Thesis for the Degree of Master of Science in Environmental Science and Management

TREND ANALYSIS OF CLIMATE CHANGE VARIABLES, ITS IMPACT AND ADAPTATION PRACTICES IN AGRICULTURE: A STUDY FROM NAMOBUDDHA MUNICIPALITY OF KAVREPALANCHOWK DISTRICT

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School of Environmental Science and Management (SchEMS)

Faculty of Science and Technology

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Supervised by Praveen Kumar Regmi

A thesis submitted in partial fulfillment of the requirements for

the degree of Master of Science in Environmental Science and Management

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Dedication

I would like to dedicate this thesis to my parents, Mr. Deepak Raj Nhemhafuki and Mrs. Shanta Nhemhafuki , and my sibling Ms. Shahisnuta Nhemhafuki and lastly my friends Shishila Baniya, Nisha Rai, Ravi Ojha and Rushma Karki for their immense support and love throughout.

Declaration

I, Kabita Nhemhafuki, do hereby declare to the School of Environmental Science and Management (SchEMS) affiliated to Pokhara University (PU) that the thesis entitled **"TREND ANALYSIS OF CLIMATE CHANGE VARIABLES, ITS IMPACT AND ADAPTATION PRACTICES IN AGRICULTURE: A STUDY FROM NAMOBUDDHA MUNICIPALITY OF KAVREPALANCHOWK DISTRICT",** submitted as a partial fulfillment for the degree of Master of Science in Environmental Science and Management. The work presented in this project work is done originally by myself and has not been submitted elsewhere for the award of any degree or professional qualification All sources of information or work done by others are cited within the report and listed in the reference section.

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Recommendation

This is to recommend that the thesis entitled "**TREND ANALYSIS OF CLIMATE CHANGE VARIABLES , ITS IMPACT AND ADAPTATION PRACTICES IN AGRICULTURE: A STUDY FROM NAMOBUDDHA MUNICIPALITY OF KAVREPALANCHOWK DISTRICT"** has been carried out by Ms. Kabita Nhemhafuki for the partial fulfillment of the degree of Master of Science in Environmental Science and Management. This original work was conducted under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree.

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Praveen Kumar Regmi

Supervisor

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Date:

Certificate

This is to certify that the thesis entitled **"TREND ANALYSIS OF CLIMATE CHANGE VARIABLES, ITS IMPACT AND ADAPTATION PRACTICES IN AGRICULTURE: A STUDY FROM NAMOBUDDHA MUNICIPALITY OF KAVREPALANCHOWK DISTRICT"** submitted by Kabita Nhemhafuki is examined and accepted as partial fulfillment for the degree of Master of Science in Environmental Science and Management. The thesis in part or full is the property of the School of Environmental Science and Management and should not be used to award any other academic degree in any other institution.

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This dissertation paper submitted by Ms. Kabita Nhemhafuki entitled **"TREND ANALYSIS OF CLIMATE CHANGE VARIABLES, ITS IMPACT AND ADAPTATION PRACTICES IN AGRICULTURE: A STUDY FROM NAMOBUDDHA MUNICIPALITY OF KAVREPALANCHOWK DISTRICT"** has been accepted for the partial fulfillment of a Master of Science in Environmental Management from Pokhara University.

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September 2023

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Abstract

This study identifies the impact of key climatic variables specifically rainfall and temperature in agriculture and adaptation practices in Namobuddha Municipality of Kavrepalanchok district A data for temperature and rainfall (1993 to 2022) was collected from Department of Hydrology and Meteorology (DHM) , a 10-year crop yield trend (2011 to 2021) data was accessed from MoALD and both were analyzed using Mann–Kendall trend analysis and Sen's Slope methods. Likewise, Seasonal mean rainfalls for four prominent seasons, namely pre-monsoon, monsoon, post-monsoon, and winter, were calculated to establish the relationships with the productivity of major crops grown in the study area and was analyzed using Spearman's rank correlation analysis and a household survey of 271 households was conducted across 11 wards using Kobotoolbox. The study revealed that the annual total rainfall was decreasing at the rate of 15.2 mm/year and the annual mean temperature had increased at a rate of 0039 ◦C/year over the last 29 years, and their variations were found to be statistically significant. Seasonal rainfall also decreased, except for the post-pre-monsoon and post-monsoon rain . Significant crop-yield correlations were observed for maize-monsoon and potato-winter, while other correlations, such as paddy-monsoon, wheat-post-monsoon, and mustard-pre-monsoon, lacked statistical significance. Agricultural production, particularly major crop yields, demonstrates a positive trajectory over a decade owing to the adoption of innovative practices such as improved seeds, chemical fertilizers, and water management techniques. Community perceptions underscore widespread awareness of climate change, with significant proportions of respondents recognizing its impacts on agriculture. Rising temperatures and shifting rainfall patterns are identified as key concerns. Farmers employ diverse adaptation practices, including improved seed varieties, water management techniques, and chemical inputs, to mitigate challenges and finance was the main barrier to adaptation.

Keywords: climate change; trend analysis; correlation; crop yield; adaptation; barriers.

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Acronym

DHM	Department of Hydrology and Meteorology
IPCC	Intergovernmental Panel on Climate Change
ICMOD	International Centre for Integrated Mountain Development
MoFE	Ministry of Forests and Environment
MoALD	Ministry of Agriculture and Livestock Development
GGGI	Global Green Growth Institute
UNFCCC	United Nations Framework Convention on Climate Change
CBS	Central Bureau of Statistics
MOF	Ministry of Finance
NAPA	National Adaptation Programme of Action
LAPA	Local Adaptation Programme of Action

CHAPTER I:

INTRODUCTION

1.1 Background

According to the Global Climate Risk Index 2021 (Germanwatch, 2021), Nepal ranks 12th on the list of the world's most at-risk countries. Nepal is considered one of the most vulnerable countries in terms of the impacts of climate change. A study conducted by the Department of Hydrology and Meteorology (DHM, 2017) indicates that the annual maximum temperature trend in Nepal is increasing by 0.056°C per year, while the annual minimum temperature trend shows an insignificant increase of 0.002°C per year. Furthermore, a report released by the Ministry of Forests and Environment (MoFE) and the International Center for Integrated Mountain Development (Ministry of Forests and Environment, Government of Nepal, 2019) predicts that average annual precipitation is expected to increase in both the short-term (2030) and long-term (2050).

Weather statistics over lengthy periods of time are referred to as climate (IPCC, 2007). Climate change can result in rising temperatures, more frequent and intense extreme weather events, and shifts in precipitation patterns, which can impact ecosystems and human societies (IPCC, 2018). It's calculated by analyzing long-term patterns of temperature, humidity, air pressure, wind, precipitation, atmospheric particle counts, and other meteorological factors in a specific region. Climate change is associated with a change in the state of the climate system over time, whether caused by natural or man-made factors. Climate change is one of the century's most pressing global issues. However, in the case of Nepal, In the medium period (2016-2045), average annual precipitation could rise by 2-6 percent, and in the long run, by 8-12 percent (2036-2065). Furthermore, the average temperature may climb by 0.92-1.07 degrees Celsius in the medium term and 1.30-1.82 degrees Celsius in the long run. The post-monsoon season (1.3-1.4 °C in the medium-term and 1.8-2.4 °C in the long-term) and the winter season (1.0-1.2 °C in the medium-term and 1.5-2.0 °C in the long-term) are predicted to have the highest rates of mean temperature increase. In addition, the study finds that seasonal precipitation would increase in all seasons except the pre-monsoon, which is anticipated to decrease by 4-5 percent in the medium term. Furthermore, the post-monsoon season is likely to experience the biggest increase in precipitation over the reference period, increasing by 6-19% in the medium term and 19-

20% in the long run . As a result, significant temperature and precipitation swings are expected to wreak havoc on food production, water management, and other livelihood resources (MoFE, 2019).

Agriculture is a main source of food, income and employment for 65.7% of the total population in Nepal which contributes 33.1% of national GDP and 50% of export of the country. However, Agricultural Gross Domestic Product has dropped by 17.8% in the last 30 years and climate change is one of the factors for this decrease (MoFE, 2018). Small holder farmers are the major pillar of Nepal's economy and are expected to contribute further to make at least a middle-income country by 2035 (Karki, Burton, & Mackey, 2020). Some of the researchers argue that mainstream farmers at community level need to be studied to identify the perception, actual impacts and effective adaptive measures (Bryan, et al., 2013). Small rural farming communities are said to be affected the most because of lack of options to sustain their livelihoods. Therefore, this research will focus on those communities and aims to identify the perceived impacts, current adaptation practices and future possibilities for the betterment on farming and livelihoods of farmers. This study, therefore, focuses on a community-level study in Kavrepalanchowk district of Nepal regarding the perception of the farming community on climate change and existing adaptations practices

1.2 Statement of the Problem

Nepal has experienced recent changes in two crucial climatic variables: temperature and precipitation (Dahal et al., 2018). There is an increasing trend of unusual climatic patterns like unpredictable rainfall, prolonged drought, floods, seasonal shifts and increasing temperature in Nepal, which has a significant impact on agricultural productivity (Malla, 2008). Therefore, Nepal is extremely vulnerable to climate change mainly because of its immense reliance on agriculture, as 65.7% of the population is engaged in it (MOAC, 2018). Mainstream farmers from the rural areas are the major victims of climate change due to lack of awareness and less options to respond to it. Therefore, from the perspective of food security as well as socioeconomic reasons, it is very crucial to understand the perceptions, identify the impacts and adaptation practices being taken to enhance the farmer's livelihoods in a better way.

Developing the appropriate strategy to cope with the effect of climate change can improve the productivity and financial stability of farmers (Parry et al., 2007). Using the traditional techniques and available resources, farmers are adapting towards climate change, but it is important to have in-depth knowledge to propose better adaptive measures for the future improvements of their livelihoods. This can also provide baseline information to the related authorities about the current trend of climatic conditions that can help in policy making process for better adaptation approaches in the future.

The Kavre district, situated in the mid-hills of Nepal, exemplifies this vulnerability with its vital role in producing cereals, potatoes, and vegetables for the capital city, Kathmandu (ICIMOD, 2015). The district faces increased risks of erratic rainfall, droughts, floods, and landslides (Zeiffert, 2021), further compounded by the 2015 earthquake's geological shifts, disrupting local water sources (GGGI, 2018). Shrinking rivers, streams, and ponds, alongside excessive borewell drilling by brick industries, have led to water scarcity (GGGI, 2018, p. 16). As climate change intensifies, the agricultural sector becomes increasingly vulnerable due to unstable water access and a higher likelihood of extreme weather events (MoPE, 2017, p. 11). Consequently, local communities are forced to adapt and seek solutions to safeguard their crops against these changes.

