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Impacts of Climate Change on Farm Based Livelihood: A Study of Panchkhal

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Abstract

Agriculture serves as the mainstay of Nepal's economy, sustaining livelihoods for a significant portion of the population and contributing substantially to Gross Domestic Product (GDP). This study conducted in Panchkhal Municipality of Kavrepalanchok district, employed a qualitative approach of research to explore lived experience of farmers regarding the impacts of climate change on their livelihoods. Through the use of both primary and secondary data, the research finds that climate change has caused a number of problems for the farmers in Panchkhal, such as reduced water availability due to drying up of small streams and disappearance of springs affecting the rain-fed farming. Additionally, farmers grapple with rising incidences of pests and diseases in crops, health problems associated with pesticide use, lower productivity, flooding, and a move away from farming. The two biggest effects that stood out among them were the scarcity of water and the increase in diseases and pests in crops. The study also underscores farmers' heightened awareness of

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climate change impacts and extreme weather events with a particular emphasis on the perceptible decrease in rainfall frequency and volume, along with delayed monsoon onset.

Introduction

Climate change poses a significant threat to global stability and agricultural sustainability, with shifting weather patterns and rising sea levels threatening food production worldwide. Scientists agree that burning fossil fuels is the main cause of climate change, which has several negative effects including rising sea levels, abnormal weather, and higher temperatures (National Aeronautics and Space Administration [NASA], 2019). Despite broad scientific agreement on climate change mitigation, communities and ecosystems around the world are already experiencing the effects of climate change, which are affecting water supplies, agriculture yields, forests, and oceans (World Wildlife Fund [WWF], 2018). Urgent action is required to counteract climate change's far-reaching impacts on human livelihoods and security as its effects escalate (UN, 2019).

National Aeronautics and Space Administration (2019) defines climate change as: "a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth’s atmosphere. These phenomena include the increased temperature trends described by global warming, but also encompass changes such as sea level rise; ice mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events". Climate is the average of weather conditions over several decades. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system (WMO, 2019). Geoscientists monitor modern climate conditions from 1880 AD to the present in part by taking direct measurements of weather data i.e., air temperature, rainfall and snowfall, wind speed, cloudiness, and so on and averaging those over at least a 30 year period (American Geosciences Institute [AGI], 2019).

The increase in greenhouse gases (GHGs) due to human activities, notably from burning fossil fuels, is a major driver of climate change (Maharjan & Joshi, 2013). Key findings from the WMO (2019) statement underscore the alarming trends in warming, GHG concentrations, sea-level rise, and polar ice loss. Human activities have caused approximately 1.10°C of global warming above pre-industrial levels. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2018). The National Academy of Science (NAS), the Intergovernmental Panel on Climate Change (IPCC) and WMO have all identified climate change as an urgent threat caused by humans that must be addressed (WWF, 2018). The 28th Conference of the Parties (COP28) climate summit marked a crucial milestone in accelerating global climate action, emphasizing the urgent need to transition from fossil fuels to renewables by 2030. In a display of international unity, representatives from nearly 200 Parties convened in Dubai to finalize the world's inaugural 'global stocktake.' This historic decision aims to intensify climate action before 2030, with the overarching goal of maintaining the global temperature increase below 1.5°C by 2100 (UNFCCC, 2023).

Climate change presents a myriad of challenges, with its impacts already felt by communities and ecosystems worldwide (UN, 2019). Its effects are extensive, harming livelihoods and human security. They range from falling food harvests to uncontrolled forest fires to increasing acid rains. This worldwide phenomenon is uncontrollably affecting economies, changing weather patterns, and escalating catastrophes. The most vulnerable groups will be disproportionately affected if global average surface temperature rises above 3°C this century if immediate action is not taken. Additionally, there are major economic and sociopolitical constraints brought about by climate change, with drought being a serious threat to future agricultural productivity and food security being jeopardized in many African countries (WMO, 2019).

People throughout the world who depend on agriculture for their employment are particularly vulnerable to the devastating effects of climate change. It is anticipated that the consequences of climate change on agricultural productivity and livelihoods would differ throughout nations and areas and will become more pronounced over time (FAO, 2016). Nepal, where the bulk of the populace makes their living through rain-fed farming techniques is extremely vulnerable to the effects of climate change, despite its little contribution to greenhouse gas emissions (International Centre for Integrated Mountain Development [ICIMOD], 2019). This affects important sectors like agriculture, forestry, water resources, and energy (MoE, 2012).

With Nepal's 4th position in terms of global climate change vulnerability (Eckstein et al., 2018) it is very much an worrying situation for Nepal whose majority of population rely on rainfed farming and forest based natural resources for livelihood (Paudel, 2016; FAO, 2019). Due to the fact that impacts of climate change are being seen, Nepal should focus on adopting measure to reduce and adapt to the impacts of climate change. However, farmers have not been able to afford adaptation measures due to various causes. Since researches have shown that effects of climate change in livelihood of farmers have been manifested and adaptation is essential to cope with climate change, it is worth understanding the impact and adaptation measures taken by farmers to maintain their livelihood. Given the seriousness of the climate change impact in agriculture, this study aims to explore the impacts of climate change on farming-based livelihoods in Panchkhal Municipality of Kavrepalanchok district, Nepal.

Through the use of a qualitative research design the study will look at farmers' perceptions of the effects of climate change on various aspects of farming. By doing that, this article seeks to contribute to a deeper understanding of the complex dynamics of climate change impacts in agriculture and inform policy interventions to support vulnerable farming communities.

The study is carried out in the Panchkhal municipality, which is located in Nepal's central hills in the Kavrepalanchok district. Kavre's location between the Mahabharat and Lesser Himalaya hills results in a variety of agro-climatic changes. The selection of this area is informed by Kavrepalanchok districts' vulnerability to climate change, as indicated in the National Adaptation Programme of Action (NAPA) document (MoE, 2010), and the growing prominence of commercial agricultural practices. Given the area's reliance on agriculture and the observed water scarcity linked to climate change, farmers face a substantial challenge to farming with the focus on farming based livelihood.

Review of the Literature

Farming has always been the foundation of human civilization, forming communities and supplying food. But this way of life is seriously threatened by climate change. An increasing amount of scholarly literature explores the complex effects of climate change on livelihoods centered on agriculture. These studies examine the ways that variations in temperature, precipitation patterns, and extreme weather affect water availability, interfere with agricultural productivity, and heighten the spread of pests and diseases. This review aims to identify and synthesize the most significant challenges faced by farmers from the study of related literatures.

Food security and climate change concerns are intertwined as the effects of climate change reduce natural resources' ability to support the world's expanding population (FAO, 2019a). Recent gains in eradicating hunger and malnutrition are being undermined by increasingly severe climate extremes, contributing to a reversal of the positive trends observed earlier (FAO, 2016). Extreme weather patterns and climate variability make food insecurity worse, especially in nations where agriculture is the primary source of income. This results in serious food crises, mainly in Asia and Africa (WMO, 2019). According to Saleth et al. (2011), climate change modifies agricultural systems by causing either an excess or a shortage of rainfall, which in turn causes floods, waterlogging, droughts, and crop wilting. Changes in temperature, precipitation, fertilization with carbon dioxide, increased weather variability, and variations in surface water runoff are just a few of the ways that climate change affects agricultural output (World Bank, 2007). Agriculture accounts for about 70% of the world's freshwater use, and projections show that by 2050, the world's water needs will have increased by 50% to meet rising food demands (FAO, 2016; IAEA, 2016). Furthermore, the livelihoods of the poor and marginalized are disproportionately affected by climate change and extreme weather events impacting their rights and capabilities (Aniah et al., 2016).

