that Marpha's residents are more likely to be in strong agreement about climate change, more so than are residents of the other communities.

Furthermore, the views among male farmers are slightly more in sync than are female farmers' views of the empirical evidence of climate change. This conclusion is somewhat contrary to narratives that argue that because women spend more time engaged with agricultural activities in rural places and because they are often the victims of severe weather conditions, their perceptions of climatic change are more accurate than are those of men (Shah and Padheria, 1993). The major contributing factor to males' more accurate perceptions of climate changes, could be a function of the average duration of residence in Lower Mustang, men tend to remain in the region longer than do women.

Middle-aged and elderly farmers (36 years old or more) are in greater agreement about climate change evidence than are the young farmers (21 to 35 years of age). Age may be a proxy for experience with weather patterns in Lower Mustang and therefore, the older one is the more likely they are to have a more robust perspective on the differences over long time periods. Apple and vegetable and livestock farmers also have stronger levels of intra-group agreement about the trends of climate-change indicators than do the other farmers of the region.

The impacts of climate change on Lower Mustang agriculture are seen as both potentially positive and potentially negative. One perceived positive impact of climate change is that the climatic conditions are becoming more favorable for diversifying vegetable farming in the region. In recent decades, farmers have begun growing types of vegetables that are more fit for warmer and wetter conditions than for the conditions of the past. Traditional vegetables, such as potatoes and cabbage, are giving way to a more-diverse assortment of crops including cucumbers, tomatoes. Another change, unrelated to climate change – development in the form of road construction along the Kali Gandaki River has improved access to markets and has subsequently promoted diversification as well.

The negative impacts of climate change include declines in apple productivity at lower elevations (Pandey, 2016). The warming climate has positively affected insect and disease infestations in plants and livestock, and the shrinking of water resources; this is consistent with previous studies (Malla, 2008; Aryal et al., 2014). Fluctuating patterns of rainfall adds to less predictable occurrences of flash floods, soil erosion, and landslides that increase damages to irrigation canals due to stronger runoff and shrinking groundwater recharge capacity (IPCC, 2007).

Female farmers' concerns about threats they perceive to be likely to impact agriculture are more aligned within their cohort than are the views among male farmers. Middle-aged farmers (36 to 50 years old) who were more ambivalent about the threats caused by climate change and were therefore "neutral" than were the members of other generations. In terms of incomes, the poor- and middle-income farmers were more likely to be concerned and were more likely to feel more threatened by climate change impacts than did other income cohorts. Likewise, farmers who had completed secondary levels of education were more concerned and more threatened by climate change than were farmers who had reached other educational levels. Finally, the farmers who grew cereals, livestock, apples, and vegetables were, as group, more concerned and more threatened than did the others.

The most important adaptation strategies in Lower Mustang agriculture are farmers' cooperative initiatives to shift apple farming to more suitable elevations, diversification of vegetable crops, the introduction of hybrid crops and livestock that are insect, disease, and heat resistant. The application of pesticides to affected crops and vegetables has been viewed as an important coping strategy. Pumping water from the Kali Gandaki River and harvesting snow and rain are alternative methods to meet the region's water demands, especially for field irrigation. The role of mothers' group over the last thirty years, these groups have been instrumental in three key administrative arenas: financial management, environmental management, and empowering women which directly indirectly directly and indirectly enhanced women's adaptive capacity among farmers in Lower Mustang. However, there are governance-related and social barriers that need to be addressed to make Lower Mustang agriculture more effective and sustainable.

7.2. Conclusions

Climate change is undoubtedly an unprecedented phenomenon for the modern residents of the Lower Mustang community in Nepal. It will become a perpetual stressor that thrusts farm communities into a mode of continuously evolving methods of coping and adaptation. However, understanding perceptions of climate change and the resulting concerns reflecting the implications of climate change in specific geographical regions, should not be formed with generalized information. But these concerns should be evaluated based on the characteristics of the communities as they may influence perceptions. For example, although male farmers' perceptions of climate-change indicators (rising temperatures, fluctuating rainfall amounts and frequency, and decreasing seasonal snowfall rates) were stronger among men than among female. Men's levels of concerns and threats from these climate driven impacts were weaker than were those of females. Even within the categories of age, income, education, and agricultural practices, the degree of agreement on their perceptions of concerns and threats from climate change varied. For example, the middle aged (36-50 years) and elderly farmers (51 and above years) had stronger level of agreement on their perception of climate change indicators compared younger generation (21-35 years) farmers. Diversification of vegetable and pro-environmental attitude highlight positive aspect of the impacts of climate change.

Men and women are both vital players in Lower Mustang food production, but the contribution that each sex makes is almost impossible to empirically determine. This study has shown that women of certain ethnic groups, especially Thakalis and Gurungs, are slightly more involved through their mothers' group initiatives to promote agriculture and rural enterprise throughout Lower Mustang. The study also found that ethnic group farmers seem to be less vulnerable to climate change impacts compared to non-ethnic caste groups in Lower Mustang due to their stronger adaptive capacity in terms of their financial capacity, resources and network.

As a result of climate change and its impacts on agriculture, farmers in Lower Mustang have been adopting to the changing climate using their own knowledge, community efforts and support from elected local government and community government. In this respect, the role of mothers' group seems to have played a vital role in empowering both ethnic and low caste women. The use of new technology by younger generation is also welcoming. However, this study concludes that enhancement of planned adaptation and increased effectiveness of governance are crucial for sustainability of farmers' coping and adaptation initiatives in Lower Mustang. Also important are the roles that income, gender, education, and age have in overcoming barriers to adaptation. The mothers' group can engage more women in the future by conducting more workshops and trainings that help diversify incomes through self-employment and other job. Likewise, the social barriers to adaptation initiatives are affected by farmers' caste and this needs to be substantiated and acknowledged in the climate-change adaptation literature, particularly when such studies are focused on the Himalayan region where caste plays a dominant role in social stratification.

APPENDIX SECTION

Appendix 1: Non-parametric statistical test results

Asymptotic Significances are displayed. The significance level is .05

Respondents' perception that the Temperature has increased in Lower Mustang over the last 30-40 years by their category of communities.

Null Hypothesis	Test	Sig.	Decision
The distribution of Temperature has increased in Lower Mustang over the last 30-40 years is same across the categories of community	Independent Samples Kruskal-Wallis Test	.681	Retain the Hypothesis

Test	Temperature has increased in Lower Mustang over the last 30-40 years is same across the categories of community
Kruskal-Wallis H	3.505
df	3
Asymp. Sig. (p)	.681

Respondents' perception that the Temperature has increased in Lower Mustang over the last 30-40 years by sex cohort.

Null Hypothesis	Test	Sig.	Decision
The distribution of Temperature has increased in Lower Mustang over the last 30-40 years is same across the categories of Sex.	Independent Samples Kruskal-Wallis Test	.263	Retain the Hypothesis

Test	Temperature has increased in Lower Mustang over the last 30-40 years is same across the categories of community.
Mann-Whitney U	4650.000
Wilcoxon W	9700.000
Z	-1.119
Asymp. Sig. (p)	.263

Respondents' perception that the Temperature has increased in Lower Mustang over the last 30-40 years by the category of Age cohort.

Null Hypothesis	Test	Sig.	Decision
The distribution of Temperature has increased in Lower Mustang over the last 30-40 years is same across the categories of age group.	Independent Samples Kruskal-Wallis Test	.320	Retain the Hypothesis

Test	Temperature has increased in Lower Mustang over the last 30-40 years is same across the categories of age group.
Kruskal-Wallis H	3.505
df	3
Asymp. Sig. (p)	.320

Respondents' perception that the Temperature has increased in Lower Mustang over the last 30-40 years by the category of Agricultural Practices.

Null Hypothesis	Test	Sig.	Decision
The distribution of Temperature has increased in Lower Mustang over the last 30-40 years is same across the categories of agricultural Practices	Independent Samples Kruskal-Wallis Test	.506	Retain the Hypothesis

Test	Temperature has increased in Lower Mustang over the last 30-40 years is same across the categories of age group.
Kruskal-Wallis H	5.299
df	6
Asymp. Sig. (p)	.506

Respondents' perception that the Rainfall has fluctuated in Lower Mustang over the last 30-40 years by their category of communities.