Climate change adaptation appears to be a critical component in addressing climate change concerns. Adaptation to climate change is therefore critical in poor countries, and it has been identified as a high or urgent priority for them (UNFCCC, 2007). Therefore, this research can be very useful to the local farmers and local government in understanding about the current climate induced events and its risks on their livelihoods and adaptive capacity. It will also analyze the successful sustainable adaptation practices or resilience options in the study area that can be scaled out in other places with similar context. These findings are expected to be useful in local development plans that advocate sustainable solutions. Furthermore, this research can provide revised information to the future researchers on the recent trend of climate change, its impacts on local communities and adaptation approaches at micro level.

1.3 Research Questions

- What is the ongoing trend of rainfall and temperature of Namobuddha Municipality?
- What is the trend of productivity of major crops of Namobuddha Municipality?
- What is the relation of seasonal rainfall with the major crop yield of Namobuddha Municipality?

- What is the people's perception on climate change and the adaptation practices adopted in agriculture to cope with changing climate?

1.4 Objective

Broad Objective:

The broader objective of the study is to analyze the trend of climate change variables , its impact and adaptation practices in agriculture in Namobuddha Municipality of Kavrepalanchowk District.

Specific Objectives:

The specific objectives of this study are:

- To assess the trend of climate data i.e., rainfall and temperature (30 years data: 1992-2022).
- To evaluate the time series data on productivity of major crops of Namobuddha Municipality
- To find the relation of seasonal rainfall with the major crop yield
- To understand the people's perception on climate change and adaptation strategies adopted by community in agriculture.

1.5 Rationale of study

One of the studies in Kavrepalanchok district revealed that trend analysis of temperature and precipitation over 27 years was facing various weather variability causing drought, delay in monsoon, hailstorm and heavy rainfall (Giri & Dahal, 2021). Agriculture serves as the primary occupation for the residents of Namobuddha Municipality, with the majority of household members engaged in cultivating crops such as maize, mustard, paddy, wheat, and barley, while situated in the northern mountains between the villages of Phulbari and Patlekhet is the national center for organic farming, from which agricultural products are distributed to various farmers' markets in Kathmandu (Maharjan et al., 2023). However, despite the agricultural importance of the region, Namobuddha Municipality is grappling with a severe shortage of water, affecting both residential and agricultural needs (Jalsrot Vikas Sanstha (JVS)/GWP Nepal, 2017).

Understanding the specific climate data trends and their implications for agriculture in Namobuddha Municipality is crucial for developing context-specific adaptation strategies and ensuring the sustainability of agricultural practices. While some studies have explored climate change impacts on agriculture at a broader scale, there is a lack of research specifically focused on Namobuddha Municipality. By conducting a detailed study, this research will fill the gap in the existing literature by providing localized data, insights, and adaptation practices relevant to the agricultural sector in the municipality.

The study will contribute to the scientific understanding of climate change impacts on agriculture and the effectiveness of adaptation practices in a specific geographical context. By analyzing climate data trends and their correlation with agricultural productivity, the research will provide evidence-based insights into the vulnerability of the agricultural sector and the adaptation strategies employed by farmers in Namobuddha Municipality. This scientific contribution can inform policymakers, researchers, and practitioners working in climate change and agriculture domains.

The findings of this study will have practical implications for policymakers, agricultural extension services, and local communities. The research outcomes can inform the development of climate change adaptation policies, agricultural planning, and resource allocation strategies at the municipal level. The identified adaptation practices and lessons learned can guide the implementation of climate-resilient agricultural practices, thereby enhancing the livelihoods of farmers and promoting sustainable development in Namobuddha Municipality.

1.6 Limitation

The limitation of the study is;

- The scope of this study is restricted to Namobuddha Municipality in the Kavrepalanchowk district due to budget and time constraints.
- The study focused exclusively on two climate change factors: rainfall and temperature, given Nepal's recent significant variations in these key variables (Dahal et al., 2018).
- In conducting the Household Survey for Namobudhha Municipality, I had to base my sample size calculations for each ward on the 2011 census data since latest ward-wise household data was not accessible.

CHAPTER II:

LITERATURE REVIEW

2.1 Global Scenario of climate change

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as “any change in climate over time, whether due to natural variability or as a result of human activity.” (IPCC, 2007, p. 1). The IPCC has also elaborated the definition as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” (IPCC, 2014, p. 1). Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased. (IPCC, 2013, p. 2). Globally, average combined land and ocean surface temperature has increased by 0.85°C over the period 1880 to 2012. Oceanic warming in the upper 75 meters has warmed by 0.11°C per decade over the period 1971 to 2010. The average rate of ice loss from glaciers around the world was almost 226 Gt yr−1 over the period 1971 to 2009, and very likely 275 Gt yr−1 over the period 1993 to 2009. Over the period 1901 to 2010, global mean sea level rose by 0.19 m. Since around 1950, changes have been observed in many extreme weather and climatic events. The number of cold days and nights has decreased, and the number of warm days and nights on a global scale has increased. There are likely more land regions where the number of heavy precipitation events has increased than where it has decreased. The study shows climate is likely to continue to change in the future. (IPCC, 2013, p. 3).

2.2 National Scenario of Climate Change

Government of Nepal undertook a climate change trend analysis which shows average annual maximum temperature trend is increasing at 0.056oC/yr with significant positive trends observed in annual and seasonal average maximum. Average minimum temperature shows significantly positive trend (0.002oC/yr) only in monsoon season. Precipitation in any season does not show significant trend. The positive temperature trend is highly significant in majority of districts (more than 90% of the districts) and in all physiographic regions in all the seasons, except in majority of the Terai districts in winter. The negative minimum temperature trend is significant in most of the northwestern districts in winter and post-monsoon seasons while positive minimum temperature trend is significant in majority of southern (Terai to Middle Mountains) districts in Eastern Development Region (EDR), Central Development Region (CDR) and WDR in all seasons. Trends of warm days and warm nights are significantly increasing in majority of the districts. Warm spell duration is increasing significantly in majority of the districts (DHM, 2017).

2.3 Impact of Climate Change

Evidence points to extensive current and future biophysical impacts of anthropogenic climate. (IPCC, 2007, 2012; Fung et al., 2011; Thornton et al., 2011) but differ in intensity, the rate of change and the regional trends (Watson, 2000). Bohle et al. 1994 points out the widely recognized idea in the climate change and vulnerability literature that countries, regions, economic sectors and social groups vary in degree of climate vulnerability. This is partly because of the fact that temperature and precipitation variations will occur unevenly, and the effects of climate change will be unevenly 14 distributed globally. In addition, irregular distribution of the resources and wealth is another fact on those peripheries.

The IPCC report, the regional Impacts of Climate Change: An assessment of Vulnerability (Watson et al., 1998), claims that a region's vulnerability depends heavily on its resources, and that poverty limits adaptive capability. The IPCC Second Assessment Report states that vulnerability depends on the level of economic development and institutions. The report argues that socio-economic environments are usually more fragile in developing countries with less favorable economic and institutional conditions. The report adds that highest vulnerability lies where there is maximum climate change sensitivity and the least ability to adapt (Watson et al., 1996).

A British organization-Maplecroft ranked Nepal as the fourth most vulnerable country in the world (Maplecroft, 2011). And, NAPA shows Nepal is highly vulnerable country (MoE, 2010). The major causes for Nepal's high vulnerability for climate change impact are its topographical complexity, weak geological structure, vulnerable habitats and the variability of climate and micro-climate zones. Poverty, illiteracy, social inequality and a high community reliance on natural resources for livelihood have added more vulnerable to the impacts. (GoN, 2019). These vulnerabilities have been felt directly in forests and biodiversity, water, human health, tourism, housing, infrastructure development as well as in the areas of livelihood, while each year there has been a huge loss of lives and properties due to climate-induced disasters such as floods, landslides, windstorms and wild fires (MoE, 2010).

2.4 Impact of climate change in agriculture

The increase in 100-110% crop production and additional 2.7-4.9 million hectares of land is needed by 2050 to feed the global population (Tilman et al., 2011). While climate variability is a crucial factor that influences farmers' income and food production (Wheeler & Barun, 2013). Climate change influences the magnitude and duration of heat and water stress, which has direct impacts on the agricultural system (Lobell et al., 2015). Climate change can also affect natural resources, especially water and land, which are important aspects of agricultural production (UN-Water, 2013). For instance, there is a rapid decline in the groundwater table in India due to the growing reliance of farmers on groundwater to adapt to the drought induced by climate change (Fishman, 2018).

An annual increase in average maximum temperature in South Asia could increase heat stress by 12% in 2030 and 21% in 2050, which could have unexpected consequences for cereal production (Ortiz et al., 2008). There will be greater fluctuations in food supplies, crop production, and market prices, which will aggravate poverty and food insecurity, affecting millions of people (Schmidhuber & Tubiello, 2007). Therefore, climate change has already influenced agricultural productivity and has threatened food security as well as the livelihoods of farmers worldwide. Poor and vulnerable people dependent on agriculture should be appropriately addressed in research and development activities (Shakoor et al., 2011).

The variables of climate change, such as temperature, radiation, and rainfall, are important parameters for crop productivity in different ways. The increase in temperature beyond 3°C is likely to have negative consequences all over the world in the agricultural sector, especially for agricultural-dependent countries (IPCC, 2007). The increase in temperature indirectly affects the yields of crops since it changes the biological and physical systems of the crops (Lobell & Field, 2007). The change in climatic patterns, such as precipitation, storms, and heat stress, can make the crops respond to the change and is likely to have negative effects on production (Lin, 2011).

The change can also increase abiotic and biotic stress, which forces the agricultural system to change in a different way. This can have serious impacts on production and food security (Jones & Parry, 2003). Previous studies on climate change and vulnerability show that the change will influence current and future food systems and farming methods due to the modification and shifts in seasons and water cycles (Bruinsma, 2003). The input side is likely to be affected by the change in fertilization patterns, reclamation of land, and alteration of agricultural water use, which can affect the agricultural output unexpectedly (Platnik & Rønnow, 2012). Using the integrated assessment and historic data, many studies show the decline in the annual crop yield due to the change in the weather pattern (Thornton et al., 2009).

2.5 Impact of climate change in agriculture of Nepal

Almost 65% of the population in Nepal depends on agriculture as a major occupation to sustain their livelihoods and about 20% of the area of Nepal is being used for agricultural purposes which relies on monsoon rainfall (MOAC, 2018). Despite agriculture as one of the major occupations for the majority of population, Nepal has turned as a net food importer with mountain and hilly regions reported a food deficit of 19% and 14% respectively in 2008 (MOAC, 2018). The heavy reliance on agriculture and tourism makes Nepal's economy very sensitive to the change in climatic conditions (World Bank, 2019). Nepal is ranked as the 4th vulnerable country in terms of climate change due to its topographical feature, geographical and biological diversity. There is the subtropical climate in the South and Arctic in the North and is highly affected by the South-Eastern monsoon that is the major source of precipitation in Nepal (Shrestha & Aryal, 2011). The precipitation during the monsoon is the major source of water resources and an important climatic element for agriculture which can change the crop production system of the country affecting the food security and livelihood of the people (Malla, 2008). There was a decrease in the production of Rice, Maize and millet by 11.3%, 8.3% and 3% respectively in 2012/2013 due to prolonged drought and inadequate rainfall in Nepal (MOF, 2013). Around 30,845 hectares of land was not cultivated over the last decade due to the droughts, erratic patterns of rainfall, landslides and flash floods (CBS, 2012).