Drought becomes a serious danger to future food security in the context of climate change, requiring better drought planning, monitoring, and mitigation measures (Wu et al., 2019; Hayes et al., 2011). However, there are still little attempts to lessen the effects of future droughts, which emphasizes the need for paradigm shifts in approaches to managing drought risk (Reid et al., 2006; Li et al., 2009; Mishra and Singh, 2010 as cited in Wu et al., 2019). According to Mendelsohn (2012), crops and livestock are extremely vulnerable to climatic differences between seasons, which cause farmers all over the world to suffer significant annual losses. However, because of their labor-intensive practices and lower latitudinal locations, the effects of global warming on agriculture in underdeveloped nations are still unknown (Maharjan & Joshi, 2013). Growing precipitation extremes threaten to degrade and destroy vital agricultural soil and water resources, making rainfed and irrigated agriculture difficult to practice without creative conservation strategies (Hatfield et al., 2014).

The majority of people in many developing nations make their living primarily from agriculture, with smallholder farmers being especially sensitive to the effects of climate change (International Fund for Agricultural Development [IFAD], 2019a). The problems that rural populations face are made worse by declining agriculturally viable land and environmental degradation (Commission for Africa, 2005 as cited in Calzadilla et al., 2011). Climate change can cause an increase in diseases and pests, which can have a major impact on agricultural productivity (FAO, 2016). The dynamics of ecosystems are impacted by climate change, which may throw off crop-pollinator synchrony and favor invading species and pests (FAO, 2015) . Farmers' livelihoods are under risk due to reduced crop output and biodiversity caused by climate change, extreme weather, and pest proliferation (Müller-Kuckelberg, 2012). The overuse of agrochemicals damages soil health and water quality, aggravating environmental deterioration (Ghorbani et al., 2010). A major factor in raising agricultural output is technological advancements like better crop types and irrigation systems (Paudel, 2016a). Agriculture is threatened by rising evaporation and altered rainfall patterns, a primary conduit of climate change impacts (FAO, 2019a). Integrated methods to sustainability and climate resilience are required because agriculture directly contributes significantly to land-use changes, deforestation, and greenhouse gas emissions (IPCC, 2017).

The variable topography of Nepal results in a range of meteorological conditions, with significant orographic effects affecting the dynamics of precipitation (Dixit, 2013). Despite obstacles, Nepal's agricultural diversity presents opportunities for growth and enables the production of a variety of crops across the nation (IFAD, 2019b). Paudel (2016b) notes that despite Nepal's varied terrain, there are signs of climate change in areas ranging from the Terai to the Himalayas. Agricultural difficulties have been made worse by the increased use of inorganic fertilizers, which has resulted in a decline in soil quality, especially in the lower elevations of the Indrawati Basin (Pradhan et al., 2015). Nepal's complicated geography and low development status make it more vulnerable to climate change, which will have an effect on the country's water, energy, forestry, and agriculture sectors (Wang et al., 2009). The necessity for adaptive measures in agriculture, such as crop diversification and organic farming, is emphasized by initiatives stated in Nepal's NAPA plan (MoE, 2010).

Nepal's agriculture has a great deal of challenges due to climate variability, which are made worse by the country's predominance of rain-fed farming systems and farmers' low ability for adaptation (Gentle & Maraseni, 2012; Adhikari, 2018). Falling winter precipitation and inadequate groundwater replenishment have significantly impacted water resource management for agriculture in western regions in Nepal, increasing drought conditions and damaging hill agricultural systems (Adhikari, 2018; Paudel, 2016a). Furthermore, diseases and pests brought on by climate change pose a greater threat to the yield of food crops. Farmers' understanding of climate change is crucial for adaptation decision-making, although issues such as poverty and illiteracy hamper their adaptive potential, reflecting challenges widespread in developing countries (Budhathoki & Zander, 2019; Chalise et al., 2015).

The reviewed literatures show consensus that agriculture is an important source of livelihood in many developed and developing countries, and climate change is likely to have severe consequences on the farming-based livelihood. Literatures point at food security in the countries with agricultural systems that are highly sensitive to rainfall and temperature variability and where the livelihood of a high proportion of the population depends on agriculture. Precipitation and temperature are widely accepted as having significant influence on crop production. Many livelihoods are directly climate sensitive, such as rain fed agriculture. Along with this, there are also ample literatures on how Nepal is likely to be affected by climate variability in the context of heavy dependence of its population on agriculture that lack irrigable land.

Literatures also indicate the challenges Nepal has in ensuring effective agriculture production across the country due to the high degree of spatial and temporal climate variability and rainfed agriculture system. And they also stress on necessity of effective adaptation measures. However, as many literatures agree that although climate change is a universal phenomenon, its indicators and manifestations are entirely local. This means the impact will differ from place to place. In view of Nepal's distinct geographies, diverse climatic conditions, and heavy dependence on rainfed agriculture, this study intends to explore location specific manifestation of climate change and its impact on the farmers' livelihood in a particular location. Given the intricate nature of climate change, more detailed information is needed on the impacts of climate change on agricultural systems so that effective adaptation options can be appropriately targeted. So, this study aims to fulfill this gap of location specific knowledge on climate change by undertaking research in the area of Panchkhal Municipality of Kavrepalanchok district in the midhill of Nepal which focuses on impacts of climate change on livelihood of farmers.

Research Methodology

The study conducted in the year 2019 uses a qualitative approach in which data were collected by the researcher from his or her interactions with the participants. The aim was to understand farmers' lived experiences with the effects of climate change on farm-based livelihoods by exploring how farming is affected by climate change. A variety of primary and secondary data sources are used. Secondary data consists of literature reviews and document analyses. To comprehend patterns of climate change, trend analysis of temperature and precipitation data from 1980 to 2023 was done by obtaining data from Department of Hydrology & Meteorology (DHM). Field observation, face-to-face interviews with farmers, focused group discussions, and key informant interviews with persons from pertinent government and non-governmental agencies are the methods employed in collecting primary data. Participants were chosen using a combination of purposeful and snowballing sampling techniques to ensure representation from a range of farming contexts within the study area. Altogether, the study engaged with 25 farmers through interviews, conducted nine Key Informant Interviews (KIIs), and facilitated four focused group discussions involving both concerned agencies and farmers in order to assess the impact of climate change on farm based livelihood.