Null Hypothesis	Test	Sig.	Decision
The distribution of rainfall has fluctuated (not stable) in Lower Mustang over the last 30-40 years is same across the categories of community.	Independent Samples Kruskal-Wallis Test	.005	Reject the Hypothesis

Respondents' perception that the Rainfall has fluctuated in Lower Mustang over the last 30-40 years by Sex Cohort.

Null Hypothesis	Test	Sig.	Decision
The distribution of Rainfall has fluctuated in Lower Mustang Lower Mustang over the last 30-40 years is same across the categories of Sex.	Independent Samples Kruskal-Wallis Test	.045	Reject the Hypothesis

Test	Rainfall has fluctuated in Lower Mustang over the last 30-40 years by their category of Sex.
Mann-Whitney U	4251.000
Wilcoxon W	9301.000
Z	-2.008
Asymp. Sig.	.045

Respondents' perception about rainfall has fluctuated in Lower Mustang by the Age cohort.

Null Hypothesis	Test	Sig.	Decision
The distribution of rainfall has fluctuated in Lower Mustang Lower Mustang over the last 30-40 years is same across the categories of Age group.	Independent Samples Kruskal-Wallis Test	.023	Reject the Hypothesis

Test	The distribution of rainfall has fluctuated in Lower Mustang Lower Mustang over the last 30-40 years is same across the categories of Age group.
Kruskal-Wallis H	9.501
df	6
Asymp. Sig.	.023

Respondents' perception about rainfall has fluctuated in Lower Mustang by the category by their agricultural Practices

Null Hypothesis	Test	Sig.	Decision
The distribution of in rainfall has fluctuated Lower Mustang over the last 30-40 years is same across the categories of agricultural Practices	Independent Samples Kruskal-Wallis Test	.098	Retain the Hypothesis

Test	Temperature has increased in Lower Mustang over the last 30-40 years is same across the categories of age group.
Kruskal-Wallis H	10.689
df	6
Asymp. Sig. (p)	.098

Respondents' perception about snowfall has decreased in Lower Mustang by the category of communities.

Null Hypothesis	Test	Sig.	Decision
The distribution of snowfall has decreased in Lower Mustang over the last 30-40 years is same across the categories of community.	Independent Samples Kruskal-Wallis Test	.131	Retain the Hypothesis

Respondents' perception about snowfall has decreased in Lower Mustang by sex cohort.

Null Hypothesis	Test	Sig.	Decision
The distribution of snowfall has decreased in Lower Mustang over the last 30-40 years is same across the categories of Sex.	Independent Samples Kruskal-Wallis Test	.001	Reject the Hypothesis

Test	Snowfall has decreased in Lower Mustang over the last 30-40 years is same across the categories of community.
Mann-Whitney U	4000.000
Wilcoxon W	9050.000
Z	-3.258
Asymp. Sig. (p)	.001

Respondents' perceptions of decreasing snowfall in Lower Mustang by age cohort

Null Hypothesis	Test	Sig.	Decision
The distribution of that the snowfall has decreased in Lower Mustang over the last 30-40 years is same across the categories of age group.	Independent Samples Kruskal-Wallis Test	.965	Retain the Hypothesis

Test	Snowfall has decreased in Lower Mustang over the last 30-40 years is same across the categories of age group.
Kruskal-Wallis H	.273
df	3
Asymp. Sig. (p)	.965

Respondents' perceptions of decreasing snowfall in Lower Mustang by agricultural practices.

Null Hypothesis	Test	Sig.	Decision
The distribution of that the snowfall has decreased in Lower Mustang over the last 30-40 years is same across the categories of age group.	Independent Samples Kruskal-Wallis Test	.805	Retain the Hypothesis

Test	Snowfall has decreased in Lower Mustang over the last 30-40 years is same across the categories of agricultural practices.
Kruskal-Wallis H	3.027
df	6
Asymp. Sig. (p)	.805

Respondents' level of concern from impacts of climate change by sex cohort.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	**2.954**	**4**	**.566**
Likelihood Ratio	3.350	4	.501

Respondents' level of concern from impacts of climate change by income cohort.

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	17.858	20	**.597**
Likelihood Ratio	18.147	20	.578
Linear-by-Linear Association	1.026	1	.311
N of Valid Cases	200		

Respondents' level of concern from impacts of climate change by age cohort.

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	14.564	12	**.266**
Likelihood Ratio	15.552	12	.213
Linear-by-Linear Association	.245	1	.621
N of Valid Cases	200		

Respondents' level of concern/threat from impacts of climate change by income cohort.

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	17.858	20	**.597**
Likelihood Ratio	18.147	20	.578
Linear-by-Linear Association	1.026	1	.311
N of Valid Cases	200		

Respondents' level of concern/threat from impacts of climate change by educational level

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.110	12	**.850**
Likelihood Ratio	7.891	12	.794
Linear-by-Linear Association	2.235	1	.135
N of Valid Cases	200		

Respondents' level of concern/threat from impacts of climate change by agricultural practices

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	49.514	24	**.002**
Likelihood Ratio	34.486	24	.076
Linear-by-Linear Association	6.075	1	.014
N of Valid Cases	200		

Appendix 2: Survey Questionnaire

Section 1: Socio-economic and Demographic Information	
1. How long have you been a Mustang resident? What is your current location of residence in Mustang?	__________ Years ____________ Months ____________.
2. Who is the head of the Household?	☐ Male ☐ Female
3. What is your ethnicity/Caste?	____________.
4. Indicate your sex	☐ Male ☐ Female ☐ Other
5.How many people live in your household?	_____________.
6. What is your family type?	☐ Nuclear ☐ Extended
7. Please indicate the highest level of your education:	_____________
8. What is your household's average yearly income from Agriculture?	☐ Below US $ 1,000 ☐ US $ 1,000- 1,999 ☐ US $ 2,000 – 2,999 ☐ US $ 3,000-3,999 ☐ US $ 4, 000 – 4,999 ☐ US $ 5, 000 and above ☐ Prefer not to say
9. How many people contribute to your household income?	_____________
11. Does anyone from your household support you financially from abroad?	☐ Yes ☐ No ☐ Other
12. How long have you been farming?	___________________________________.
13. What is the main source of income in your family?	___________________________________.
14. What is your age group?	☐ 21 to 35 ☐ 36 to 50 ☐ 51 to 65 ☐ 66 and above
Section 2: Opinions about changing weather patterns and their impacts on agriculture in your community	

15. How often do you hear farmers talking about climate change in your community?	☐ Often ☐ Sometimes ☐ Never
16. Indicate what are your sources of knowledge about climate change and its impacts on agriculture in your community? Check all that apply to you?	☐ Print media ☐ Social media ☐ Public notices ☐ Internet Search/Websites ☐ Public seminars/talk series ☐ Newsletters ☐ Radio/ Television talks and announcements ☐ Word of Mouth ☐ Pamphlets and brochures ☐ Don't know ☐ Other, please specify ________________.
17. If you marked any one of the options in question 16 (other than "Don't know"), how much did these sources adequately inform you about the impacts of climate change?	☐ Adequately ☐ Neutral ☐ Less than adequately ☐ Inadequately ☐ Don't know
18. In your opinion, have the patterns of weather in your community changed in the last 30 to 40 years?	☐ Yes ☐ No
19. If you answered "Yes" to question 18, How much do you agree with the following statements pertaining to weather patterns in your community.	If you answered "No" to question 18, **please skip to question 19**.
a. The temperature has risen in the last 30- 40 years.	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
b. The temperature has been constant over the last 30 to 40 years.	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
c. The temperature has decreased over the last 30 to 40 years	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
d. Rainfall has decreased over the last 30 to 40 years.	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