In the hilly region, about 10% of productive agricultural land was left fallow because of the rain deficit whereas many agricultural lands were highly affected by the flood due to heavy rain in mid-western Terai region that reduced 30% of crop production in 2007. However, some of the crops are maturing early which has a positive impact on yields and enables an option of double cropping in some areas (MOAC, 2018). Similarly, Himalayan region is also at risk due to glacier retreat caused by rise in temperature. For example, Glacier Lake Outburst Flood occurred in 2012 at Seti River destroyed 9.5-hectare paddy field and an estimation of US$1million was lost. The investigation of satellite maps after the flood showed the missing of 3200 sq. m of ice from Mt. Machhapuchre (Oi, Higaki, Yagi, Usuki, & Yoshino, 2014). Moreover, (Poudel, 2012) found that the Climate change favors the growth of weedy and exotic species which disrupt the local agroecosystem and its functions. This has led some indigenous crop varieties of Nepal such as local wheat, maize and rice of Nepal towards extinction and resulted in decrease of productivity of crops (Poudel, 2012).

2.6 Importance of perception-based study on climate change

Perception is strongly related to the degree of induced risks and opportunities led by climate change that affects the livelihood of farmers and their adaptation strategies and responses are determined by those perceptions (Adger, 2003). The perception of natural and environmental factors varies individually. It depends on the social groups, geographical locations, seasons, length of exposure, resilience and adaptive capacity. Though the perception is non consistent with the measured reality, they are considered to reflect the real changes (Nandanni & Watanabe, 2015). The perceived knowledge can help the farmers to change the farming methods and safeguard to the probable risks and challenges in the future (Makate, Makate, & Mango, 2017). Perception based studies play a vital role in understanding the phenomenon of climate change at grass root level which are important in devising a strategy to respond to it (Jin, Gao, Wang, & Pham, 2015). It also helps in understanding the different levels of awareness among the group of people or communities and analyze the existing risk and its solutions (Abid, Scheffran, Schneider, & Ashfaq, 2015). Therefore, perception can be taken as an alternative form of knowledge derived from local experiences. Perception is recognized to be the precondition for adaptation to climate change and variability. It is one among the factors that can influence farmer's decision whether to adapt or not 35 to climate change and variability as it determines decisions of the farmers in management of agricultural activities (Meddison, 2007)

2.7 Previous studies on farmer's perception and adaptation practices throughout the world

The large-scale survey conducted in 11 African countries (Maddison, 2007) revealed the increase in temperature and decrease in the precipitation which was perceived by a significant number of farmers. Years of farming experience was the major factor to notice the climate change and poverty was the major barrier towards the adaptation. The same trend in the decrease in precipitation in Southern Ethiopia can be seen (Gebre et al., 2013), which was similar with the data recorded in nearby meteorological stations. Farm household survey in Limpopo River Basin in South Africa (Gbetibouo, 2009) shows farmer's perception on the increase in temperature and large variability in the rainfall pattern which corresponds with the meteorological data. Lack of access to credit was considered as a barrier to inhabit the adaptations. The study carried out in eastern Saloum of Senegal (Mertz et al., 2009) shows the excess rainfall and wind as the most destructive climatic factors which have reduced the crop yield and led to poor livestock health. Household survey conducted in seven districts in Kenya (Bryan et al., 2013) shows farmers perception on the increase in temperature and rainfall and are adapting by changing the planting decisions but lack of access to extension services and improved seeds are the major barrier for them. However, the survey conducted in Canadian farmers (Bradshaw et al., 2004) shows a good access to technology and management tools and have adapted finely towards climatic changes.

Study conducted in the Northern China Plain (Zhang et al., 2015) shows a significant increase in mean annual temperature and no change in mean annual precipitation which has led to the water shortage, increasing food grain demands and high inputs in farming. Farmers have adapted to the change by changing plantation dates and water saving irrigation systems. Study conducted in the Kullu valley in the western Himalayas of India (Vedwan & Rhoades, 2001) shows farmers have perceived the decrease in snowfall, increase in temperature and no change in the precipitation. Their perception seems to be influenced by crop-climate interaction and productivity. Farm household data were collected from three districts in three archeological zones in Punjab province of Pakistan (Abid et al., 2015) that shows farmers are adapting by changing planting dates, crop varieties, fertilizers and planting shade trees. Farmers have also perceived the lack of budget, information and resources as a constraint for adaptation.

Perception of farmers on the change in climatic conditions is different from place to place and the scientific data or studies also show the same result. Even the perception and climatic condition may vary from community to community. However, most of the study is conducted in a broader perspective and larger geographical area. So, these results cannot be generalized to the small communities that can have the different perception and adaptation approaches towards climate change.

2.8 Global emergence of adaptation concept and its development

UNFCCC has highlighted the importance of adaptations since the sign of Convention in 1992 by addressing it in the ultimate objective. "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner"(UNFCCC, 1992). In addition, the Convention also provided 'adaptation' quite an important space on its key articles. The important provision was to assist developing countries financial needs of adaptation under article 4.4 and provisions with respect to funding, transfer of technologies to the developing countries 4.8, 4.9 of the Convention.

Despite the formal endorsement of 'adaption approach' in UNFCCC documents, the developed countries' emphasis in climate change negotiations had been primarily on mitigation and on getting an aggressive target from developing countries to achieve 7 mitigation goal without sufficient financing, technology and capacity-building support (Bose and Singh, 2018) rather than putting debate about the adaptation approach parallel to the focused mitigation approach.

For e.g., 1990s most of the intervention on climate negotiation were on mitigation while the adaptation has not been considered as important as mitigation. This has been supported by the concentrated actions against changing climate is through the continuous action-oriented decisions and implementation of the many mitigations project. However, adaptation began to reach in the climate negotiations platform only when the IPCC on 2000 had published a report on the climate negotiations. The report attempts to show the importance of the adaptations against climate change for all the countries of the globe but hitting the most to developing countries' all sectors.

Debate of climate change raises the issues not only by the general question - will climate change in response to human activities, but also by the crucial questions: how much (magnitude); how quickly (the rate of change); and where (spatial/regional pattern) will change. The fundamental findings of climate change impact, taken from already approved / IPPC assessments, thorough and unbiased review of all applicable science, technological and economic knowledge by thousands of experts from academia, governments, industry and environmental organizations from the globe, are clear on the adverse effect on global scale. These impacts cover almost all sectors including, water, agriculture, forestry, fisheries and human settlements, ecological systems, and human health being the developing countries most vulnerable. Many experts believe that one of the options to reduce the adverse effect of the climate change, to some degree, is through proactive adaptation measures (Watson, 2000).

There was an acceptance within the United Nations Framework Convention on Climate Change (UNFCCC), of the need to respond to climate change and to support those countries that are least capable of adapting. Realizing that the world is already committed to some climate change, the UNFCCC Parties (especially developing countries) took the issue of adaptation very seriously. Consequently, adaptation was seen as one of the main "developing country issues" in the climate negotiation process (Olmos, 2001).

COP 7 held in Marrakech, Morocco, in 2001 is perceived as the great achievement for 'adaptation'. Under the Decision 5/CP.7, Parties set up a special Work Program for the 8 Least Developed Countries (LDC) known as the LDC Work Programme, to tackle specific and urgent climate change needs (UNFCCC, 2001). By implementing article 4.9 of the 1992 convention, the COP, in 2001, established the least developed countries work programme, that included the national adaptation programmes of action (NAPAs), to support LDCs to tackle the climate change issues. The COP also established a Least Developed Countries Fund (LDCF) to fund the planning and execution of NAPAs and an LDC Expert Group (LEG) to provide technical support and advice to the LDCs (UNFCCC 2020). This entailed developing National Adaptation Programmes of Action (NAPAs) for the LDCs and forming an LDC Expert Group (LEG). Specific funds—the Special Climate Change Fund (SCCF) and the LDC Fund (LDCF)—were established. The LDCF was to fund the preparation and implementation of NAPAs (Bose and Singh, 2018).

2.9 Adaptation and its development in Nepal

For many decades, adaptation to climate change at the local level has been conducted informally by rural communities in Nepal (West S. 2012). But formal engagement started since it signed the 1992 convention which led to fix objective to stabilize the GHG concentration in the atmosphere to certain level which should allow ecosystems to adapt naturally to climate change that would ensure sustainable food production (UNFCCC, 1992).

International debate on climate change solution was primarily focused on the mitigation aspect in the starting decade of the implementation of the convention thereby adaptation part was poorly recognized. Central, but, poorly represented response against climate change -'adaptation issues', was taken seriously by developing countries in the international climate negotiation process (Olmos, 2001). Further discourse in 2001, COP 7 Marrakesh Agreement, was concrete and a landmark agreement between the parties that allowed to address specific and urgent climate needs. The COP 2001 call for the national adaptation programmes of action (NAPAs) by establishing a Least Developed Countries Fund (LDCF) to fund the planning and execution of NAPAs (Bose and Singh, 2018). This entailed developing National Adaptation Programmes of Action (NAPAs) for the LDCs like Nepal (Bose and Singh, 2018).

Finally, at the national level adaptation strategy, first formal policy document, Nepal finalized the national adaptation Programme of Action (NAPA) in 2010 in line with Marrakesh agreements (West 2012). Observing that an estimated annual warming rate of nationwide average 0.04 –0.06 degrees centigrade (Practical Action, 2009) has led to decline crop yields, increase risk of floods, droughts and landslides harm to agriculture and infrastructure, upward shift of agro-ecological zone including increase expansion of pests and alien invasive species. The NAPA recognizes six thematic areas for the intervention to cope with the climate change impact supported by variety of adaptation actions (MoE, 2010).