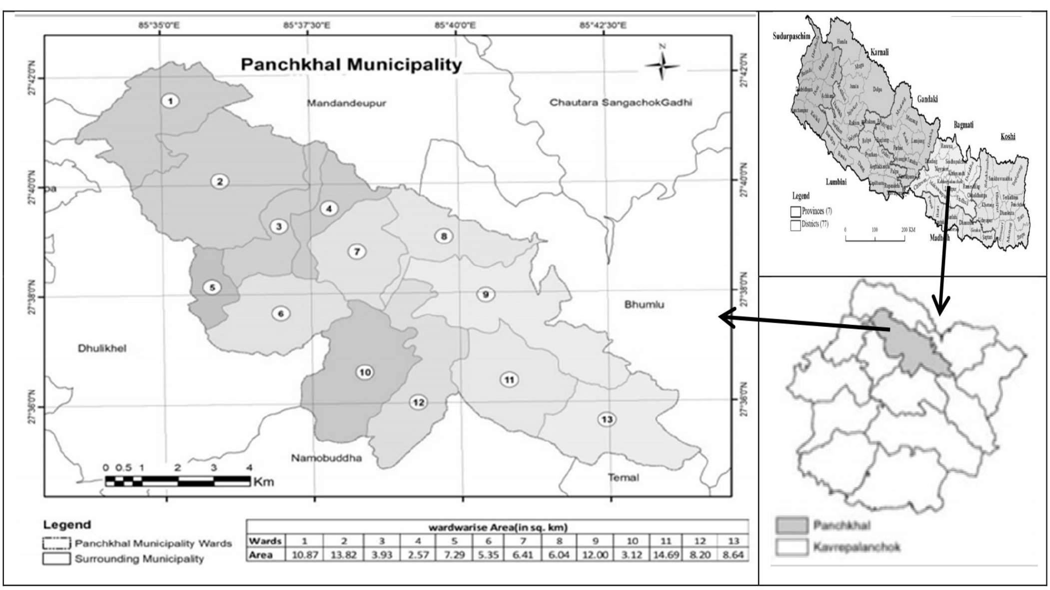
Findings and Discussion

General Description of the Study Area

The Panchkhal municipality is located in Kavrepalanchok district of Bagmati Province, Nepal (figure 1), It is made up of 13 wards and has a total area of 102.95 km^2. Elevation in the study area ranges from 594m at Koshidakha to 1612m at Anaikot View Tower (Panchkhal Municipality, 2019). The Arniko Highway, which passes through the center of the municipality, serves as a crucial link between Kathmandu and the China border in Kodari of Sindhupalchok, facilitating trade and providing access to broader markets in Dhulikhel, Banepa, Bhaktpur, and Kathmandu for agricultural products from Panchkhal.

Figure 1

Location Map of Panchkhal Municipality



Source: This map demonstrates the location of Panchkhal Municipality which is adopted from Panchkhal Municipality (2019)

Located 45 km east of Kathmandu and 15 km southeast of Dhulikhel, Panchkhal municipality encompasses the largest flat land area in the Kavrepalanchok district.

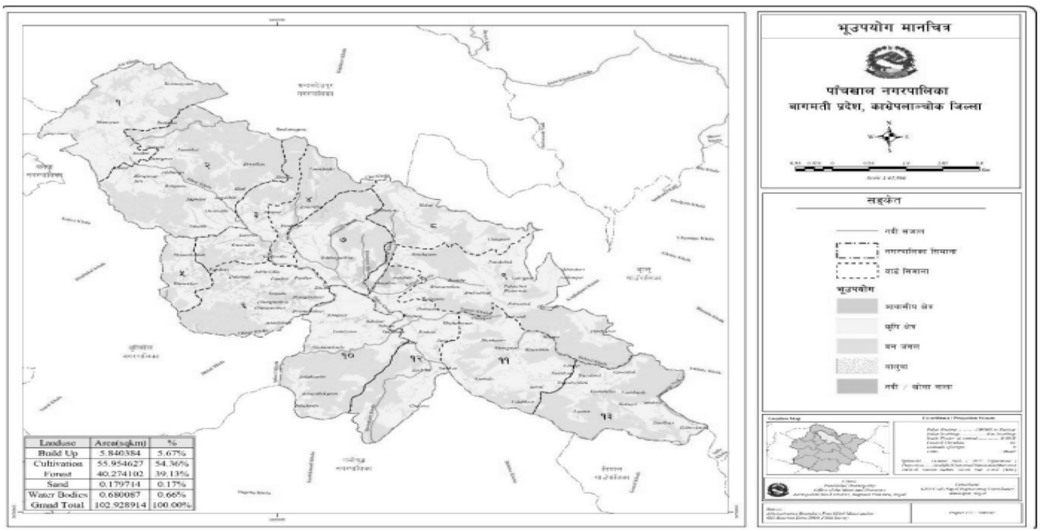
Furthermore, there are portions of sloping terrain in Sathighar Bhagawati, Anaikot, and Hoksebazaar. The Kavrepalanchok district, which is regarded as a location of considerable agricultural output, has a great deal of potential for farming and is a major supplier of the agricultural goods, mostly vegetables that are consumed in Kathmandu. With a focus on vegetable cultivation—a vital component of Nepal's Gross Domestic Product—Panchkhal hopes to become a city of agriculture (LTS International Limited, 2017).

Panchkhal Municipality experiences a diverse climatic and ecological landscape. The region is characterized by sub-tropical to temperate climate with dry winter and cool summer (Tiwari et al., 2020). The area's elevation and topography contribute to variations in climate and ecology, with higher elevations experiencing cooler temperatures and lower elevations being warmer. This area receives high rainfall due to the low pressure wind arriving from the Bagmati and Roshi watersheds of the district that fall in the rain shadow of the Mahabharat region (Panchkhal Municipality, 2019). Precipitation trends over 44 years show fluctuations in annual rainfall levels with average rainfall of 1155 mm. During the period year 1999 recorded the highest precipitation at 1676 mm, and 2015 witnessed the lowest at 699.7 mm. The average max temperature and average minimum temperature for the same 44 years period showed 28.28°C and 14.22°C respectively.

Panchkhal's commercial agriculture might be further enhanced by cooperative efforts with neighboring regions (GGGI, 2018). Over the course of four decades, traditional farming practices have changed as a result of a number of reasons, including the building of the Araniko highway, the creation of horticulture centres, and interventions by NGOs and INGOs (Adhikari, 2015). The change in Panchkhal towards the extensive cultivation of vegetable crops is indicative of this transformation. Major crops like rice, maize, and wheat occupy 75% of the land, with 61.76% of it being used for cultivation; nevertheless, vegetable agriculture has recently experienced a boom (Panchkhal Municipality, 2019).

Figure 2

Land Use Map of Panchkhal Municipality



Source: This map shows the Land use pattern of Panchkhal Municipality which is adopted from Panchkhal Municipality (2023). It shows the areas of forest, arable land, water, sand, and other topographical features of Panchkhal Municipality.

The land use pattern in the area comprises various categories, with arable land occupying the majority at 54.35%. Forested areas cover a substantial portion, accounting for 39.12% of the land, while residential areas constitute 5.67%. Rivers and streams contribute to 0.68% of the landscape, along with 0.17% of riverside sand areas (Panchkhal Municipality, 2023). Panchkhal Municipality comprises two distinct types of land - flatlands (Khet) and highlands (Bari). While flatlands benefit from easy irrigation access, highlands rely mainly on rain-fed agriculture. The cropping pattern varies based on land type and irrigation availability, with lowlands supporting three cropping patterns compared to highlands constrained to one or two crops per year (Paudel et al., 2011). Climate irregularities, particularly droughts, significantly impact crops in the highlands, necessitating fallow periods. In the low lands, agricultural practices have undergone modernization, marked by innovative farming techniques, intensive land use, and increased mechanization (Adhikari, 2015).