e. Rainfall has increased over the last 30 to 40 years.	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
f. Rainfall has fluctuated (has not been constant) over the last 30 to 40 years.	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
g. Snowfall has increased over the last 30 to 40 years.	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
h. Snowfall has been constant over the last 30 to 40 years.	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
i. Snowfall has decreased over the last 30 to 40 years.	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
j. Water sources are diminishing and are drying up.	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
20. What agricultural activity or activities are you involved with? Please check all that all apply to you.	☐ Crops and Livestock ☐ Crops and Apple Farming ☐ Cereals and Vegetable ☐ Crops. apple and vegetable farming ☐ Crops and vegetable Livestock and apple farming ☐ Crops, livestock, apple and vegetable farming ☐ Other, please mention________________.
21. In your opinion, are there any positive impacts of climate change in your community over the last 30 to 40 years?	____ ____ ______.
22. What major impacts has climate change had on the health of livestock that you own?	_______________________________________
23. Please describe incidences of significant insect-pest impacts on your crops over the years due to climate change?	______________________________________
24. Have the types of crops that farmers grow in your community changed over the past 30 to 40 years?	☐ Yes ☐ No If yes, please explain__________________.
25. Have the methods of tilling land (or tillage practices) in your community changed over the past 30 to 40 years?	☐ Yes ☐ No If yes, please explain______________.

26. Has irrigation in your community increased or decreased over the past 30 to 40 years?	☐ Increased ☐ Decreased ☐ No change.
27. Has livestock raising gotten more difficult over the past 30 to 40 years because of climate change?	☐ Yes ☐ No
a. If you answered "Yes" to Question 29, choose the answer that best explains the causes for the changes to livestock raising? Check that all apply.	☐ Reduction in grazing area ☐ Degradation of grass ☐ Emergence of diseases ☐ Others, please specify __________.
28. What is your level of concern about the impacts of climate change on the agriculture of your community?	☐ Highly concerned/ Highly threatened ☐ Concerned/ Threatened ☐ Neutral ☐ Not concerned/ Not threatened ☐ Not at all concerned and Threatened
29. Do you think current education and training systems are helpful to raise awareness about the impacts of climate change on your community?	☐ Yes ☐ No If "yes", please explain ______________________
30. Is there anything else you would like to say about the impacts of climate change on crop farming and livestock in your community?	☐ Yes ☐ No If Yes, please explain. ______________________
Section 3: Adaptation strategies and initiatives in the agricultural practices of your community	
31.What is your level of awareness about any adaptation and coping strategies in agriculture that farmers have employed in your community?	☐ Highly aware ☐ Aware ☐ Neutral ☐ Not aware ☐ Not at all aware
32. Do you have any experiences with or knowledge about any adaptation and coping strategies that you or other farmers have implemented in your community?	☐ Yes ☐ No

33. If you replied "Yes" to question 32, please identify any farming adaptation that is being implemented by you or other farmers to minimize the impacts of extreme weather conditions or climate change. Check all that apply.	☐Shifting to higher altitude (e.g., apple farming) ☐ Raising hybrids crops and livestock resistant heat and extreme weather conditions ☐ Planting or raising livestock which are disease and pest resistant ☐ Others, please identify. ____________________
34. Are there any disaster risk reduction measures being in used in your community to avoid the impacts of climate change and variability? Check all that apply to you.	☐ Storage facilities for harvested produce ☐ Livestock pens/shelters at elevated places ☐ Evacuation centers on higher grounds/open spaces ☐ Food storage for livestock ☐ Alarming centers to inform potential dangers ☐ Local networks to risk analysis ☐ Others, please specify____________.
35. Are there any indigenous adaptation strategies (using traditional agricultural practices) being used in your community?	☐ Yes ☐ No If you replied "Yes" to question 35 **answer questions a through m.** Or if you replied "No", then **skip to question 36**.
a. Please identify the practices pertaining to crop change that have been used in your community over the last 30 to 40 years.	____ __.
b. Please identify the practices pertaining to crop rotation activity that have been used in your community over the last 30 to 40 years.	____ __.
c. Please identify the practices pertaining to pest control that have been used in your community over the last 30 to 40 years.	____ __.
d. Please identify the practices pertaining to crop disease control have been used in your community over the last 30 to 40 years.	____ __.

e. Please identify the practices pertaining to livestock disease control that have been used in your community over the last 30 to 40 years.	____.
f. Please identify the practices pertaining to irrigation that have been used in your community over the last 30 to 40 years.	____ ____.
g. Please identify the practices pertaining to protection of local rivers or water resources for irrigation that have been used in your community over the last 30 to 40 years.	____ ____.
h. Please identify the practices pertaining to land tilling that have been used in your community over the last 30 to 40 years.	____ ____.
i. Please identify the practices pertaining to the application of manures (e.g., composts rather than chemical fertilizer) that have been used in your community over the last 30 to 40 years.	____ ____.
j. Please identify the practices pertaining to the burning of agricultural remains (organic remains or wastes) on farmland that have been used in your community over the last 30-40 years.	____ ____.
k. Please identify the practices pertaining to the control of forest or grassland fire during drought to protect agricultural land that have been used in your community over the last 30 to 40 years.	____ ____.
l. Please identify the practices pertaining to the protection of lands from landslides or flooding that have been used in your community over the last 30 to 40 years.	____.

m. 38. In your opinion, how effective are the indigenous methods of adaptation in the present context of climate change?	☐ Highly effective ☐ Effective ☐ Neutral ☐ Less effective ☐ Not at all effective
36. Do you think current education and training systems have helped with agrarian adaptation to climate change in your community?	☐ Yes ☐ No If "Yes", please explain. ____.
37. Is there anything else you would like to say about agrarian adaptation to climate change in your community?	☐ Yes ☐ No If "Yes", please explain ____.
Section 4: Role of Local Governance, Gender, Income and Age: Barriers and Opportunities to Agrarian Adaptation in your community.	
38. What kinds of support do you receive from the local government for adaption to climate change?	____.
39. Has there been any public meetings/workshops, called by local government (led by Mukhiya or Village Municipality) to support famers' adaptation?	☐ Yes ☐ No
40. Have you attended any public meeting /workshop or any program to support farmers' adaptation to climate change?	☐ Yes ☐ No If you replied "Yes", **please answer questions "a" to "e".** If you replied "No", then **proceed to question 48**.
a. The location of the meeting held was:	☐ Very convenient ☐ Somewhat convenient ☐ Neutral ☐ Somewhat inconvenient ☐ Very inconvenient
b. The description about the aim of the meeting program was:	☐ Easy to understand ☐ A little difficult to understand ☐ Hard to understand ☐ Very difficult to understand

c. The descriptions of the potential impacts of climate change in the agriculture of your community was:	☐ Very Clear ☐ Somewhat clear ☐ Neutral ☐ A bit unclear ☐ Very unclear
d. The level of discussion on issues and policy alternatives to agrarian adaptation in your community were:	☐ Thoroughly discussed ☐ Discussed ☐ Discussed less than desired ☐ Not discussed at all
e. What major concerns did you raise in the meetings/workshops? Please elaborate.	____ __.
f. 44. In your view, what would the role of local government be in terms of expediting farmer's adaptation initiatives in your community? Please elaborate.	____ __.
41. Do the local government or other organizations provide information about climate change and possible adaptation practices?	☐ Yes ☐ No ☐ Don't know
42. In your opinion, what are the barriers to adaptation activities or programs from the local government in your community?	☐ Farmers do not know care ☐ No planned adaptation ☐ Few public outreach programs by the local government ☐ Distance is a problem to acquire information/resources from the local government ☐ Poor flow of information, budget and resources ☐ Other, please specify: ____
43. Do local governments or other organizations provide resources or any support to adapt to the climate change?	☐ Yes ☐ No ☐ Don't know
44. Do you believe that gender roles are crucial to achieving adaptation to climate change in your community?	☐ Yes ☐ No

45. How much do you agree that gender bias affects the ability to obtain and access information from government agencies and other stakeholders regarding agriculture in your community?	☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
46. How much do you agree that gender bias affects the ability to obtain credit, loans, subsidies, and extension services from government agencies and other stakeholders regarding the promotion of agriculture in your community?	☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
47. How much do you agree that gender bias affects the introduction of innovative approaches (i.e., use of technology, use of highly resistant crops, etc.) for agrarian adaptation to climate change?	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
48. In your opinion, how much have mothers' groups or women's groups in your community empowered women's roles in agrarian adaptation initiatives in your community? Please elaborate.	____ _.
49. In your opinion, aside from the issues mentioned above, what other barriers do gender issues create for agrarian adaptation to climate change in your community?	____ __.
50. In your opinion, how much has your household income contributed to your ability to adapt your agricultural activity to climate change?	☐ Contributed a lot ☐ Contributed a little ☐ Neutral ☐ Not contributed much ☐ Not contributed at all
51. Has your income been a barrier to your adaptation to climate change?	☐ Yes ☐ No If you replied "Yes" to question 51, please answer question "a". If you replied "No", then skip to question 52.
a. How has income been a barrier to adaptation?	____ __.