Other two important policy instruments: the Climate Change Policy 2011, and the National Framework on Local Adaptation Plan for Action 2011 (LAPA framework) have been seen as the historically significant policy documents for addressing the effects of climate change in Nepal (Uprety & Bishwokarma, 2016). Climate change policy aims at improving livelihoods of people by mitigating and adapting to the adverse impacts of climate change, adopting a way of low-carbon emissions socio-economic development and supporting and collaborating in the essence of the commitments of country to national and international agreements to climate change. The Policy highlights the implementation of climate adaptation and resilience activities. Both NAPA and the policy have made mandatory provisions to disburse at least 80 per cent of the available budget for the implementation of climate change adaptation activities at the local level (Darjee, 2017)

2.10 Local development of adaptation

Climate change adaptation happens at wide ranges from international level to household, and occurs in a variety of systems, from human to natural (Smit et al. 1999; Smit and Wandel 2006; Burton et al. 2007). It is generally localized, contextual in nature, and locally challenging and difficult due to connection of communities and their livelihood services to a broader complex network of ecosystems and changing climate and its instability (Adger et al. 2009; Dessai and Hulme 2004). It has been conducted by rural societies on an ad-hoc basis for many decades(West 2012) and largely govern by the past experience of weather, climate and associated disaster pattern(Adger et al. 2009; Dessai and Hulme 2004).

Local-level adaptation is strongly related to the other decision-making levels up to national level(OECD, 2009). It matters for higher level decision making in order to adequately respond to the climate change impacts. Because, first, the impacts of climate change are observed locally on the livelihood activities of the communities. Global climate change impact is translated into the localized phenomena with respect to local geography and other environmental and socio-political factors. Second, there is also local realization of vulnerability and adaptive capability. They are context specific and result from interaction of many socio-ecological factors and processes. Third, actions on adaptation are best observed at the local level. The anticipated or actual climate change experience affects the decision-making and intervention for adaptation –the latter being the transformation of knowledge and capability into behaviors and activities (OECD, 2009). It is important that the level of risk accepted by a community determines first threshold and is influenced by its values and largely governs the future interventions (Adger et al. 2009). Climate change adaptation will involve both autonomous adaptation policies and the integration of adaptation measures into existing development processes and activities (OECD, 2009).

Realizing the significance of the local adaptation, the NAPA recognizes the importance of linking local adaptation with the policies and plans at national level. NAPA section 3.1.3 provides an explanation of the local adaptation plans and how implementation of the plans would contribute to direction regarding policy improvement and formulation (MoE, 2010, p.17).The context overview highlights the development of an effective framework to facilitate adaptation by incorporating it within current policy frameworks into the planning process local , regional and national level within existing government mechanisms. NAPA as a national climate change adaptation framework put emphasis on intervention through local community-level institutions such as Community Forest User Group (CFUG), various Farmers‘ Group (FGs), Irrigation Groups and other groups (Darjee, 2017).

Local Adaptation Plan of Action (LAPA) framework chiefly concerns vulnerable local communities and is relevant for strengthening adaptation practices at the local level. The LAPA design process offers local communities and households' opportunities to assess location-specific climate vulnerabilities, propose recommendations of alternatives for adaptation and execute urgent and immediate climate adaptation measures (KR Tiwari et al. 2014). LAPA accepts the bottom-up, inclusive, responsive and flexible approach as the directive principles (MoE, 2011). The LAPA framework has been appreciated globally for its focus on consultative approach, the bottom-up nature of information gathering and the bridging between governance scales in its institutional settings. (Ayers & Forsyth, 2009; Karki et al., 2011). Regarding the needs of the local community, LAPA links local adaptation practices with national policies, as it links community-level adaptation planning to the overall development planning process at the level of the then Village Development Committee (VDC) now rural municipality government level. (Huq & Reid, 2014). The district level primarily acts as the key link between the national and local programs and initiatives where the government offices are expected to organize and coordinate activities with other agencies and stakeholders (Nightingale, 2017). At lower local scales, Community Level Adaptation Plan of Action (CAPA) have been formulated under the LAPA framework and implemented by community- based user groups including CFUGs in some of the districts as proposed in the NAPA document. CAPA focuses on the identification of local level climate change impacts, identification of the alternatives against the impacts and planning and execution of the best alternatives against the climate change impact (MoE, 2011).

CHAPTER III:

METHODS AND MATERIALS

3.1 Study Area

Namobuddha Municipality is located in the Kavrepalanchowk District of Bagmati Pradesh, Nepal. It lies 52 km east of the capital city Kathmandu and is easily accessible via the Arniko Highway to Dhulikhel and on along the BP Highway. The municipality was formed in 2017 by combining the two erstwhile village development committees of Kanpur Kalapani and Syampati Simalchour with Dapcha Kashikhanda Municipality. Dapcha Kashikhanda Municipality had been formed in December 2014 by amalgamating Dapcha Chatrebhanga, Daraune Pokhari, Khanalthok, Mathurapati Fulbari, Methinkot and Puranogaun VDCs. The current municipality is divided into the 11 wards (GGGI, 2018). It covers an area of 102.4 square kilometer and has a population of 26,160 people and 7,148 households , made up primarily the Tamang ethnic community and the Parbate hill community (CBS, 2021) .

Also, it is one of six designated 'urban municipalities' of Kavre District and lies adjacent to the Dhulikhel and Panauti towns as well as the Panchkhal Valley (Namobuddha Municipality, 2021). There is a high elevation range in the municipality, where the valley floors are around 900 meters high, and the heights are almost reaching 2000 meters. That means the winters are especially cold in the heights, and even the valley can be cold because of the natural fog that rises from the rivers. While mid-winter can be cold, the climate in the rest of the year is warm and sub-tropical (Namobuddha Municipality, 2021).