Water Availability in Panchkhal Municipality

There are hundreds of large and small rivers in the Kavrepalanchok district; some of the larger ones are the Sunkoshi, Indrawoti, Roshi, and Bagmati. Among these, the Sunkoshi and Indrawoti rivers, which have a combined watershed area of 742 km^2, border Panchkhal Municipality. The municipality's main irrigation sources include Jhiku Khola and Danfe Khola. The main supply of water comes from the Jhiku Khola, a tributary of the Sunkoshi River, however water is only available mostly during wet seasons of the year. In the summer, it almost completely dries up and experiences flash floods during rainy season. Local residents have observed a significant decline in the flow of Jhiku Khola. This decrease in flow extends to other perennial streams in the area, which have either become seasonal or completely dried up. Springs have also experienced diminished discharge, suggesting a correlation between spring discharge and stream flow (ICIMOD 2009a, as cited in Sharma & Gyawali, 2016). Consequently, inhabitants of the study area increasingly rely on traditional water sources such as Kuwa and local streams to meet their water needs.

Panchkhal Municipality's existing drinking water supply is insufficient. The Municipality intends to draw water from the Sunkoshi River in order to meet the increasing demand for drinking water (Ministry of Water Supply, 2019). People hope that after the project is completed, extra water may be used for irrigation on small family farms, increasing the area's agricultural output. The municipality relies on age-old irrigation techniques including Rajkulo, streams, and small canals due to a lack of well-managed irrigation infrastructure. Because water sources dry up over time, there are severe water shortages in some locations, especially in Upper and Middle Hokse. Many water springs have vanished in places like Salghari, Hokse, and Ojetar, leaving locals to handle their own or the community's water needs. These places are prime examples of this trend.

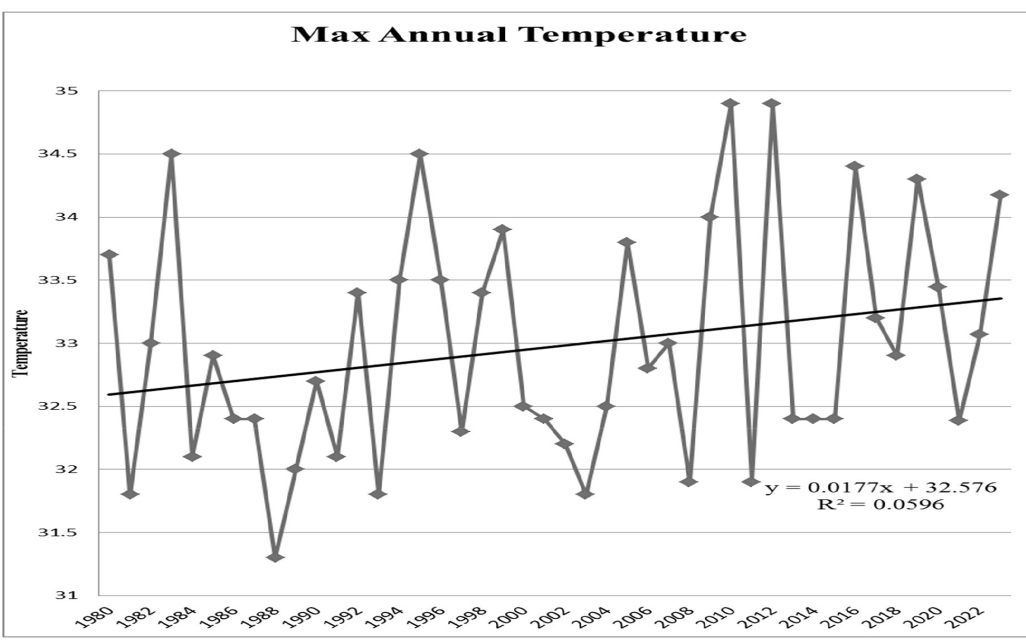
Status of Temperature and Precipitation in Panchkhal

The most pertinent climatic characteristics are annual temperature and precipitation. Temperature and rainfall are the most essential climatic variables often used for characterization of climate change and variability (Hayes et al., 2011). Therefore, to understand the climate change trend of Panchkhal, the study has analyzed the trend of temperature and rainfall data from 1980 to 2023 recorded at Panchkhal station which was received from Department of Hydrology & Meteorology. In some months in certain year, both maximum and minimum temperature data was not available. For the calculation purpose in this study, these data are entered in average of 44 years for that month. Similarly, the data for precipitation for some months were not available, for which average rainfall for that month from 44 years is calculated. For the whole year 2008, the data has been filled on average as the data was not available for the entire year.

DHM has analyzed the data from 93 weather measurement stations from 1971 to 2014 which found that the temperature increment is 0.056°C per year. Changes have also been observed in the frequency, amount and intensity of rainfall (JVS/GWP Nepal, 2017). Observed data shows steady warming and rise in the maximum temperature at an annual rate of 0.04 – 0.06°C. Studies also indicate that the observed warming trend is not uniform across the country. Warming is more pronounced in high altitude regions compared to the Terai and Siwalik hills (MoE, 2010).

Figure 3

Annual Maximum temperature 1980-2023 at Panchkhal valley during 1980-2023

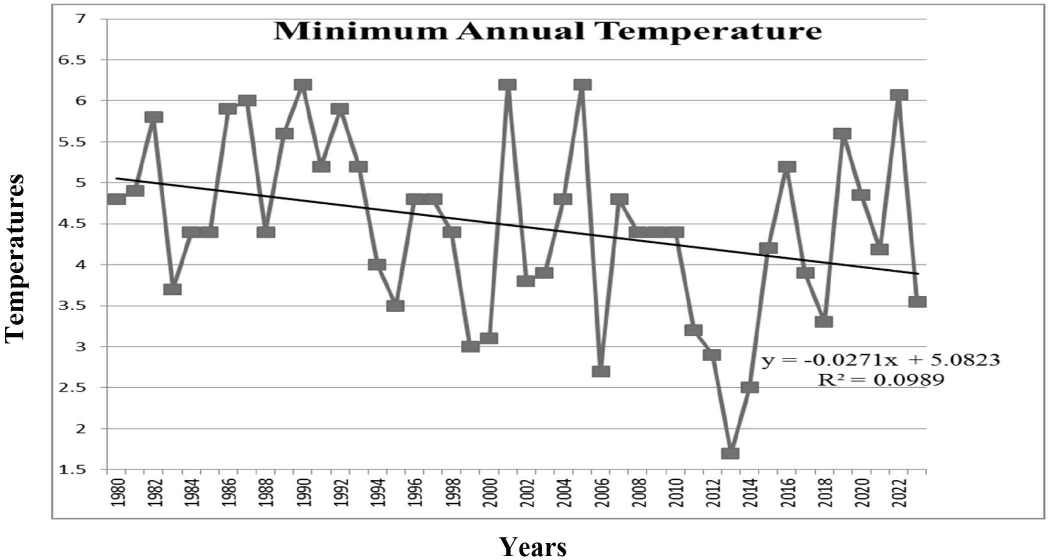


Source: This figure examines the linear trends and patterns over 44 years from 1980 to 2023 for maximum temperature. R^2 is a statistical measure that shows proportion of the variance in the temperature y over the independent variable years (x). Data adopted from Department of Hydrology and Meteorology (DHM).