52. Would an increase in your income enable you to undertake more adaptations? What adaptation opportunities would arise due to an increased household income?	____
53. In your opinion, has your age positively affected your ability to adapt agriculturally to climate change?	☐ Helped a lot ☐ Helped a little ☐ Neutral ☐ Has not helped much ☐ Has not helped at all
54. Do you think new technology (as opposed to traditional practices) would help you to adapt your farming to climate change?	☐ Yes ☐ No ☐ Don't know If you replied "Yes" to question 54, please answer question "a". If you answered "No", then please skip to question.
a. How likely are you to use or introduce new technology (such as new crops, new equipment, etc.) for adaptation to climate change?	☐ Highly likely ☐ Somewhat likely ☐ Neutral ☐ Not very likely ☐ Not at all likely
55. How much has your experience as a farmer over the years contributed to your ability to implement planned and unplanned coping strategies?	☐ Contributed a lot ☐ Contributed somewhat ☐ Neutral ☐ Contributed a little ☐ Has not contributed at all
56. Has your age made it more difficult to adapt to climate change?	☐ Yes ☐ No If you replied "Yes" to question 56, answer question "a". If you replied "No", then please skip to question 57.
57. Please describe how your age has affected your ability to adapt to climate change.	____.
58. In your opinion, has your age created any opportunities to support your planned and unplanned adaptation efforts?	____.
59. Do you believe that current education and training system provide important knowledge and skills for agrarian adaptation to climate change in your community?	☐ Yes ☐ No If you replied "Yes", please explain. ____.

60. Is there anything that you would like to add regarding opportunities for agrarian adaptation to climate change in your community?	☐ Yes ☐ No If you replied "Yes", please explain. ____ __
61. Is there anything that you would like to add regarding barriers to achieving effective agrarian adaptation to climate change in your community?	☐ Yes ☐ No If you replied "Yes", please explain. _________________________________.

Thank you for your time and participation!!!

Appendix 3: Focus group discussion/key informant interview questions

1. What kind of weather pattern did we have in the past 30- 40 years ago?
2. What kind of weather pattern do we have these days?
3. What change did you experience in the last 30-40 years in the weather pattern?
4. What are the positive things with these changes of weather patterns (if it changed)?
5. What are the negative things with these changes of weather patterns (if it changed)?
6. Have you heard of climate change?
7. Do you all believe that climate change is already impacting the agricultural activities in lower Mustang?
8. To be more specific, have you noticed any change in precipitation pattern over the years? (snowfall, rainfall, hailstone, frost) over the years? If yes, please explain.
9. Have you noticed changes in temperature trend in this area over the years?
10. Do you feel that your livelihood/occupation are presently at because of climate change?
11. Do you feel that your assets, agricultural land, crops and livestock, are presently at risk because of climate change?
12. What are the major crops grown in Lower Mustang? Have you noticed any changes/introduction of crops including vegetables over the years?
13. Please explain if there has been any change in production of winter and summer crops? If yes, please explain.
14. Since apple farming is a major cash crop in Mustang? How has climate change impacted it in terms of production and change in growing season and shifting to higher altitudes for growth over the years?
15. Do the farmers have sufficiency of food throughout the year? if no what is main reason behind it?
16. Has there been change in agricultural practices (farming style, timing, type of crops, irrigation trend etc.) over the years? If yes, please explain.
17. Is there any problem of flash floods in Lower Mustang? If yes, what do you think is main cause behind it?
18. Please mention the nature of flood and impact caused by it?

19. Please mention if there have been any changes in frequency of landslide as compared to past and impacting the agricultural activities in Lower Mustang
20. Are aware of the any new diseases in crops and domesticated animals in the recent years?
21. If there was a change in the weather pattern in the last 30-40 years, did it affect farming? How?
22. If there was a change in the weather pattern in the last 30-40 years, did it affect livestock? How?
23. If there was a change in the weather pattern in the last 30-40 years, did it affect daily livelihood pattern of people? How?
24. If there was a change in the weather pattern in the last 30-40 years, did it affect professional choice/practice of public in your area? How?
25. Have there been any changes in livestock raising practices over the years? If yes, please mention.
26. What are the ongoing adaptation initiatives of farmers to minimize the impacts of climate change in Lower Mustang? What are the major roles of local community governance, non-government organizations and other institutions assisting in such initiatives?
27. Have you participated in activities that raise public awareness about the impacts of climate change in the agriculture of Lower Mustang? if yes briefly explain.
28. Do farmers (male and female) have similar or equal conditions in which to address and adapt to climate change? Do they have the same skills and capabilities to confront it?
29. How are agrarian communities coping with the changes due to change in weather pattern in the last 30-40 years?
30. How are forest and natural resources been affected by changes due to weather pattern in the last 30-40 years? How these changes have affected livestock?
31. How are farmers changing their lifestyle in response to change in the weather pattern? (Like grazing, crop rotations, mix crops, integrated farming, farm specialization or farm segregation, loss of farming and farming land, etc.)
32. Does gender biased exists while getting credits, loans, subsidies, extension services from the government agencies and other stakeholders pertaining to promote agriculture in Lower Mustang? If yes, please explain the barriers.
33. Does gender biased exists while trying to obtain and accessing the information form the government agencies and other stakeholders regarding any kind

information pertaining to agriculture in Lower Mustang? If yes, please explain the type of barriers.

34. How has the ownership of agricultural land based on gender affected decision making process at household level to make decision in relation to agricultural activities?

35. What do you think are the possible ways incorporate gender perspectives into adaptation process for a win-win outcome?

36. Are there any difficulties in obtaining information from various stake holders (government, non-government organizations and other institutions) involved in the promotion of agriculture in Lower Mustang?

37. How have the local clubs, organizations and groups such as mothers' group (locally known as "Aama Samuha") played role in empowering women in relation to agricultural activities in Lower Mustang?

38. How do you think income of the farmers in lower Mustang is affecting the agrarian adaptation process in Lower Mustang? What are the barriers /opportunities due to this economic variable in the adaptation process?

39. How do you think the age of farmers affecting the Lower Mustang is affecting the agrarian adaptation process, what are the advantages and disadvantages brought by the experience of farmers in this aspect?

40. What are the lessons learnt from the ongoing adaptation initiatives?

Thank you for your participation in the study!!!

Appendix 4: List of Vegetables Grown in Lower Mustang

1. Potato
2. Cabbage
3. Cauliflower
4. Tomato
5. Carrot
6. Black Eyed Beans
7. Green Peas
8. Bottle Gourd
9. Brinjal
10. Capsicum
11. Green Pepper
12. Chayote
13. Coriander / Cilantro
14. Cucumber
15. Fenugreek Green
16. Luffa Gourd
17. Garden cress
18. Mushrooms
19. Okra
20. Onion
21. Pumpkin
22. Radish
23. Spinach
24. Sweet Potato
25. Taro root
26. Taro leaf
27. Mustard green

LITERATURE CITED

Adger, W. N., Huq, S., Brown, K., Conway, D., and Hulme, M. 2003. Adaptation to climate change in the developing world. *Progress in Development Studies*, 3(3), 179-195.