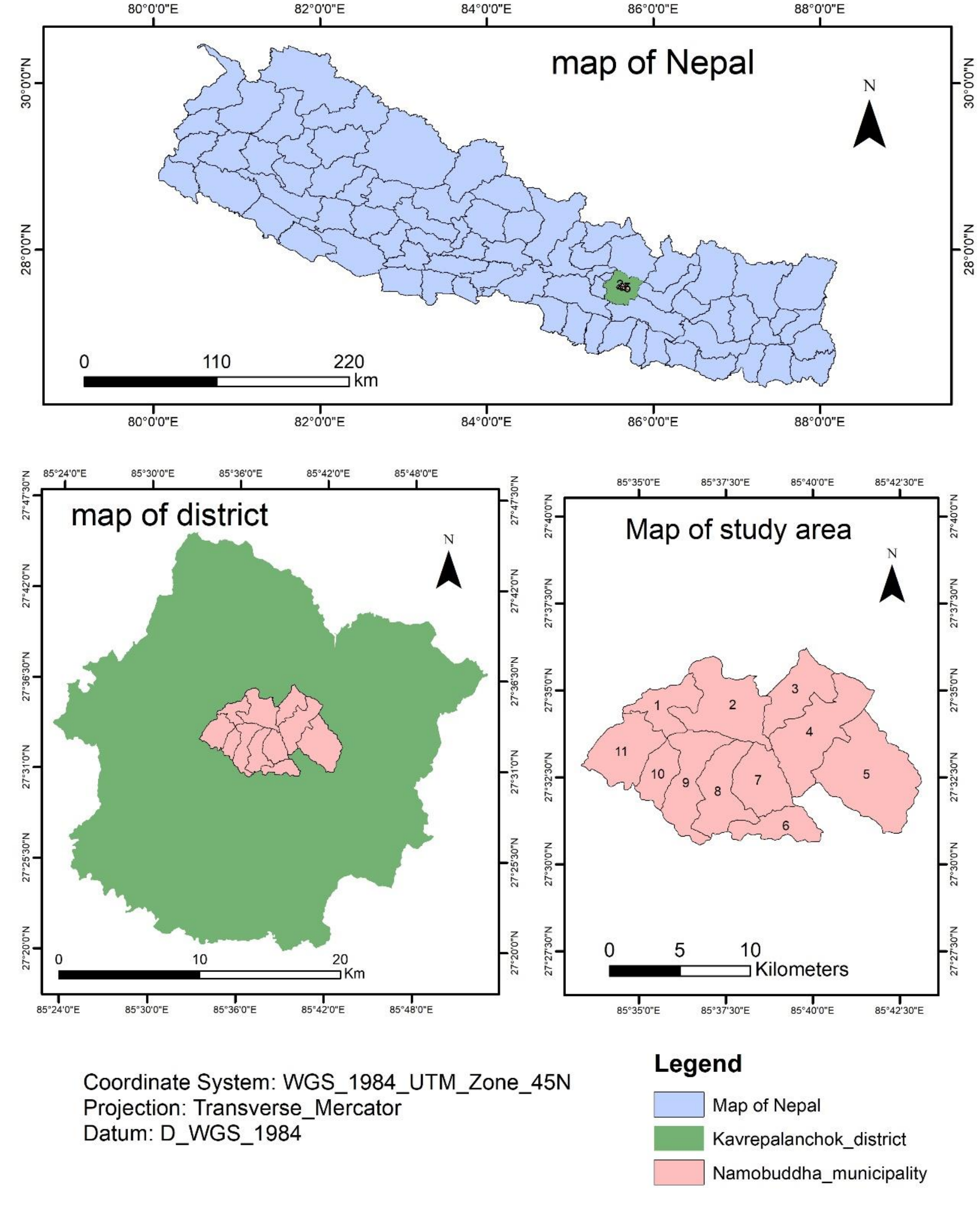

Figure 1 Map of Namobuddha Municipality

3.2 Research Methodology Design

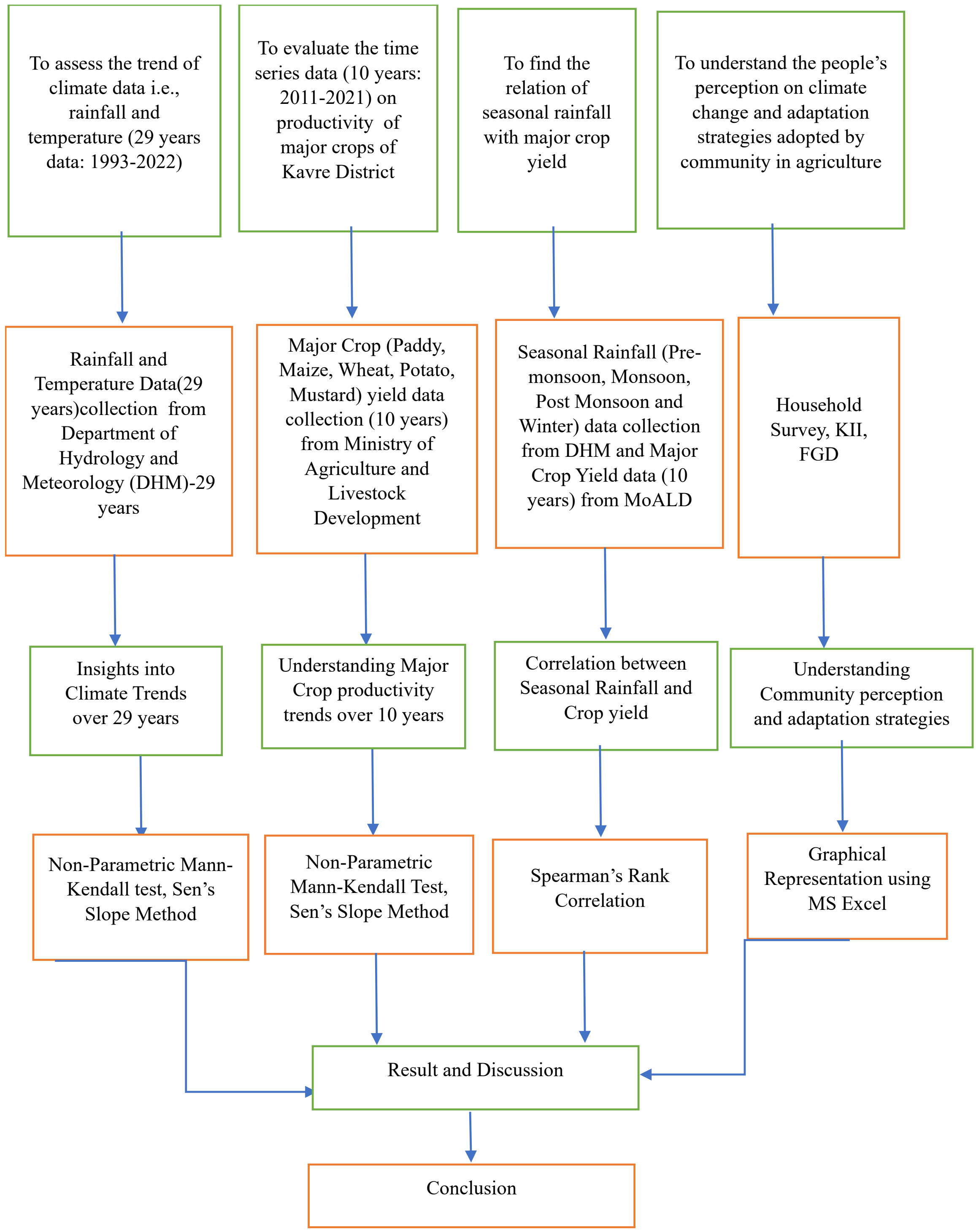

Figure 2 Methodological Framework

3.3 Objective Wise Research Matrix

Table 1: Objective Wise Research Matrix

Objectives	Data needed	Data Collection Method	Data Analysis Tools	Expected Outcome
To assess climate data trends (rainfall and temperature) over 29 years (1993-2022)	Rainfall, Minimum Temperature, Maximum Temperature	Collected data from Dhulikhel Weather Station: Rainfall (29 years) and Temperature (29 years)	Non-parametric Mann-Kendall statistical test, Sen's Slope Method	Identification of significant rainfall and temperature trends
To evaluate the 10-year (2011-2021) time series data on major crop productivity in Kavre District	Yield (Kg/ha) of Paddy, Maize, Wheat, Potato, Mustard	Collected crop yield data (10 years) from Ministry of Agriculture and Livestock Development	Non-parametric Mann-Kendall test, Sen's Slope Method	Understanding trends in Paddy, Maize, Wheat, Potato, and Mustard productivity
To find the relationship between seasonal rainfall (Pre-monsoon, Monsoon, Post-Monsoon, Winter) and major crop yield over 10 years	Seasonal Rainfall, Major crop yield	Rainfall and Temperature data (29 years) from Dhulikhel Weather Station; Crop yield data (10 years) from Ministry of Agriculture and Livestock Development	Spearman's Rank correlation	Establishment of correlation between seasonal rainfall patterns and major crop yield
To understand community perceptions of climate change and adaptation strategies adopted by the community in agriculture	Data on People's perception on climate change and adaptation strategies	Household surveys, Key Informant Interviews (KII), Focus Group Discussions (FGD)	Data visualization using MS Excel	Insights into local perceptions and adaptation strategies for climate resilience in agriculture

3.4 Sampling technique and Data Collection

3.4.1 Sample size was calculated using Cochran's formula,

$n_o = Z^2pq/e^2$

Where, Z= statistical value corresponding to level of confidence required (1.96)

p= the (estimated) proportion of the population which has the attribute in question (0.95)

q= 1 – p (0.5) e= the margin of error (5%)

Modification for the Cochran Formula for Sample Size Calculation in Smaller Populations n= [n0/(1+((n0-1)/N)].

Where, n0= Cochran sample size

N= household number

n= sample size

All 11 Wards of Namobuddha Municipality were chosen for data collection. There is total 7,148 households Namobuddha Municipality (CBS, 2021). Using Cochran's formula, sample size was 271 after applying 90% confidence limit. Sample size in each ward is calculated using population proportion of each ward shown in Appendix A. Simple random sampling is used for selecting the targeted number of sample households from the study area.

3.4.2 Data Collection

This research was conducted using a combination of qualitative and quantitative methods for collection of relevant data from both primary and secondary sources. Firstly, primary data with respect to the community perception on climate change, community adaptation practices for agricultural systems, and the impacts on productivity of major crops and livelihoods of farmers in the study areas were collected through purposive random sample survey of households using Kobo toolbox. Structured questionnaire was prepared to collect data from sample households. The outline of the questionnaire is given in Appendix B. For this purpose, 271 respondents altogether were selected randomly from 11 wards of Namobuddha Municipality. Key Informants' Interviews (KII) were also conducted with selected individuals who were considered knowledgeable about the issues of climate change and its impacts on the agriculture production system in the community in general and adaptation practices of the farmers in the study area in particular. The responses and views expressed by the key informants were analyzed and used in cross checking the findings of the study. Along with that two Focus Group Discussion (FGD) were conducted with Farmers group and Water User group of Namobuddha Municipality. Data collection took place from March 5, 2023, to March 20, 2023, encompassing a total sampling duration of 114 hours.

Data on temperature and rainfall was collected from the Department of Hydrology and Meteorology of the Nepal government of the nearest Dhulikhel station. The data on key climatic variables such as rainfall were collected for 29 years (1993 to 2022), and mean maximum and minimum temperature for 29 years (1993 to 2022). Time series data on yield of crops grown in the Kavre district were accessed from the website of the Ministry of Agriculture and Livestock Development (MoALD) of the Nepal government for the past 10 years (2011 to 2021). Seasonal mean rainfalls for four prominent seasons, namely pre-monsoon, monsoon, post-monsoon, and winter, were calculated to establish the relationships with the productivity of major crops grown in the study area.

3.5 Data Analysis

3.5.1 Meteorological data and Analysis

Data on temperature and rainfall was collected from the Department of Hydrology and Meteorology of the Nepal government for the nearest Dhulikhel station The data on key climatic variables such as rainfall were collected for 29 years (1993 to 2022), and mean maximum and minimum temperature for 29 years (1993 to 2022). Seasonal mean rainfalls for four prominent seasons, namely pre-monsoon, monsoon, post-monsoon, and winter, were calculated to establish the relationships with the productivity of major crops grown in the study area. Nonparametric Mann–Kendall statistical tests were used to detect trends in temperature and rainfall nearly during the last three decades. This test is the most common one used by researchers in studying hydro-meteorological time series trends and can be used even if there is a seasonal component in the series. The null hypothesis (H0) for these tests is that there is no trend in the series. The alternative hypothesis (H1) is that there is a trend. Each test has its own parameters for accepting or rejecting HO. On rejecting the null hypothesis, the result is said to be statistically significant. This test is based on the calculation of Kendall’s tau (τ) measure of association between two samples, which is itself based on the ranks with the samples. The trend was quantified using Sen’s slope method, which is another index to quantify the trend using the nonparametric procedure developed by Sen.

3.5.2 Yield of major crops

Time series data on yield of crops grown in the study area were accessed from the website of the Ministry of Agriculture and Livestock Development (MoALD) of the Nepal government for the past 10 years (2011 to 2021). The trends of the yields were determined using Mann–Kendall tests and they were quantified using Sen’s slope method. The same data were used for analysis of yields against seasonal and mean rainfalls of the corresponding years. Paddy, maize, wheat, potato and mustard are the dominant crop types in the working area and their yields have been analyzed. Spearman’s rank correlation was conducted to find the relationship between seasonal rainfall and the production of major crop types in the study area. The null hypothesis in this test is that as the ranks of one variable increase, the ranks of the other variable are not more likely to increase or decrease; the Spearman correlation coefficient, $ (“rho”) is 0. If the dependent variable tends to increase when the independent variable increases, the Spearman correlation coefficient is positive. If the dependent variable tends to decrease when the independent variable increases, the Spearman correlation coefficient is negative. A Spearman correlation of zero indicates that there is no tendency for the dependent variable to either increase or decrease when the independent variable increases. When the independent and dependent variables are perfectly monotonically related, the Spearman correlation coefficient becomes 1.

3.5.3 Household survey data analysis

Data collected related to the community perception on climate change, community adaptation practices for agricultural systems, and the impacts on productivity of major crops and livelihoods of farmers through Household Survey in the study area was gathered and visualized using Ms. Excel.

CHAPTER IV:

RESULTS AND DISCUSSIONS

4.1 RESULTS

4.1.1 Climate Change Indicators

Temperature and rainfall are considered major climate change indicators in this study. The analysis of variation of rainfall and temperature within the last 29 years are presented in this section.

4.1.1.1 Temperature

The monthly climatic data for nearly the last three decades, given in Table 2, show that the average annual maximum and minimum temperatures in the past 29 years were 22.21 ◦C and 11.89 ◦C, respectively. The mean annual temperature for the same period was 17.05 ◦C. The variation of annual temperature for the last 29 years in the study area is shown in Figure 2, which shows that the temperature follows a linear trend of increase.

The result of the Mann–Kendall test and Sen's slope for the variation of annual average maximum and minimum temperature is shown in Table 3, which shows that the trends of both of these temperatures are increasing, as indicated by the positive Tau (τ) values, but statistically insignificant at 95% confidence level, as indicated by the p-values greater than 0.05. Table 3 also shows that the maximum, minimum, and annual mean temperatures increased by 0.053 ◦C/year, 0.026 ◦C/year, and 0.039◦C/year, respectively, over the last 29 years.