Temperature data of four months April, May, June and July that experiences higher temperatures observed fluctuation in the maximum temperature between 27.9°C in April in 1981 and 34.9°C in June in 2010 and 2012, with few variations from year to year (Fig.3). There is a general trend of variability in maximum temperatures over the years, with random rises and drops. Figure 3 shows the maximum temperature has increased by 0.0177°C per year over 1980-2023. The linear regression analysis (R^2 =0.0596) indicates that the maximum temperature rise with time is statistically insignificant.

Figure 4

Annual Minimum Temperature at Panchkhal valley during 1980-2023

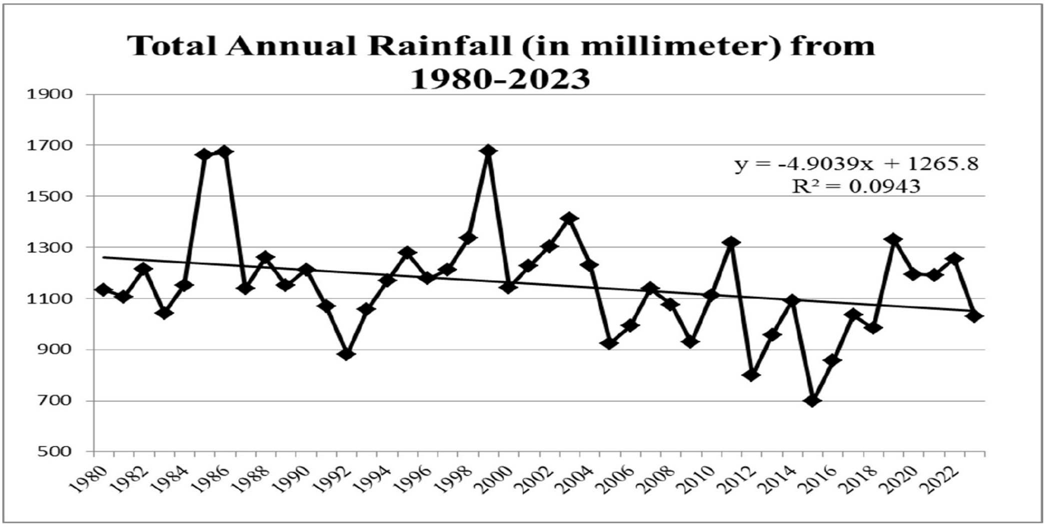


Source: This figure examines the linear trends over 44 years from 1980 to 2023 for minimum temperature. This linear regression analyzes the trend of minimum annual temperatures (y-axis) over the years (x-axis). Data adopted from Department of Hydrology and Meteorology (DHM).

During 1980 to 2023, the minimum annual temperature ranges from 1.7°C in 2013 to 6.2°C in 2001 and 2005; all in the month of January, indicating considerable variability. Similar to maximum temperature, there is no clear upward or downward trend in minimum temperatures over the years. While there are fluctuations, this doesn't appear to be a consistent trend in minimum temperatures over the entire period. Figure 4 shows the minimum temperature has dropped by 0.0271°C per year over 1980-2023. The linear regression analysis (R^2=0.0989) indicates that the minimum temperature drop with time is statistically insignificant.

Figure 5

Total Annual Rainfall at Panchkhal valley during 1980-2023



Source: The data depicted in this figure presents the annual rainfall patterns observed over a span of 44 years from the year 1980 to 2023 as recorded at the Panchkhal station which lies in the research area. It displays the linear relationship between annual rainfall (y-axis) and time (x-axis) using linear regression. Data adopted from Department of Hydrology and Meteorology (DHM).

Precipitation trend of 44 years indicates fluctuations in annual rainfall levels, with 1999 recording the highest precipitation at 1676 mm, while 2015 witnessed the lowest at 699.7 mm. When closely observed, the noticeable decline can be seen after 2004 until 2018. The annual rainfall didn't go above the year 2004 except for

2011. If the separation is made at 2004, the average rainfall until 2004 is 1236.98 mm and after 2004, from 2005 to 2018 the average rainfall is 994.5 mm which shows a remarkable drop in precipitation. MoE (2010) confirms that a general decline in pre-monsoon precipitation in far and mid-western Nepal, with a few pocket of declining rainfall in western, central and eastern regions have occurred. Conversely, the analysis of data from 166 stations across Nepal from 1976 to 2005 revealed an increasing trend in annual rainfall in eastern, central, western and far-western Nepal (MoE, 2010). In Panchkhal, in the period from 2019 to 2023, there is a visible escalation in rainfall quantities compared to the preceding period from 2005 to 2018. Specifically, 2019 emerges as the year with the substantial rainfall accumulation, reaching 1330.4 mm. These findings align with global climate scenario modeling which suggest that the impacts of climate change may be intense at high elevations and in regions with complex topography, as is the case in Nepal's mid-hills (Dixit, 2013).

According to the linear regression of rainfall data, there is a negative relationship of precipitation with time. In particular, it is expected that the precipitation will fall by roughly 4.9039mm for every increase in time. With a coefficient of determination (R^2) of 0.0943, the linear relationship with time can account for about 9.43% of the variability in precipitation. This implies that the model only partially explains the variation in precipitation, suggesting that precipitation variability may also be influenced by other factors not included in the model.

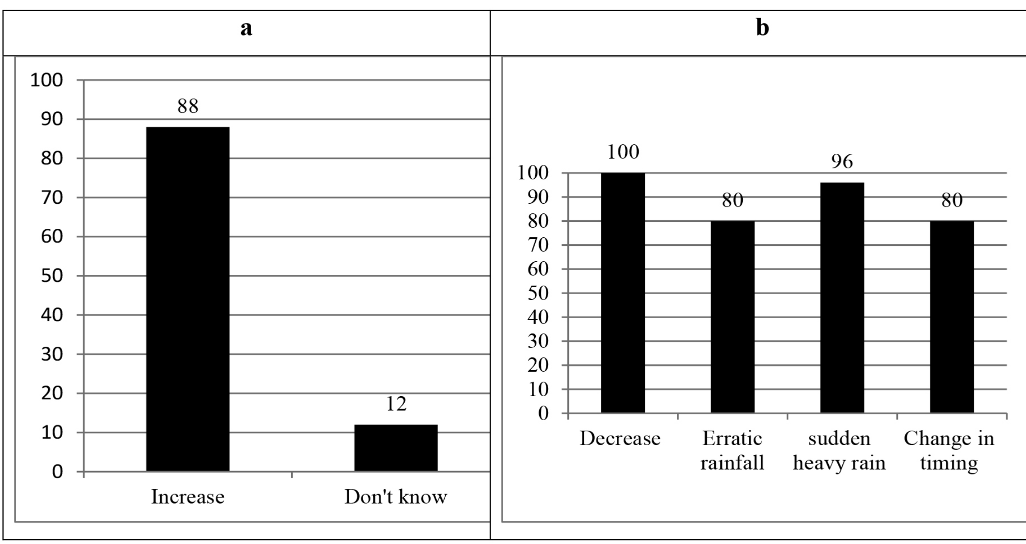
Changes in rainfall and other precipitation forms are critical factors in determining the overall impact of climate change. Rainfall is much more difficult to project than temperature. However, the total volume of precipitation is likely to increase by 1-2% per degree of warming (Clark, 2011). Although the data points to some annual variability, its applicability is too narrow to make a firm determination about the effects of climate change. Robust comprehension necessitates the combination of analysis of numerous climate variables with long-term, multi-regional information. There's evidence to show that regions that are already wet are likely to get wetter and the dry regions of the subtropics are likely to get drier. It is likely that in a warmer climate heavy rainfall will increase and be produced by fewer more intense events. This could lead to longer dry spells and a higher risk of floods (NASA, 2019).