Adger W.N., Dessai S., Gulden M., Hulme M., Lorenzoni I., Nelson D.R., Naess L.O., Wolf J., Wreford, A. 2009. Are there social limits to adaptation to climate change*?* *Climatic Change* 93:335–354.

Adger, W. N., Butler, C., and Walker-Springett, K. 2017. Moral reasoning in adaptation to climate change. *Environmental Politics*, 26(3): 371-390.

Agho, K., Stevens, G., Taylor, M., Barr, M., and Raphael, B. 2010. Population risk perceptions of global warming in Australia. *Environmental Research* 110(8): 756-763.

Agarwal, B. 2010. *Gender and green governance: the political economy of women's presence within and beyond community forestry*. Oxford University Press.

Agrawal, A. 2008. The role of local institutions in adaptation to climate change. Accessed October 3, 2018. In: Papers of the Social Dimensions of Climate Change Workshop. The World Bank, Washington DC, March 5–6, 2008. Accessed October 3, 2018. https://openknowledge.worldbank.org/bitstream/handle/10986/28274/691280WP0P11290utions0in0adaptation.pdf?sequence=1.

Ahmed, S., and Fajber, E. 2009. Engendering adaptation to climate variability in Gujarat, India. *Gender and Development*, 17(1), 33-50.

Agricultural Management Information System. 2016. Mustang District Profile. Accessed December 2, 2017. http://namis.gov.np/downloadfile/Mustang%20District%20Profile_1466675136.pdf.

Ainsworth, E. A., and Long, S. P. 2005. What have we learned from 15 years of free-air CO2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO2. *New Phytologist* 165(2):351-372.

Altieri, M. A., and Nicholls, C. I. 2017. The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change*, 140(1): 33-45.

Ali, A., and Erenstein, O. 2017. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management*,16:183-194.

Arora-Jonsson, S. 2009. discordant connections: discourses on gender and grassroots activism in two forest communities in India and Sweden. *Journal of Women in Culture and Society* 35(1):213-240.

Aryal, S., Panthi, J., Dhakal, Y. R., Gaire, N. P., Karki, K., and Joshi, N. R. 2018. Historically evolved practices of the Himalayan transhumant pastoralists and their implications for climate change adaptation. *International Journal of Global Warming*, 14(3), 356-371.

Aryal, D. Y., Abshare, M. W., Desta, S., and Leal Filho, W. 2017. Pastoralists and farmers coping and adaptation strategies to climate variability and their perceived success in Ethiopia. In *Climate Change Adaptation in Africa* 457-473: Springer, Cham.

Aryal, A., Raubenheimer, D., and Brunton, D. Impact of climate change on human-wildlife-ecosystem interactions in the Trans-Himalaya region of Nepal Food and Agricultural organization, found at http://agris.fao.org/agris search/ ID=US201400051723, accessed on April 15, 2016.

Attavanich, W., and McCarl, B. A. 2014. How is CO2 affecting yields and technological progress? A statistical analysis. *Climatic Change*, 124(4), 747-762.

Ayers, J., and Forsyth, T. 2009. Community-based adaptation to climate change. *Environment: science and policy for sustainable development*, 51(4), 22-31.

Becken, S. 2013. A review of tourism and climate change as an evolving knowledge domain. *Tourism Management Perspectives*, 6, 53-62.

Bhagawati, R., Bhagawati, K., Jini, D., Alone, R. A., Singh, R., Chandra, A., ... and Shukla, K. K. 2017. Review on Climate Change and its Impact on Agriculture of Arunachal Pradesh in the Northeastern Himalayan Region of India. *Nature Environment and Pollution Technology*, 16(2), 535.

Biagini, B., Bierbaum, R., Stults, M., Dobardzic, S., and McNeeley, S. M. 2014. A typology of adaptation actions: A global look at climate adaptation actions financed through the Global Environment Facility. *Global Environmental Change*, 25, 97-108.

Bishwokarma, D., Paudel, N. S., and Thing, S. J. (2014). Policy-practice gap on Chure management: analysis of Chure policy implications on community right on forest resources. Right and Resources Initiatives (RRI) and Forest Action Nepal, Kathmandu, Nepal.

Bizikova, L., Nijnik, M., and Nijnik, A. 2014. Exploring institutional changes in agriculture to inform adaptation planning to climate change in transition countries. *Mitigation and Adaptation Strategies for Global Change*, 1-22.

Bizikova, L., Crawford, E., Nijnik, M., and Swart, R. 2014. Climate change adaptation planning in agriculture: processes, experiences and lessons learned from early adapters. *Mitigation and adaptation strategies for global change*, 19(4), 411-430.

Boydell, S., Giurco, D., Rickwood, P., Glazebrook, G., Zeibots, M., and White, S. 2010. Using an integrated assessment model for urban development to respond to climate change in cities. *Energy efficient cities: Assessment tools and benchmarking practices*, 65-91.

Brody, S. D., Zahran, S., Vedlitz, A., and Grover, H. 2008. Examining the relationship between physical vulnerability and public perceptions of global climate change in the United States. *Environment and Behavior*, 40(1), 72-95.

Brügger, A., Dessai, S., Devine-Wright, P., Morton, T. A., and Pidgeon, N. F. 2015. Psychological responses to the proximity of climate change. *Nature Climate Change*, 5(12), 1031.

Burke, M., and Emerick, K. 2016. Adaptation to climate change: Evidence from US agriculture. *American Economic Journal: Economic Policy* 8(3):106-40.

Carmichael, J. T., and Brulle, R. J. 2017. Elite cues, media coverage, and public concern: an integrated path analysis of public opinion on climate change, 2001–2013. *Environmental Politics*, 26(2), 232-252.

Carr, E. R., and Thompson, M. C. 2014. Gender and climate change adaptation in agrarian settings: Current thinking, new directions, and research frontiers. *Geography Compass*, 8(3), 182-197.

Capstick, S., Whitmarsh, L., Poortinga, W., Pidgeon, N., and Upham, P. 2015. International trends in public perceptions of climate change over the past quarter century. Wiley Interdisciplinary Reviews: *Climate Change*, 6(1), 35-61.

Challinor, A. J., Watson, J., Lobell, D. B., Howden, S. M., Smith, D. R., and Chhetri, N. 2014. A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*, 4(4), 287.

Chatrchyan, A. M., Erlebacher, R. C., Chaopricha, N. T., Chan, J., Tobin, D., and Allred, S. B. (2017). United States agricultural stakeholder views and decisions on climate change. *Wiley Interdisciplinary Reviews: Climate Change*, 8(5), e469.

Choudhary, V. K., Kumar, P. S., and Bhagawati, R. 2013. Response of tillage and in situ moisture conservation on alteration of soil and morpho-physiological differences in maize under Eastern Himalayan region of India. *Soil and Tillage Research*, 134, 41-48.

Chaudhary, P., Thapa, K., Lamsal, K., Tiwari, P. R., and Chhetri, N. 2012. Community-based climate change adaptation for building local resilience in the Himalayas. In *Human and Social Dimensions of Climate Change*. IntechOpen.

Crona, B., Wutich, A., Brewis, A., and Gartin, M. 2013. Perceptions of climate change: Linking local and global perceptions through a cultural knowledge approach. *Climatic Change* 119(2): 519-531.

Central Bureau of Statistics Nepal. 2011. District Profile. Found at http://cbs.gov.np/, accessed on April 2, 2015.

Cutter, S. L. 1996. Vulnerability to environmental hazards. *Progress in Human Geography*, 20(4), 529-539.

Dahal, N. 2006. Perceptions of climate change in Himalayas. *Tiempo Bulletin*. Issue number 26: 19-24.

Dankelman, I., and Jansen, W. (2010). Gender, environment, and climate change: understanding the linkages. In *Gender and climate change: An introduction*, 21-54.

Dankelman, I. (Ed.). 2010. *Gender and climate change: An introduction.* Routledge.