Table 2:Monthly temperature and rainfall data for nearly the past three decades in the study area

Monthly Temperature (°C) (1993-2022)				**Monthly Rainfall (mm) (1993-2022)**
Month	**Max**	**Min**	**Mean**	**Average**
January	14.43	3.7	9.065	13.1
February	17.64	5.57	11.605	22.69
March	22.12	9.04	15.58	24.15
April	25.38	12.19	18.785	58.41
May	26.28	14.86	20.57	128.78
June	26.7	17.62	22.16	216.59
July	25.85	18.58	22.215	375.47

August	25.75	18.39	22.07	337.53
September	24.74	16.73	20.735	180.11
October	22.74	12.84	17.79	50.21
November	19.09	8.25	13.67	4.63
Dec	15.81	4.95	10.38	9.64
Average	22.21	11.89	17.05	Total: 1421.31

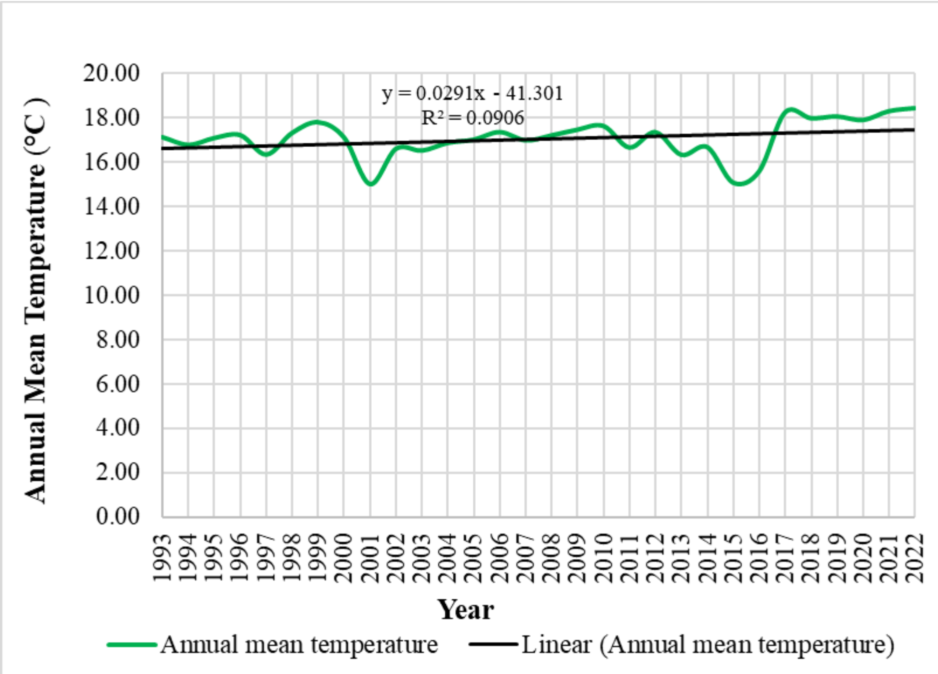

Figure 3: Annual Mean Temperature for the last 29 years (1993-2022) in the study area

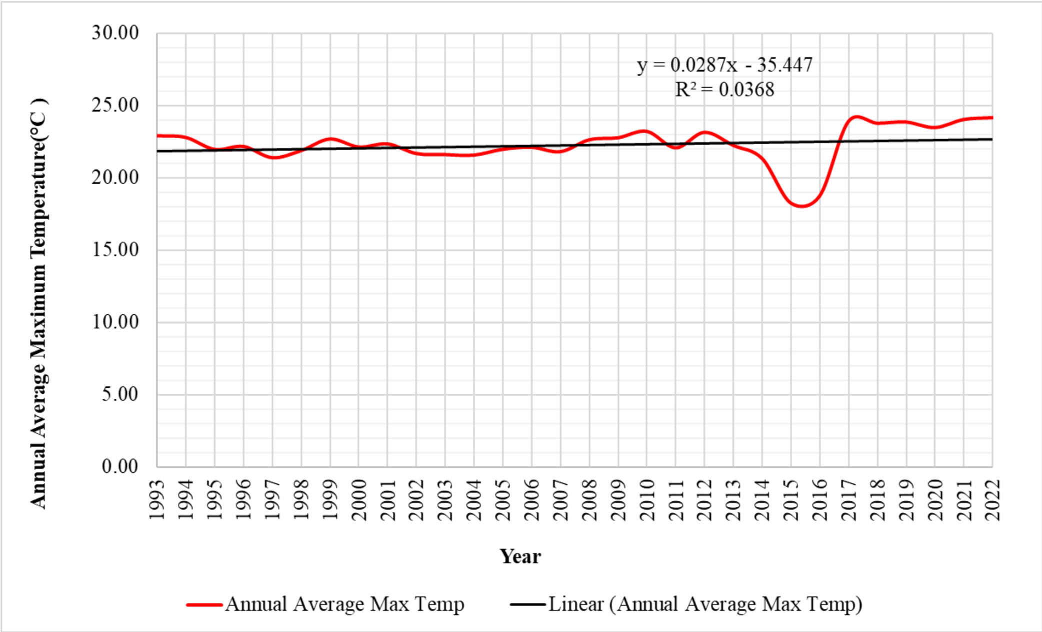

Figure 4: Annual Average Maximum Temperature over 29 years (1993-2022) over 29 years

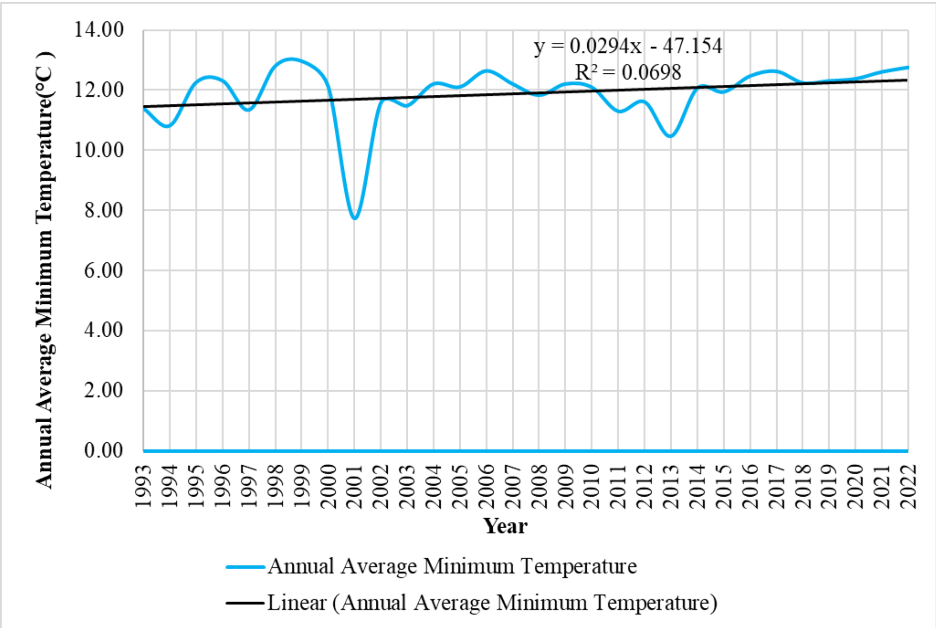

Figure 5: Annual Average Minimum Temperature over 29 years (1993-2022) in the study area

Table 3: Mann-Kendall test and Sen's slope result of mean annual, maximum and minimum temperature for 1993-2022 in the study area

Temperature	p-value	τ- value	Sen's Slope (°C/year)	Trend	Significance	Alpha value
Tmax	0.064	0.241	0.053	Increasing	Insignificant	0.05
Tmin	0.094	0.218	0.026	Increasing	Insignificant	0.05
Average	0.038	0.269	0.039	Increasing	Significant	0.05

4.1.1.2 Rainfall

Monthly rainfall data for the last 29 years are given in Table 2, which shows that the months of May, June, July, August, and September get most of the rainfall. The annual average and seasonal rainfall for the last 29 years is plotted in Figure 6, which shows that the seasonal and average annual rainfall pattern is periodically changing, as felt by a majority of the respondents.

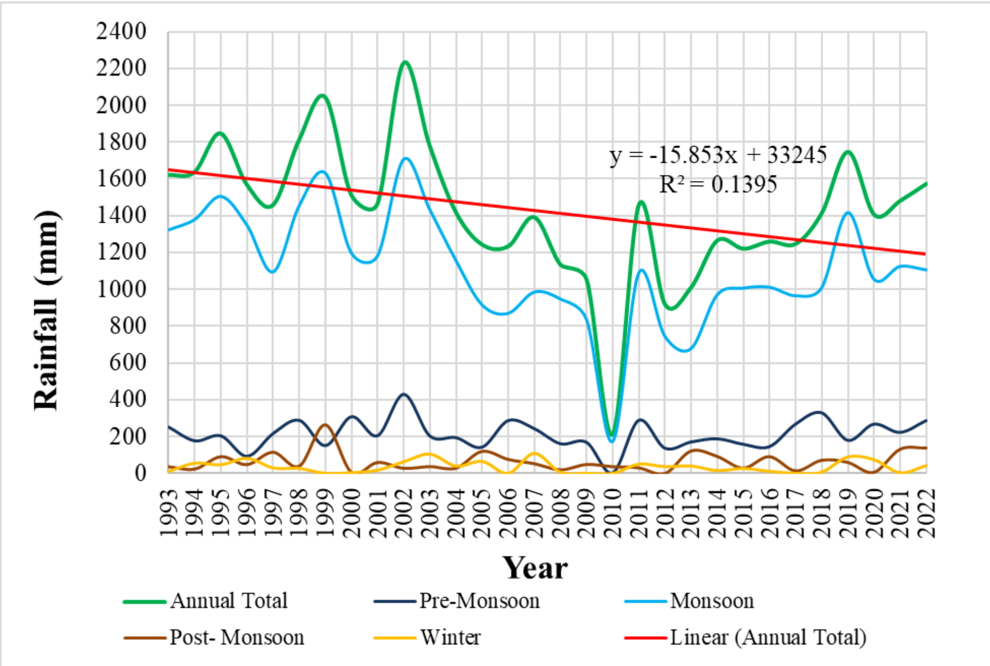

Figure 6 :Variation of seasonal and annual total rainfall over 29 years (1993-2022) in the study area

The results of the Mann–Kendall test and the Sen's slope for the variation of annual average, annual total and seasonal rainfall from 1993 to 2022 are shown in Table 4. It is evident from Table 4 that the annual total, annual average, monsoon, and winter rainfalls have a decreasing trend, as indicated by the negative Tau (τ) values and are statistically significant, but the pre- monsoon, and post-monsoon rainfall is on an increasing trend, as indicated by the positive Tau (τ) value. However, pre- monsoon, post- monsoon and winter rainfalls are statistically insignificant at the 95% confidence level, as indicated by the p-values greater than 0.05 in all cases. Sen's slope method quantified that the monsoon, winter, and average annual and annual total rainfalls are all decreasing at a rate of 14.6 mm/year, 0.307 mm/year, 1.267 mm/year, and 15.2 mm/year, respectively; however, the pre-monsoon, post-monsoon rainfall has been increasing at the rate of 0.255 and 0.413mm/year since 1993.