Farmer's Perception of Climate Change

Understanding farmer's perception on climate change is important because their adaptation to climate change largely depends on their perception that climate is changing and likely to have impact in their farm. Timely and accurate perception is an important determinant of farmers' intentions and the choice of adaptation methods (Deressa et al. 2011, as cited in Abid et al., 2019). Comprehending climatic variability and extreme events are part of climate change is important in assessing the adaptation measures. This is particularly so for agriculture, which is vulnerable to irregular or extreme conditions such as more frequent droughts and deviations from 'normal' growing season (Smit & Skinner, 2002). This understanding is also important for authorities to establish effective adaptation policies (Abid et al., 2019).

Figure 6

Farmers' Perception on Rise in Temperature (a) and Changes in Rainfall Pattern (b) in Panchkhal (in %)



Source: These figures show the farmers' perception of rise in temperature and changes in rainfall pattern in Panchkhal. This is based on the data collected through field survey.

Farmers' perceptions of climate change and variability coincide with the actual data that demonstrate fluctuation in annual rainfall and slight upward trend of temperatures as mentioned above. Over the past fifteen years, majority of farmers have noted shifts in local weather patterns, with 88 percent experiencing heightened temperatures during summer days. To cope with the scorching sun, many farmers have adapted their working hours, preferring to toil in the fields during cooler morning and evening hours. Some have even experienced discomfort from rising nighttime temperatures, resulting in increased sweating.

The precipitation is more realized than temperature by the farmers. All farmers, key informants and focused group discussion respondents agreed on decrease in rainfall amount and frequency. This might be due to the fact that farmers are more concerned about rain than temperature. Notably, 80 percent of farmers have cited concerns about sudden, heavy downpours disrupting cultivation and harvest seasons. Farmers have also realized that the rainfall timing has changed. Onset of monsoon is delayed by almost two months which deferred the plantation of crops contingent upon monsoon rain. Regmi & Bhandari (2013) also states that over the past few years, the delay in monsoon season experienced in Nepal has changed the cropping pattern and crop maturity period. Overall, farmers perceive a diminishing support from annual rainfall for crop production during both the rainy and winter seasons. Such perceptions of farmers' on changes in climate-related parameters like rainfall, temperature and wind may influence the choice of adaptation measures in different ways (Waibel et al., 2018). Current discussions centered on the connection between climate change drivers and agricultural adaptation acknowledge that climate change encompasses not only long-term average condition changes but also variations in growing season conditions from year to year and the frequency and intensity of extreme weather events (Smit & Skinner, 2002).

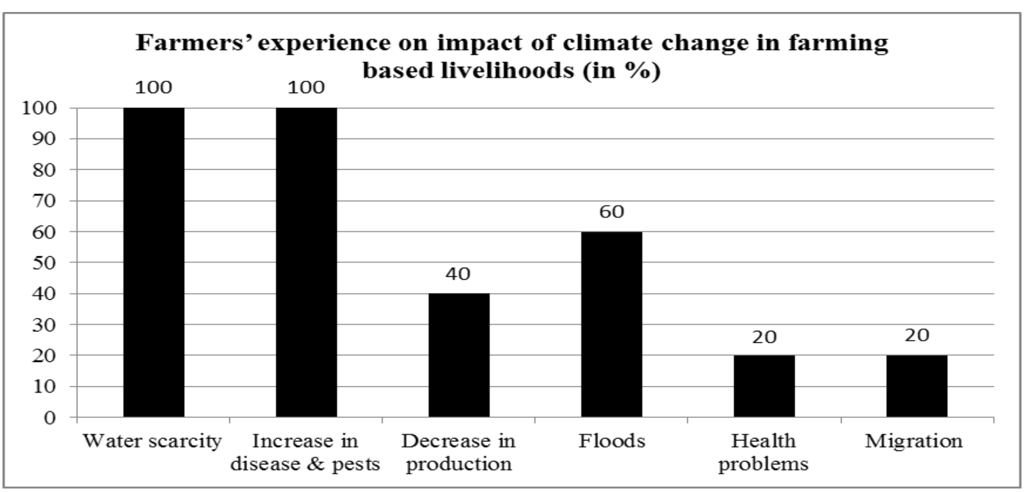
Impact of Climate Change in Farming

In recent years, climate change has shown unprecedented consequences in Nepalese agriculture, posing greater risks especially to small and marginal farmers practicing subsistence agriculture. There are increase of mean temperature; changes in rainfall patterns; increased variability both in temperature and rain patterns; changes in water availability; the frequency and intensity of 'extreme events'. The extent of these impacts will depend not only on the intensity and timing of the changes but also on their combination, which are more uncertain, and also depends on local conditions (FAO, 2013). The most immediate impacts of climate change will be the increased variability of rainfall, higher temperatures, and extreme weather events, such as droughts and floods (FAO, 2017). Climate and climatic variability, therefore, plays a major role in defining agricultural production around the world (Hayes, Wilhite, Svoboda, & Trnka, 2011).

In the Panchkhal area, the farmers have experienced multiple impacts of climate change in the farming. The impacts include scarcity of water, increase in incidence of disease and pests, use of pesticides and health impacts, decrease in production, floods and shift towards off-farm activities. While all respondents acknowledged the growing water scarcity and prevalence of diseases and pests, only 40 percent reported a noticeable decrease in crop production (Fig.7). Additionally, 20 percent cited health issues, and another 20 percent noted an increase in migration from drought-affected regions. The local community has attributed declining crop yields largely to reduced rainfall. Decline in rainfall from November to April adversely affects the winter and spring crops (MoE, 2010) Both Rainfed and irrigated farms are found to be sensitive to climate, although they have different climatic responses (Fleischer & Kurukulasuriya, 2011).

Figure 7

Farmers' Experience on Impact of Climate Change on Farming-based Livelihoods in Panchkhal Municipality



Source: This figure shows Farmers' experience about impacts of climate change in related to farming and livelihoods based on the data collected through field survey

Water Scarcity

When considering the impact of climate change on agriculture, water assumes a central role. Climate induced water stresses directly affects agricultural productivity (MoE, 2010). There are also reports of decrease in water used for irrigation, recharging of natural ponds, reservoirs and lakes. Even in those areas where the total annual rainfall is high, water scarcity is a problem. For example, Cherrapunji in the northeastern Indian Himalayas is one of the world's highest rainfall areas, but is called a 'wet desert' because it still suffers from water scarcity. This is similar to the case in Godavari, a typical mid hill area of Nepal where 80% of the total annual rainfall falls during the monsoon period, the remaining eight months are more-or-less dry (ICIMOD, 2019).