Dankelman, I. 2002. Climate change: Learning from gender analysis and women's experiences of organising for sustainable development. *Gender and Development,* 10(2):21-29.

Dixit, A. 2010. Scoping Assessment on Climate Change Knowledge Platform in Nepal. Bangkok: AIT-UNEP http://www. climateadapt. asia/upload/publications/files/4d415f41a406dScoping_Report_Nepal. pdf.

Demski, C., Capstick, S., Pidgeon, N., Sposato, R. G., and Spence, A. 2017. Experience of extreme weather affects climate change mitigation and adaptation responses. *Climatic Change*, 140(2), 149-164.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., and Yesuf, M. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental change* 19(2):248-255.

Dhakal: C. K., Regmi, P. P., Dhakal, I. P., Khanal, B., Bhatta, U. K., Barsila, S. R., and Acharya, B. 2013. Perception, impact and adaptation to climate change: an analysis of livestock system in Nepal. *Journal of Animal Science Advances*, 3(9):462-471.

Djoudi, H., and Brockhaus, M. 2011. Is adaptation to climate change gender neutral? Lessons from communities dependent on livestock and forests in northern Mali. *International Forestry Review*, 13(2), 123-135.

Dovers, S. R., and Hezri, A. A. 2010. Institutions and policy processes: the means to the ends of adaptation. *Wiley Interdisciplinary Reviews: Climate Change*, 1(2), 212-231.

Duncan, J. M., Biggs, E. M., Dash, J., and Atkinson, P. M. 2013. Spatio-temporal trends in precipitation and their implications for water resources management in climate-sensitive Nepal. *Applied Geography*, 43, 138-146.

Eakin, H., and Lemos, M. C. 2010. Institutions and change: the challenge of building adaptive capacity in Latin America. *Global Environmental Change*, 1(20), 1-3.

Eriksson, M., Xu, J., Shrestha, A. B., Vaidya, R. A., Santosh, N., and Sandström, K. 2009. *The changing Himalayas: impact of climate change on water resources and livelihoods in the greater Himalayas*. International center for integrated mountain development (ICIMOD).

Etkin, D., and Ho, E. 2007. Climate change: perceptions and discourses of risk. *Journal of Risk Research*, 10(5), 623-641.

Fan, X., Fei, C. J., and McCarl, B. A. 2017. Adaptation: An agricultural challenge. *Climate*, 5(3):56.

Fischer, G., Shah, M., Tubiello, F. N., and Van Velhuizen, H. 2005. Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990–2080. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360(1463):2067-2083.

Franzel, S. 1999. Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa. *Agroforestry Systems* 47(1-3):305-321.

Füssel, H. M. 2007. Adaptation planning for climate change: concepts, assessment approaches, and key lessons. *Sustainability Science* 2(2):265-275.

Gale, P., Drew, T., Phipps, L. P., David, G., and Wooldridge, M. 2009. The effect of climate change on the occurrence and prevalence of livestock diseases in Great Britain: a review. *Journal of Applied Microbiology*, 106(5), 1409-1423.

Gautam, M. R., Acharya, K., and Tuladhar, M. K. 2010. Upward trend of streamflow and precipitation in a small, non-snow-fed, mountainous watershed in Nepal. Journal of hydrology, 387(3-4), 304-311.

Gallup Polls. 2018. *Global Warming Age Gap: Younger Americans Most Worried* https://news.gallup.com/poll/234314/global-warming-age-gap-younger-americans-worried.aspx

Gergan, M. D. 2017. Living with earthquakes and angry deities at the Himalayan borderlands. *Annals of the American Association of Geographer*s, 107(2), 490-498.

Goh, A. H. 2012. A literature review of the gender-differentiated impacts of climate change on women’s and men’s assets and well-being in developing countries. *International Food Policy Research Institute,* CAPRi Work.

GoN/MoE. 2010. *National adaptation program of action (NAPA) to climate change*. Kathmandu: Ministry of Environment (MoE), Government of Nepal

GoN 2011. *Local Adaptation Plans for Action (LAPA)*. Kathmandu: Ministry of Environment (MoE), Government of Nepal. Kathmandu: Ministry of Environment.

Holmelin, N., and Aase, T. H. 2013. Flexibility of scope, type and temporality in Mustang, Nepal. Opportunities for adaptation in a farming system facing climatic and market uncertainty. *Sustainability* 5(4):1387-1405.

Hansen, J., Sato, M., and Ruedy, R. 2012. Perception of climate change. *Proceedings of the National Academy of Sciences*, 109(37), E2415-E2423.

Hoorn, C., Wesselingh, F. P., Ter Steege, H., Bermudez, M. A., Mora, A., Sevink, J., and Jaramillo, C. 2010. Amazonia through time: Andean uplift, climate change, landscape evolution, and biodiversity. *Science*, 330(6006), 927-931.

Howden, S. M., Crimp, S. J., and Stokes, C. J. 2008. Climate change and Australian livestock systems: impacts, research and policy issues. *Australian journal of experimental agriculture*, 48(7), 780-788.

Ingty, T. 2017. High mountain communities and climate change: adaptation, traditional ecological knowledge, and institutions. *Climatic Change*, 145(1-2), 41-55.

IPCC. 2001. *Climate change 2001: The scientific basis*. Cambridge University Press, Cambridge.

IPCC. 2007. Climate change 2007: Synthesis report. Working group contribution to the fourth assessment report of Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change (IPCC), Geneva.

IPCC 2014. Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Ishaya, S., and Abaje, I. B. 2008. Indigenous people's perception on climate change and adaptation strategies in Jema'a local government area of Kaduna State, Nigeria. *Journal of Geography and Regional Planning* 1(8) 138-143.

Janssena, M. A., and Ostrom, E. 2006. Resilience, vulnerability, and adaptation: A cross-cutting theme of the International Human Dimensions Programme on Global Environmental Change. *Global Environmental Change* 16(3): 237-239.

Jerneck, A. 2017. Taking gender seriously in climate change adaptation and sustainability science research: views from feminist debates and sub-Saharan small-scale agriculture. *Sustainability Science* 1-14.

Jones, L. 2010. *Overcoming Social Barriers to Adaptation*. Overseas Development Institute, Background Note.

Joshi, B. L., and Rose, L. E. 1966. Democratic innovations in Nepal: A case study of political acculturation. Univ of California Press.

Kandlikar, M., and Risbey, J. 2000. Agricultural impacts of climate change: if adaptation is the answer, what is the question? *Climatic Change* 45(3): 529-539.

Khanal, U., Wilson, C., Hoang, V. N., & Lee, B. (2018). Farmers' adaptation to climate change, its determinants and impacts on rice yield in Nepal. *Ecological Economics*, 144, 139-147.

Kebede, Y., Gunjal, K., and Coffin, G. 1990. Adoption of new technologies in Ethiopian agriculture: The case of Tegulet-Bulga district Shoa province. *Agricultural Economics* 4(1):27-43.

Kimball, B. A., Kobayashi, K., and Bindi, M. 2002. Responses of agricultural crops to free-air CO 2 enrichment. *Advances in Agronomy* 77:293-368.

Le Treut, H., Somerville, R., Cubasch, U., Ding, Y., Mauritzen, C., Mokssit, A.., and Prather, M. 2007. Historical overview of climate change. Found at https://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter1.pdf, Accessed March 5, 2015.

Leiserowitz, A. 2007. International public opinion, perception, and understanding of global climate change. *Human Development Report*, 2008.

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., and Naylor, R. L. 2008. Prioritizing climate change adaptation needs for food security in 2030. *Science*, 319(5863):607-610.

Long, S. P., Ainsworth, E. A., Leakey, A. D., Nösberger, J., and Ort, D. R. 2006. Food for thought: Lower-than-expected crop yield stimulation with rising CO_2 concentrations. *Science*, 312(5782):1918-1921.

Lorenzoni, I., and Pidgeon, N. F. 2006. Public views on climate change: European and USA perspectives. *Climatic Change* 77(1-2):73–95.