Table 4: Mann-Kendall test and Sen's slope result of mean annual, annual total, pre-monsoon, monsoon, post-monsoon and winter rainfall for 1993-2022 in the study area

Rainfall	**p-value**	**τ- value**	**Sen's Slope (mm/year)**	**Trend**	**Significance**	**Alpha value**
Annual Average	0.027	-0.287	-1.267	Decreasing	Significant	0.05
Annual total	0.027	-0.287	-15.2	Decreasing	Significant	0.05
Pre-monsoon	0.901	0.018	0.255	Increasing	Insignificant	0.05
Monsoon	0.025	-0.292	-14.620	Decreasing	Significant	0.05
Post-Monsoon	0.643	0.062	0.413	Increasing	Insignificant	0.05
Winter	0.592	-0.072	-0.307	Decreasing	Insignificant	0.05

4.1.2 Agricultural Production

The data on production of major crop types of Kavre district were collected from the database of the Ministry of Agriculture and Livestock Development, Nepal government. Unfortunately, the data were available only from 2011 to 2021; an attempt was made to find the data before 2011 as well, but authentic data were not available by any means. Paddy, maize, wheat, potato and mustard are the major crop types in the study area. The yearly yields of these crops per year from 2011 to 2021 are given in Table 5 and are plotted in fig 7. Mann–Kendall trend analysis and Sen's slope method were applied to find the trend of the yields of major crops from 2011 to 2021, and the results are presented in Table 6. Table 6 shows that the yields of all crops had an increasing trend. However, only the increasing trends of mustard was statistically insignificant at the 95% confidence level. Sen's slope method quantified that the yields of paddy, maize, wheat, potato and mustard increased at a rate of 112 Kg/Ha per year, 163 Kg/Ha per year, 175.67 Kg/Ha per year, 313.33 Kg/Ha and 16.50 Kg/Ha per year between 2011 and 2021 (Table 6).

Table 5: Yearly Yield of major crops grown in the study area

Yield (Kg/Hectare)					
Year	**Paddy**	**Maize**	**Wheat**	**Potato**	**Mustard**
2011	3120	2590	750	18500	1067
2012	3526	1906	750	17264	825
2013	3012	2125	1909	18132	1100
2014	3272	2400	2410	18597	1000
2015	3005	2400	2373	18868	1346
2016	3288	2769	2740	19072	1133
2017	3422	2947	2860	20302	1202
2018	3830	3110	2900	20590	1240
2019	3910	3230	3000	17760	1060
2020	3920	3330	2990	19180	1220
2021	4240	3400	3240	21860	1060

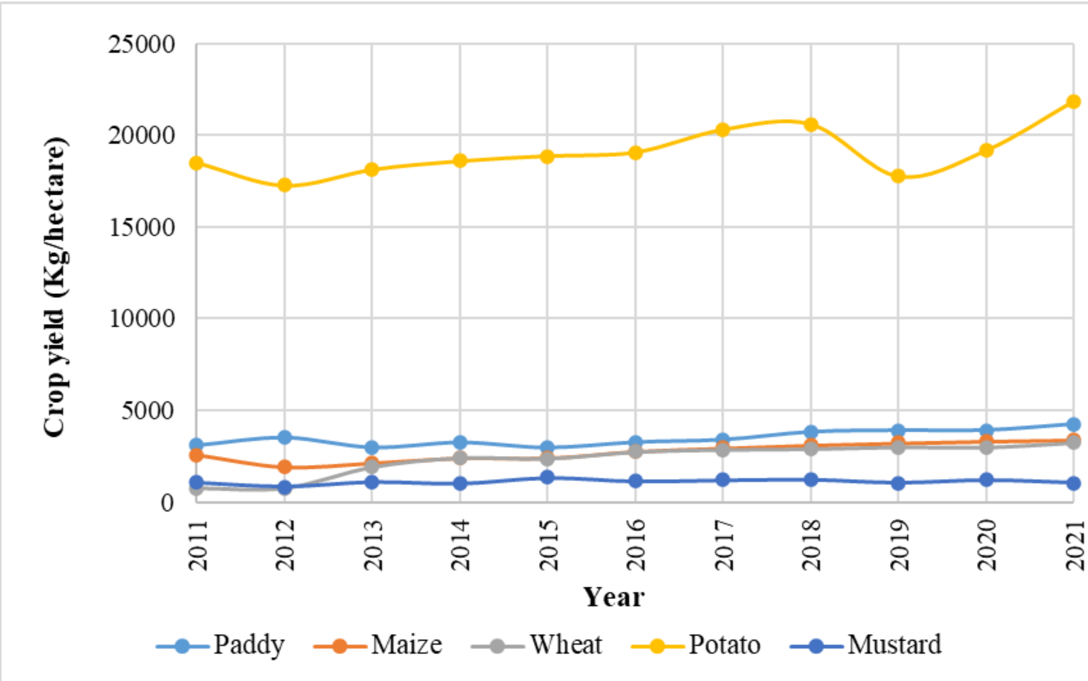

Figure 7: Major crop yield over 10 years (2011-2021) in the study area

Table 6 : Mann-Kendall test and Sen's slope result of paddy, maize, wheat, potato and mustard for 2011-2021 in the study area

Crops	p-value	τ- value	Sen's Slope (kg/hec/year)	Trend	Significance	Alpha value
Paddy	0.005	0.673	112	Increasing	Significant	0.05
Maize	0.000	0.844	163	Increasing	Significant	0.05
Wheat	0.000	0.917	175.67	Increasing	Significant	0.05
Potato	0.013	0.6000	313.33	Increasing	Significant	0.05
Mustard	0.390	0.220	16.50	Increasing	Insignificant	0.05

As discussed in Section 4.1.1, rainfall generally had a decreasing trend in the study area over the last 29 years or so. To find the relationship between seasonal rainfall and the yield of major crops in the study area, a Spearman's rank correlation was conducted. The correlation results are given in Table 7, which shows Paddy cultivation during the monsoon season shows a moderate positive correlation (0.527) with seasonal rainfall. The p-value of 0.100 suggests that this correlation might not be statistically significant at the 95% confidence level of significance. Maize cultivation displays significant positive correlations with both Pre-Monsoon (0.557) and Monsoon (0.770) rainfall. The low p-values (0.080 and 0.008) indicate that these correlations are likely meaningful. Wheat cultivation has a weak positive correlation (0.255) with post-Monsoon rainfall. However, there is a weak negative correlation (-0.200) with Winter rainfall. Neither of these correlations appears to be significant based on their p-values. Potato cultivation shows a modest positive correlation (0.236) with post-Monsoon rainfall, but it exhibits a strong negative correlation (-0.700) with Winter rainfall. The low p-value (0.021) for the Winter correlation suggests a significant relationship. Mustard cultivation demonstrates a mild positive correlation (0.315) with Pre-Monsoon rainfall, but weak negative correlations with both post-Monsoon (-0.187) and Winter (-0.169) rainfall. None of the correlations have particularly low p-values.

Table 7: Spearman's rank correlation test results for the yield of major crops with seasonal rainfall

Crops	Seasonal Rainfall	Rho-Coefficient	p-value
Paddy	Monsoon	0.527	0.100
Maize	Pre-Monsoon	0.557	0.080

	Monsoon	0.770	0.008
Wheat	Post -Monsoon	0.255	0.450
	Winter	-0.200	0.557
Potato	Post Monsoon	0.236	0.485
	Winter	-0.700	0.021
Mustard	Pre-Monsoon	0.315	0.346
	Post-Monsoon	-0.187	0.585
	Winter	-0.169	0.623

4.1.3 Community Perception on Climate Change, its impact on agriculture and adaptation practices by the community

4.1.3.1 Demographic Distribution of the Respondents

Table 8:Demographic Distribution of the Respondents

Caste/Ethnicity	**Number of respondents**	**%**
Brahmin/Chhetri	78	28.8
Janajati	119	43.9
Dalit	74	27.3
Total	271	100
Sex	**Number of respondents**	**%**
Male	121	44.6
Female	150	55.4
Total	271	100
Age groups (Year)	**Number of respondents**	**%**
Less than 40	75	27.7
41-50	83	30.6
51-60	58	21.4
60 and above	55	20.3
Total	271	100
Occupation	**Number of respondents**	**% of respondents**
Farmer	99	36.5
Day Laborer	74	27.3
Businessman	67	24.7
Teacher	30	11
Government Officials	1	0.4
Total	271	100

Farmland size	Number of respondents	% of respondents
0-0.3 hectare	157	57.9
0.4-0.6 hectare	88	32.5
0.7-0.9 hectare	16	5.9
1-3 hectare	10	3.7
Total	271	100
Education	**Number of respondents**	**% of respondents**
No schooling	55	20.2
Functional Literacy	109	40.2
Primary	62	22.9
Secondary	33	12.1
Graduate (Bachelor's)	10	3.7
Post Graduate (Master's)	2	0.7
Total	271	100