In urban areas, piped water serves as the key source of drinking water, while rural households in terai mainly depend on tube wells or boreholes (IIDS, 2012). Similarly, in Panchkhal, most farmers utilize deep tube wells or wells for both drinking water and irrigation. However, in Hokse, the shortage of water for irrigation has led to the abandoning previously cultivable lands. According to a farmer's account -

> *The village used to have 10-12 ponds. These ponds were used for wallowing buffalos. Springs were abundant, particularly in the lower areas. Now, no ponds exist. They are either disappeared or encroached by road expansion, disrupting the recharge of lower springs. Consequently, the once-flowing streams from forested areas and the people walking under rain with wet bodies have become rare sight. In the last 12 -15 years, things have changed. Agricultural activities now heavily rely on rainfall.*

Farmers across upper Hokse, middle Hokse, and Salghari unanimously express the acute water shortage gripping their communities, indicating a significant reduction in water sources attributed to climate change. This observation aligns with a similar trend noted by the National Planning Commission, highlighting the gradual shortage of water sources in Kavrepalanchok and nearby districts over the past decade. It is notable that the government has designated 11 villages in Kavrepalanchok as drought-affected areas, further underscoring the severity of the situation (NPC, 2013).

Even the flat lands of of lower Hokse which are close to Jhiku Khola suffer from insufficient irrigation water. Difficulties are exacerbated by the younger generation's declining interest in agriculture. Due to problem of water shortage, farmers have abandoned their farms to brick kilns, making these sites unusable for farming. While Nepal has an abundance of water resources, efficient use of them is still a problem. Adopting techniques like as pivot and drip irrigation, as recommended by Kaini, (2019), may improve water-use efficiency and lessen the effects of water scarcity. Furthermore, People in the area experienced that the issue was made worse by the 2015 earthquake. Many of the area's springs and water supplies dried up after the earthquake, which had a negative impact on farming and livelihoods in the area.

Increase in Diseases and Pests in Crops

Every farmer interviewed stressed a visible growth in disease and pest issues, encompassing the emergence of new species. Among these, aphids and *Tuta absoluta* were frequently cited as inflicting maximum damage to their crops. Aphids, notorious for infesting vegetable crops (AUSVEG, 2019), possess remarkable reproductive capabilities, with a single aphid capable of producing hundreds to thousands of offspring within weeks (Townsend, 2019). In the absence of timely response, the whole field of crops can be quickly damaged.

Another pest reported by farmers is *'Tuta absoluta'* in tomato crops. This pest was first time reported in commercial tomato farm in Kathmandu in 2016. It is originated from Latin America. In Nepal, it is suspected to have transferred from India (Shah et al., 2017 as cited in Adhikari et al., 2019). In the first incidence in Kavrepalanchok district in 2016, it damaged approximately 57.51 percent of tomato crops (Adhikari et al., 2019). A study in UK by Cuthbertson et al. (2013) found the optimum temperature for *Tuta* development ranged from 19–23 °C. Development time appeared to decrease with the rise in temperature above 23°C. A study carried out in Laboratory of entomology, Khumaltar, Nepal in 2016-17 revealed compatible result that the increase of temperature and relative humidity lessened the development period by three times (Simkhada & Thapa, 2019). Concurrently, studies show new alien species are emerging and their habitat is spreading rapidly. Increased temperature and rainfall variability have caused protracted dry spell and higher incidences of pests and diseases (MoE, 2010). Additionally, a shift in climate could bring in new diseases but also shift the optimal conditions for existing pathogens. Thus, the observed temperature rise not only fosters the proliferation of invasive species but also poses a significant threat to crop health and productivity.

The Fall Armyworm (FAW) pest infestation is another alarming concern, with reports indicating diverse awareness among farmers in the affected regions. While some respondents acknowledged its presence in specific areas of Panchkhal, others appeared unaware about it. However, technicians confirmed it's extensive across multiple crops and locations. FAW, known for its damaging impact on various crops, including maize, poses a substantial threat to agricultural productivity (GC, 2019). Studies showed yield losses ranging from 39% to over 70%, underlining the severity of its impact (Bhusal & Bhattarai, 2019). The voracious nature of FAW larvae, coupled with their ability to swarm in large numbers, worsens the damage on crops. Additionally, their resistance to many chemical pesticides further complicates its control. Its first incidence in Nepal was recorded in Gaidakot, Nawalparasi district in 2019, marking the beginning of its destructive presence in numerous districts across the country (GC, 2019).

Farmers in Ojetar, ward No. 8 of Panchkhal Municipality, have reported a prevalent rice fungal disease locally known as 'kalipoke'. This disease has become widespread in the area, causing significant damage to rice crops. Tiny black balls replace the affected rice grains, leading to decreased yields. During harvesting, these black balls turn into powders, covering farmers' bodies and potentially causing health issues upon inhalation. Such rice fungal disease is currently known as one of the most damaging rice fungal diseases worldwide, attributed to the extensive farming of hybrid rice varieties and the impacts of climate change. In China, it has affected approximately 2.4 million hectares per year between 2015 and 2017, and its occurrence is reported in rice-growing regions globally. The disease grows in areas with high relative humidity and temperatures ranging from 25−35 ºC (Jiehua et al., 2019).

Furthermore, the spread of diseases and pests is closely related to water management practices. Sufficient water provision to plant roots is essential for ensuring reliable crop yields. However, both excess water application and water deficiency can contribute to the spread of fungal and bacterial plant diseases (Café-Filho et al., 2019). This highlights the significance of improving water use behaviors to mitigate the spread of diseases and pests in agricultural settings.

Use of Pesticides and Effect on Health

With the increase in pests and diseases, the use of pesticides has also increased. Fungicide and insecticides were common pesticides used by vegetable farmers in Nepal (Aryal et al., 2016). Pesticide use is intensive in commercial farming of vegetables (Sharma, 2015). In consistent with this, farmers in Panchkhal appears to have used intensive pesticides in the past. At one time, agricultural product from Kavrepalanchok was banned from Kathmandu's largest vegetable market because of the use of heavy chemicals by the district's farmers (ICIMOD, 2015). However, farmers now seem to have acknowledged the drawbacks of excessive pesticide use and are gradually transitioning towards bio-pesticides as an alternative solution, recognizing their environmental and economic benefits. During a conversation with a farmer, he said:

> *Village was once filled with the strong odor of chemical pesticides sprayed in the fields. One of my elder used to express concern remarking 'I think I am going to die of this smell'. However, the village environment has since changed, with the absence of the pungent odor.*

This shows that people have become cautious in pesticide use. A local vendor of seed and pesticide in Panchkhal agreed that hard pesticides are less used but said pesticide sale have not decreased.

The environmental effects of applying pesticides to crop fields can be widespread because these substances can be absorbed, spread by wind, and water. A lot of widely used pesticides damage non-target organisms as well as the environment and cause pollution in addition to their intended targets (Nyaupane, 2022). Human health concerns from exposure to these pesticides include immunological suppression, neurological disorders, anomalies of the reproductive system, hormonal imbalances, and possibly cancer (Kaur et al., 2024). Additionally, farmers who are exposed to these chemicals may feel tired, irritated on their skin, have headaches, and have respiratory discomfort. Furthermore, the delicate balance of ecosystems is troubled when synthetic pesticides are used in agricultural regions, endangering natural enemies and pollinators (Samanta et al., 2023). Beneficial species and natural predators exist in agricultural ecosystems to aid in the management of dangerous pests. Pest management and crop pollination are greatly aided by these "natural enemies," which include earwigs, damsel bug, earthworms, ladybird beetles, ground beetles, ants, birds, and bats. Indeed, they constitute as much as 33 percent of pest management in agricultural contexts, and they play a major role in natural pest control (FAO, 2018; Karp et al., 2018).