Lorenz, S., Dessai, S., Forster, P. M., and Paavola, J. 2017. Adaptation planning and the use of climate change projections in local government in England and Germany. *Regional Environmental Change* 17(2): 425-435.

Mader, T. L., Johnson, L. J., and Gaughan, J. B. 2010. A comprehensive index for assessing environmental stress in animals. *Journal of Animal Science*, 88(6), 2153-2165.

Manandhar, S., Pandey, V. P., and Kazama, F. 2014. Assessing suitability of apple cultivation under climate change in mountainous regions of western Nepal. *Regional Environmental Change* 14(2):743-756.

Manandhar, S., Pandey, V. P., Ishidaira, H., and Kazama, F. 2013. Perturbation study of climate change impacts in a snow-fed river basin. *Hydrological Processes* 27(24): 3461-3474.

Manandhar, S., Vogt, D. S., Perret, S. R., and Kazama, F. 2011. Adapting cropping systems to climate change in Nepal: A cross-regional study of farmers' perception and practices. *Regional Environmental Change* 11(2): 335–348.

Macchi, M., Gurung, A. M., and Hoermann, B. 2015. Community perceptions and responses to climate variability and change in the Himalayas. *Climate and Development,* 7(5), 414-425.

Mendelsohn, R. 2000. Measuring the effect of climate change on developing country agriculture. In: Two essays on climate change and agriculture: A developing country perspective, Economic and Social Development Paper 145: 2–31. Food and Agriculture Organization of the United Nations, Rome.

Maharjan, K. L., and Joshi, N. P. 2013. Effect of climate variables on yield of major food-crops in Nepal: A Time-Series Analysis. In *Climate Change, Agriculture and Rural Livelihoods in Developing Countries* 127-133: Springer Japan.

Maddison, D. 2007. The Perception of and Adaptation to Climate Change in Africa 4308: World Bank Publications.

Makondo, C. C., Chola, K., and Moonga, B. 2014. Climate change adaptation and vulnerability: A case of rain dependent small-holder farmers in selected districts in Zambia. *American Journal of Climate Change* 3(04): 388.

Maplecroft, V. 2011. *Climate change vulnerability index 2016*. Climate Change and Environmental Risk Atlas.

Measham, T. G., Preston, B. L., Smith, T. F., Brooke, C., Gorddard, R., Withycombe, G., and Morrison, C. 2011. Adapting to climate change through local municipal planning: barriers and challenges. *Mitigation and Adaptation Strategies for Global Change*, 16(8), 889-909.

Moser, Susanne C. and Pike, C. 2015. Community engagement on adaptation: Meeting a growing capacity need. *Urban Climate*, 14(Part 1): 111-115, DOI 10.1016/j.uclim.2015.06.006.

Moore, F. C., and Lobell, D. B. 2014. Adaptation potential of European agriculture in response to climate change. *Nature Climate Change* 4(7): 610.

Nature. 2018. *Climate Change*. Found at https://www.nature.com/subjects/climate-change, accessed on July 22, 2018.

Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M. S., and Bernabucci, U. 2010. Effects of climate changes on animal production and sustainability of livestock systems. *Livestock Science* 130(1): 57-69.

Naskar, S., Gowane, G. R., and Chopra, A. 2015. Strategies to improve livestock genetic resources to counter climate change impact. In *Climate Change Impact on Livestock: Adaptation and Mitigation* (pp. 441-475). Springer India.

Nogués-Bravo, D., Araújo, M. B., Errea, M. P., and Martinez-Rica, J. P. 2007. Exposure of global mountain systems to climate warming during the 21st Century. *Global Environmental Change*, 17(3-4), 420-428.

Norton, A., and Leaman, J. 2004. The day after tomorrow: Public opinion on climate change. MORI Social Research Institute, London.

Nielsen, J.O and Reenberg A. 2010. Cultural barriers to climate change adaptation: A case study from Northern Burkina Faso. *Global Environmental Change* 10: 142–152.

Nelson, G. C., Rosegrant, M. W., Koo, J., Robertson, R., Sulser, T., Zhu, T., and Lee, D. 2009. *Climate Change: Impact on Agriculture and Costs of Adaptation*. Intl Food Policy Res Inst.

Nightingale, A. J. 2017. Power and politics in climate change adaptation efforts: Struggles over authority and recognition in the context of political instability. *Geoforum,* 84, 11-20

Ojha, H. R., Ghimire, S., Pain, A., Nightingale, A., Khatri, D. B., and Dhungana, H. 2016. Policy without politics: technocratic control of climate change adaptation policy making in Nepal. *Climate Policy*, 16(4), 415-433.

Ostrom, E. 2005. *Self-governance and forest resources*. Terracotta reader: A market approach to the environment, 12.

Onta, N., and Resurreccion, B. P. 2011. The role of gender and caste in climate adaptation strategies in Nepal: emerging change and persistent inequalities in the far-western region. *Mountain Research and Development*, 31(4), 351-356.

Quisumbing, A.,and Pandolfelli, L. 2008. *Promising approaches to address the needs of poor female farmers*. Washington, DC: International Food Policy Research Institute.

Palazzoli, I., Maskey, S., Uhlenbrook, S., Nana, E., and Bocchiola, D. (2015). Impact of prospective climate change on water resources and crop yields in the Indrawati basin, Nepal. *Agricultural Systems*, 133, 143-157.

Pandey, R., and Bardsley, D. K. 2015. Social-ecological vulnerability to climate change in the Nepali Himalaya. *Applied Geography*, 64, 74-86.

Pandey, R. (2016). Human ecological Implications of climate change in the Himalaya: Investigating opportunities for adaptation in the Kaligandaki Basin, Nepal (Doctoral dissertation).

Parasai, R. B. and Shrestha, A. J (2006). A Perspective on Gender and Climate Change in Nepal. https://www.researchgate.net/profile/Rupa_Basnet_Parasai/publication/235675542_A_Perspective_on_Gender_and_Climate_Change_in_Nepal/links/0fcfd51276b5b8709b000000.pdf. Accessed July 15, 2018.

Paavola, J., and Adger, W. N. (2006). Fair adaptation to climate change. Ecological economics, 56(4), 594-609.

Perry M., Rosenzweig, C., and Livermore, M. (2005). Climate change, global food supply and risk of hunger. *Philosophical Transactions of the Royal Society B* 360, 2125–2138.

Polley, H.W., Briske D.D., Morgan J.A. 2013. Climate change and North American rangelands: Trends, projections, and implications. *Rangeland Ecology Management* 66:493–511.

Practical Action, (2009). Temporal and Spatial Variability of Climate Change Over Nepal (1976-2005). Practical Action, Kathmandu Office.

Preston, B.L., Westaway R.M.., Yuen, E.J. (2011) Climate adaptation planning in practice: an evaluation of adaptation plans from three developed nations. *Mitigation and Adaptation Strategies for Global Change* 16 (4):407–438.

Price, R. (2018). *Women-initiated measures to cope with environmental stresses and climate change in South Asia*." Accessed October 15, 2018. https://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/13595/Women-initiated_measures_to_cope_with_environmental_stresses_in_South_Asia.pdf?sequence=1.

Ravera, F., Martín-López, B., Pascual, U., and Drucker, A. (2016). The diversity of gendered adaptation strategies to climate change of Indian farmers: A feminist intersectional approach. *Ambio*, 45(3), 335-351.

Reddy, P. P. (2015). *Climate resilient agriculture for ensuring food security* (Vol. 373). New Delhi, India: Springer India.

Regmi, B. R. (2014). Identifying Operational Mechanisms for the Mainstreaming of Climate Change Adaptation in Nepal. https://flex.flinders.edu.au/file/5785eb64-b662-4916-8c19-d0b0a881d42b/1/Bima20RaRegmi-pdf.

Reid, P., and Vogel, C. 2006. Living and responding to multiple stressors in South Africa—Glimpses from KwaZulu-Natal. *Global Environmental Change*, 16(2), 195-206.