Impact on Crop Production

The impacts of climate change will have major effects on agricultural production, with a decrease of production in certain areas and increased variability of production (FAO, 2013). While 92 percent of farmers interviewed observed a significant surge in production, only 4 percent reported a drop, with another 4 percent noting no change. However, this apparent growth is largely attributed to the use of hybrid seeds, acknowledged unanimously by farmers. This shift has proven beneficial even in arid regions like Hokse, where certain maize hybrids have nearly doubled yields, compensating for declines in local seed production and allowing for diversification of crops where conditions permit. In conformity with Müller-Kuckelberg (2012), perennial droughts, erratic and delayed rainfall pattern has led to declining crop production in Panchkhal as well. Farmer's in Panchkhal experienced the decrease in production as they were compelled to plant late because of late onset of monsoon. Absence of rainfall hindered the sowing process of maize crops which adversely affected the yield potential of early-planted crops. Besides, as mentioned earlier, the Rice *false smut* disease reported by farmers in Ojetar caused yield loss. It reduces grain quality as the *false smut* balls replaces the grain which is the typical symptom of this disease (Jiehua et al., 2019)

Araus et al. (2008, as cited in Gollin, 2011) point out that water availability is one of the main limits to crop yield. Cereal harvests in Asia in 2018 declined to below-average levels in the Near East (WMO, 2019). In Nepal also the untimely start of monsoon rainfall resulted in rain deficit in the eastern Terai lowlands in 2005/06. This reduced crop production by 12.5 percent nationwide and about 10 percent of agricultural land was left fallow due to rain deficit. On the other hand, heavy rain with floods in the midwestern Terai reduced crop production by 30 percent (Regmi, 2007, as cited in Poudel, 2016). Due to the centrality of agriculture to the subsistence of farmers and the national economy of Nepal, such decrease in production also will have detrimental effect in rural households and overall economy. In some parts of Sub-Saharan Africa, increase in crop failures is already incurring high economic damages and threatening food security and they are projected to be severe as global warming continues (World Bank, 2007).

Floods and Landslides

Floods during the monsoon are a natural phenomenon in Nepal (Dixit, 2013) and incessant rainfall in August 2017 resulted in widespread floods across 35 of the country's 77 districts. In the study area, 60 percent farmers (fig. 7) reported that in 2019 monsoon, flash flood in Jhiku Khola River damaged crops in its lower watershed area. But it is not a prominent problem for their farming. Historical trends show that floods are the result of combination of the natural factors in Nepal such as continuous rainfall and cloudbursts, snowmelt and rainfall, glacial lake outburst floods and bishyari (NPC, 2017). A bishyari is a flood that occurs when a landslide breaches dams by the reservoir of water in the river which forms upstream of it (Dixit, 2013). During monsoon cloudbursts, landslides and flash floods occur in the mountains (NPC, 2017). The landslide situation in Panchkhal is in contrary to other places in the mid-hills as no major landslides have occurred as stated by farmers.

Out Migration and Expansion of Forests in Cultivable Lands

The heavy dependence on rain for irrigation and nonexistence of alternate source of water for the irrigation purpose in Hokse has forced the new generation to seek alternatives for livelihood. This response of farmers is consistent with NPC (2013) which mentions that in Kavrepalanchok, people with homes in the highlands have moved to lower elevations where more water is available. The lands that used to yield three crops a year have turned barren. As a result, the forest species started invading this fallow land and now can be seen expanding its size in the area. FAO & IPCC (2017) agrees that the outmigration from agriculture, together with a structural change in the economy over the past 10−15 years have opened agricultural lands for reforestation.

Off-farm Activities

In Hokse area, residents of Ward No. 8 in Panchkhal Municipality have noted a significant trend of newer generations migrating away from farming. This phenomenon is prevalent across resource-poor villages in Nepal, where migration serves as a crucial livelihood strategy (NPC, 2013). In Hokse, this migration pattern primarily due to the lack of irrigation water and inadequate resources to sustain agricultural livelihoods. As one senior citizen in Hokse stated -

> *The village once had number of water sources. But over the past decade or so, these sources gradually disappeared and the farming has become difficult. There is no other source except this newly built deep boring. Young members in the family started moving away from agriculture. Many houses now have only elder members who are unable to tend to the farms. This trend resulted in the growth of uncultivated land.*

This was particularly pronounced in the Hokse area. In the low lands of Hokse and some parts of Baluwa (ward No. 12), lack of water accessibility has led to the conversion of land for brick kilns. Numbers of brick kilns have increased in the area as people started seeking alternative income from the sale of soil. This trend mirrors that observed in Namobuddha Municipality within the same district where increasing urbanization and loss of farmlands has seen many people transition to non-farm occupations such as working in brick kilns (Global Green Growth Institute [GGGI], 2018).

On the one hand, the current trend of abandoning farming and converting lands into brick kiln sites will bring environmental harm despite economic gains. Farmers have observed that crops in nearby areas of brick kilns often suffer discoloration due to emissions from chimneys, leading to frequent protests from affected farmers. On the other hand, the sustainability of income from brick kilns is questionable in the long term. As urbanization increases, there will be more local demand and stronger local markets for agro-products (GGGI, 2018) which cannot be met if this trend keeps growing.

Conclusion

Climate change has become a critical issue in agriculture sector of Nepal. Panchkhal

Municipality in the mid hills of Nepal, due to diverse climate, has tremendous potential for agriculture, particularly the vegetable products. Increased temperature and rainfall variability have posed a great risk to livelihoods of farmers heavily depended on rain-fed farming in the Panchkhal. The linear regression of temperature data shows the maximum temperature has increased by 0.0177°C per year and the minimum temperature has dropped by 0.0271°C per year over 1980-2023. The regression value for both maximum temperature rise and minimum temperature drop with time is statistically insignificant. Similarly, the 44-year precipitation trend shows variations in yearly rainfall totals. The majority of the farmers in Panchkhal area perceive fluctuation in temperature and precipitation and extreme weather events in their locality in the last fifteen or so years. The precipitation is more realized than temperature by the farmers. They agree on decrease in rainfall amount and frequency and late onset of monsoon. This has led to decrease in production although hybridized seeds seem to have relieved to some extent.

The Panchkhal Municipality significantly depends on streams like Jhiku Khola and Danfe Khola for irrigation but locals have seen a notable decrease in these streams' flow. This also holds true to other perennial streams in the vicinity as the streams dried up partially or completely especially in upper and middle Hokse. The disappearance of water springs in areas like Salghari, Hokse, and Ojetar has worsened the situation, exacerbating water shortages. As the temperature and precipitation trend and farmers perception on climate change show, farmers are already feeling the adverse impact of climate change in their farming which is primarily felt in the form of scarcity of water and increase in diseases and pests in crops. The farmers have experienced multiple impacts of climate change in the farming, including scarcity of water, increase in disease and pests, use of pesticides and health, decrease in production, floods and shift towards off-farm activities. Drying up of small streams and disappearance of springs resulted in acute shortage of water in many places which have affected the rain-fed farming. The heavy dependence on rain for irrigation and nonexistence of alternate source of water for the irrigation purpose in Hokse has forced the new generation to seek alternatives for livelihood.

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