Risbey, J., Kandlikar, M., Dowlatabadi, H., and Graetz, D. 1999. Scale, context, and decision making in agricultural adaptation to climate variability and change. *Mitigation and Adaptation Strategies for Global Change* 4 (2):137-165.

Ruddell, D., Harlan, S. L., Grossman-Clarke, S., and Chowell, G. 2012. Scales of perception: public awareness of regional and neighborhood climates. *Climatic Change* 111(3-4): 581-607.

Rutt, R. L., and Lund, J. F. 2014. What role for government? The promotion of civil society through forestry-related climate change interventions in post-conflict Nepal. *Public Administration and Development*, 34(5), 406-421.

Schäfer, M. S., Ivanova, A., and Schmidt, A. 2014. What drives media attention for climate change? Explaining issue attention in Australian, German and Indian print media from 1996 to 2010. *International Communication Gazette*, 76(2), 152-176.

Schlenker, W., and Lobell, D. B. 2010. Robust negative impacts of climate change on African agriculture. *Environmental Research Letters* 5(1):014010.

Secor, A. 2010. Social surveys, interviews, and focus groups. *Research Methods in Geography: A Critical Introduction*, 6, 194.

Seo, S. N., Mendelsohn, R., Dinar, A., and Kurukulasuriya, P. 2009. Adapting to climate change mosaically: an analysis of African livestock management by agro-ecological zones. *The BE Journal of Economic Analysis and Policy*, 9(2).

Silanikove, N. 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. *Livestock Production Science*, 67(1-2), 1-18.

Sharma, E., Chettri, N., Tse-Ring, K., Shrestha, A. B., Jing, F., Mool, P., and Eriksson, M. 2009. Climate change impacts and vulnerability in the Eastern Himalayas. Accessed October 18,2018. http://agris.fao.org/agris-search/search.do?recordID=XF2016041125.

Shah, U. B., & Padheria, M. M. (1993). *Role of Women in Agriculture*. Found at http://www.gjoee.org/papers/628.pdf, accessed October 12, 2018.

Shi, J., Visschers, V. H., Siegrist, M., and Arvai, J. 2016. Knowledge as a driver of public perceptions about climate change reassessed. *Nature Climate Change*, 6(8), 759.

Shiferaw, B., and Holden, S. T. 1998. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: a case study in Andit Tid, North Shewa. *Agricultural Economics*, 18(3), 233-247.

Shrestha, U. B., Gautam, S., and Bawa, K. S. 2012. Widespread climate change in the Himalayas and associated changes in local ecosystems. *PLoS One*, 7(5), e36741.

Shrestha, A. B., and Aryal, R. 2011. Climate change in Nepal and its impact on Himalayan glaciers. *Regional Environmental Change*, 11(1), 65-77.

Shrestha, U. B., and Bawa, K. S. 2014. Impact of climate change on potential distribution of Chinese caterpillar fungus (Ophiocordyceps sinensis) in Nepal Himalaya. PLoS one, 9(9), e106405.

Shukla, R., Chakraborty, A., Sachdeva, K., and Joshi, P. K. 2018. Agriculture in the western Himalayas–an asset turning into a liability. *Development in Practice*, 28(2), 318-324.

Shukla, R., Sachdeva, K., and Joshi, P. K. (2018). Demystifying vulnerability assessment of agriculture communities in the Himalayas: a systematic review. *Natural Hazards*, 91(1), 409-429.

Shukla, R., Sachdeva, K., and Joshi, P. K. 2016. Inherent vulnerability of agricultural communities in Himalaya: A village-level hotspot analysis in the Uttarakhand state of India. *Applied Geography*, 74, 182-198.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., At, K. B., and Miller, H. L. 2007. IPCC, 2007: The physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change.

Smith, N., and Leiserowitz, A. 2012. The rise of global warming skepticism: Exploring affective image associations in the United States over time. *Risk Analysis*, 32(6):1021-1032.

Smith, T. F., Preston, B., Brooke, C., Gorddard, R., Abbs, D., McInnes, K., ... and Measham, T. G. 2009. Managing coastal vulnerability: new solutions for local government. *In Integrated Coastal Zone Managem*ent (pp. 331-340). Wiley-Blackwell Oxford, UK.

Statistics, L. 2018.Testing for normality. Retrieved from. https://statistics.laerd.com/

Steiner, J. L., Briske, D. D., Brown, D. P., and Rottler, C. M. 2018. Vulnerability of Southern Plains agriculture to climate change. *Climatic Change*, 146(1-2), 201-218.

Steentjes, K., Pidgeon, N. F., Poortinga, W., Corner, A. J., Arnold, A., Böhm, G., ... and Sonnberger, M. 2017). *European Perceptions of Climate Change* (EPCC): Topline findings of a survey conducted in four European countries in 2016.

Thomas-Slayter, B., and Bhatt, N. 1994. Land, livestock, and livelihoods: Changing dynamics of gender, caste, and ethnicity in a Nepalese village. *Human Ecology*, 22(4), 467-494.

U.S. National Aeronautics and Space Administration (NASA). 2018. Annual Global Analysis for 2017, Accessed October 2018. Found at https://www.giss.nasa.gov/research/news/20180118/NOAA-NASA_Global_Analysis-2017.pdf.

U.S. National Oceanic and Atmospheric Administration (NOAA). 2018. *Climate.* https://www.noaa.gov/climate, accessed October 15, 2018.

U.S. National Oceanic and Atmospheric Administration (NOAA). 2019. *Global* Climate https://www.ncdc.noaa.gov/sotc/global/20190. Accessed Feb 2, 2019.

Uprety, Batu 2018. *Localizing Climate Change Adaptation*, found at https://www.spotlightnepal.com/2018/04/22/localising-climate-change-adaptation/, retrieved on 10/25/18.

United Nations Development Program (UNDP) (2011). National Adaptation Program of Action – NAPA. Retrieved from www.undp.org.np/energy/projects/napa/index.php?ProgramID=89, Accessed July 15, 2018.

United Nations Framework Convention on Climate Change (UNFCCC). 2014. Glossary of climate change acronyms, Retrieved October 5, 2017.

United Nations Framework Convention on Climate Change (UNFCCC). 2004. The convention and Kyoto Protocol, www.unfccc.int/resource/convkp/html, Accessed October 28,2018.

Uprety, Y., Shrestha, U. B., Rokaya, M. B., Shrestha, S., Chaudhary, R. P., Thakali, A., and Asselin, H. 2017. Perceptions of climate change by highland communities in the Nepal Himalaya. *Climate and Development* 1-13.

Uddin, M. N., Bokelmann, W., and Entsminger, J. S. 2014. Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh. *Climate* 2(4): 223-241.

Vedwan, N., & Rhoades, R. E. (2001). Climate change in the Western Himalayas of India: a study of local perception and response. *Climate research*, 19(2), 109-117.

Weber, E. U., and Stern, P. C. 2011. Public understanding of climate change in the United States. *American Psychologist*, 66(4), 315.

Wolf, J., and Moser, S. C. 2011. Individual understandings, perceptions, and engagement with climate change: insights from in-depth studies across the world. Wiley Interdisciplinary Reviews: *Climate Change*, 2(4): 547-569.

Xu, J., and Grumbine, R. E. 2014. Building ecosystem resilience for climate change adaptation in the Asian highlands. Wiley Interdisciplinary Reviews: *Climate Change*, 5(6), 709-718.

Xu, J., Grumbine, R. E., Shrestha, A., Eriksson, M., Yang, X., Wang, Y. U. N., and Wilkes, A. (2009). The melting Himalayas: cascading effects of climate change on water, biodiversity, and livelihoods. *Conservation Biology*, 23(3), 520-530.

Yadav, B. D., Bigsby, H., and MacDonald, I. 2015. How can poor and disadvantaged households get an opportunity to become a leader in community forestry in Nepal? *Forest Policy and Economics*, 52, 27-38.

Yu, H., Wang, B., Zhang, Y. J., Wang, S., and Wei, Y. M. 2013. Public perception of climate change in China: results from the questionnaire survey. *Natural Hazards*, 69(1):459-472.