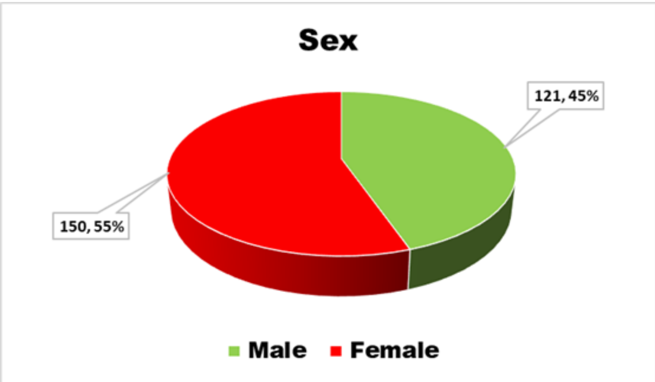

Figure 8: Sex of the respondents

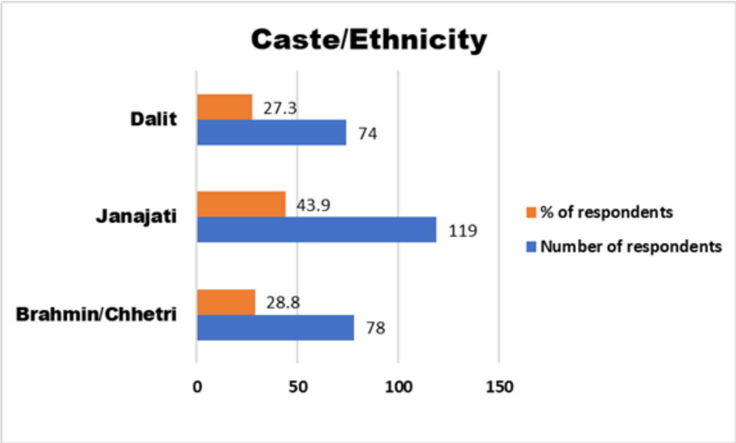

Figure 9: Caste/Ethnicity of the respondents

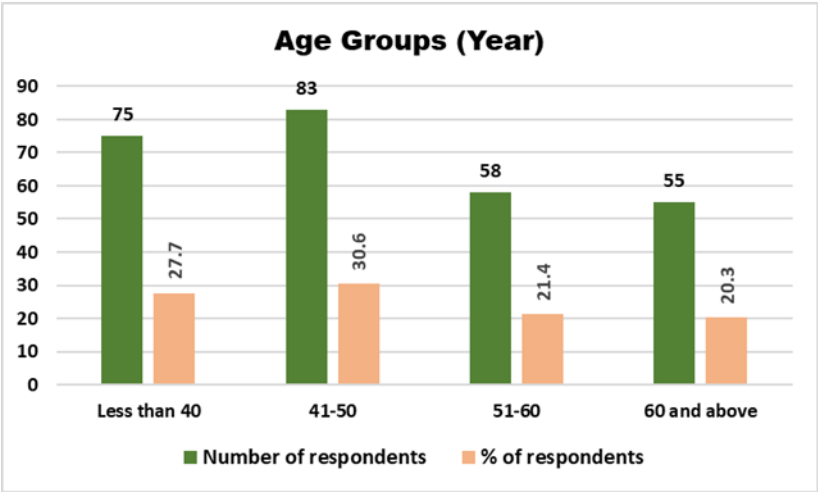

Figure 10: Age group of the respondents

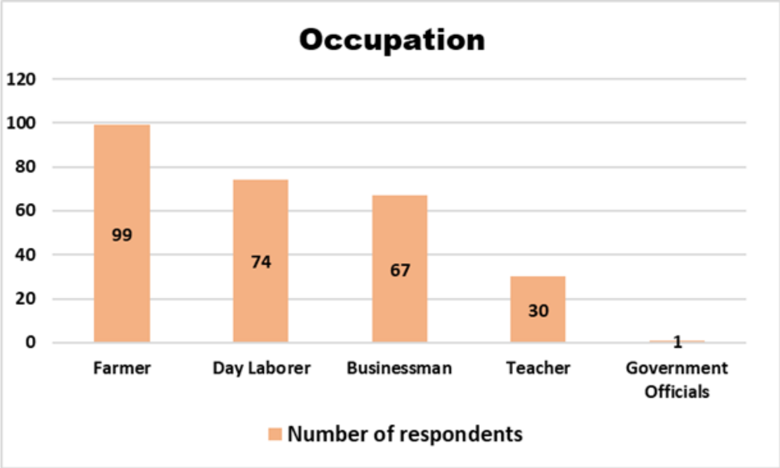

Figure 11: Occupation of the respondents

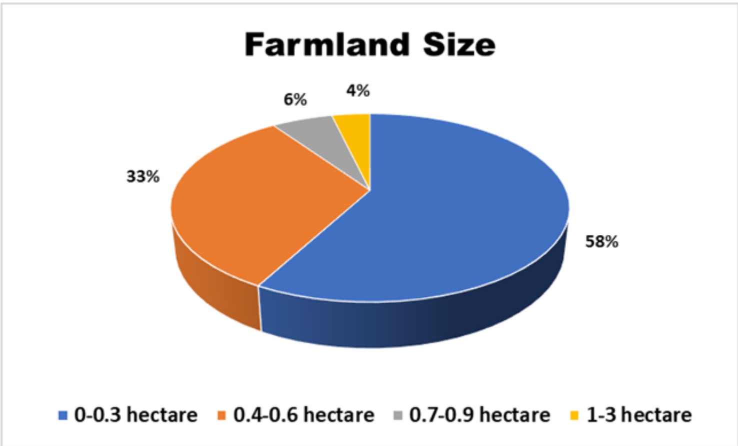

Figure 12: Farmland size of the respondents

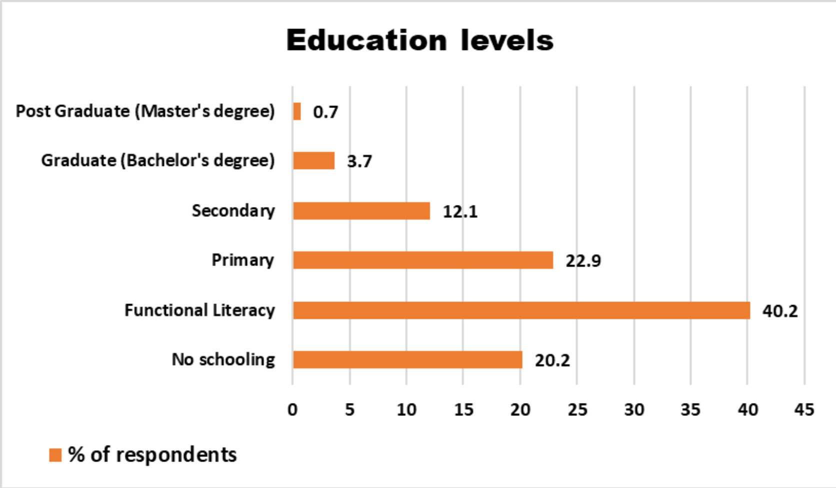

Figure 13: Education levels of the respondents

The survey results provide insights into various demographic and socio-economic factors among the respondents. In terms of caste/ethnicity, the distribution is as follows: Brahmin/Chhetri constitutes 28.8% of the respondents, Janajati makes up 43.9%, and Dalit represents 27.3% of the total. Regarding gender, the respondents consist of 44.6% males and 55.4% females. When considering age groups, 27.7% fall under the category of less than 40 years, 30.6% are between 41-50 years, 21.4% fall within the 51-60 age range, and 20.3% are 60 years and above. In terms of occupation, the survey reveals that 36.5% are farmers, 27.3% are day laborers, 24.7% are businessmen, 11% are teachers, and a mere 0.4% are government officials. When analyzing farmland size, 57.9% of the respondents own land in the 0-0.3-hectare range, 32.5% possess land in the 0.4-0.6-hectare range, 5.9% have land within the 0.7-0.9 hectare range, and 3.7% own land spanning 1-3 hectares. Finally, with regards to education, the distribution indicates that 20.2% have received no schooling, 40.2% have functional literacy, 22.9% have completed primary education, 12.1% have undergone secondary education, 3.7% are graduates with a Bachelor's degree, and 0.7% hold a Post Graduate (Master's) degree. These figures shown above collectively provide a comprehensive overview of the demographic and socio-economic composition of the respondents.

4.1.3.2 People's perception on climate change, rainfall and temperature

The majority of respondents almost 83% out of total respondents we interacted with during Household survey (HHs) informed us that they are aware about climate change and have been experiencing its adverse impacts in the past decade and 17% of the respondents were unknown about the climate change shown in the figure below:

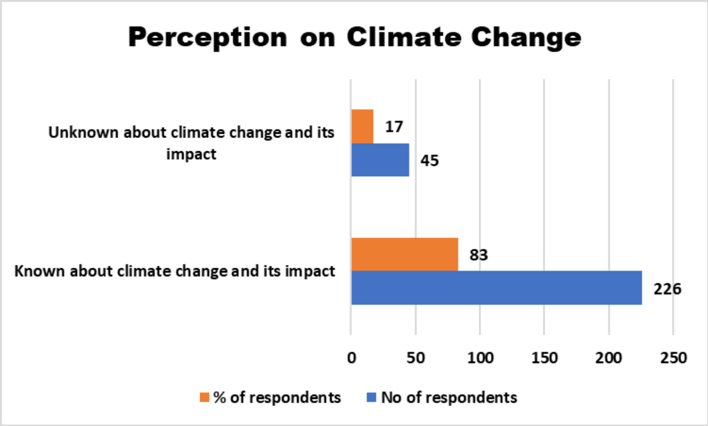

Figure 14:Perception on Climate change of the respondents

Among those who noticed changes in the climate, a significant proportion about 83% reported that increased temperatures were a noticeable impact. Likewise, 11% felt decrease in temperature over the past decades and 6% reported no change at all. Regarding the perception in rainfall pattern, 11% of the respondents observed increase in rainfall and around 83% of the respondent observed decreased in rainfall over the past decades whereas 6% didn't noticed any change in rainfall pattern. This result aligns with the finding of the section 4.1.1.

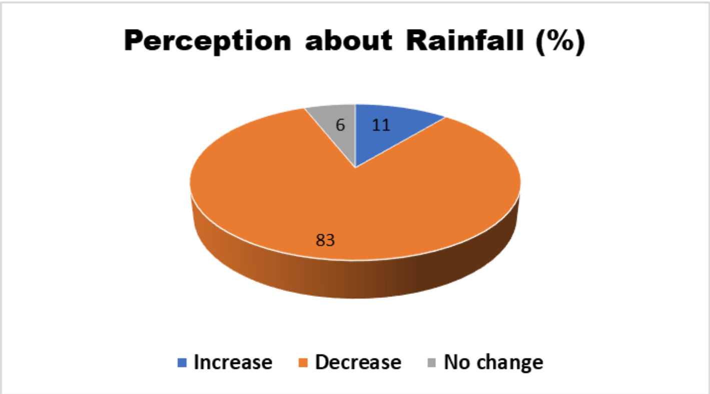

Figure 15: Perception about Rainfall of the respondents

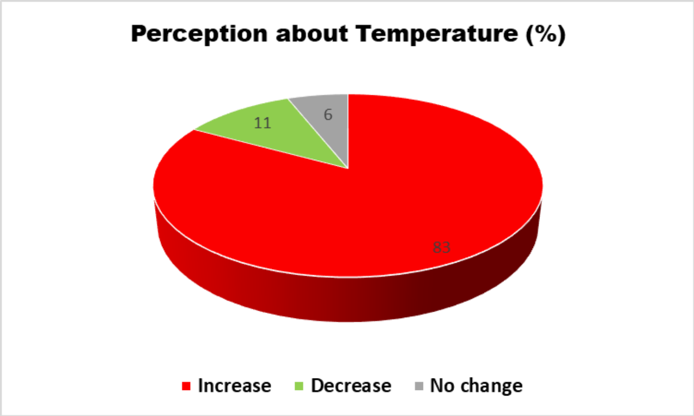

Figure 16: Perception about Temperature of the respondents

4.1.3.3 Climate change impact on agriculture

According to the HH survey, 77% of the participants reported that they have observed a direct influence of climate change on agricultural activities, whereas only 23% stated that they haven't noticed any direct impact. A noteworthy finding is that a considerable portion of these respondents depend on rainfed agricultural systems. The survey assessed the impact of climate change on agriculture through five distinct parameters. Among all the participants, the largest group, accounting for 28.4% of respondents, identified water scarcity for irrigation as a primary repercussion on agriculture. This was followed by 25.5% of respondents expressing concerns about the deterioration of soil health. Around 16.6% of respondents highlighted alterations in crop growth cycles as a significant impact, while a similar proportion of 16.2% noticed a reduction in crop yield. Additionally, 13.3% of respondents pointed out an increase in the occurrence of pests and diseases in crops.

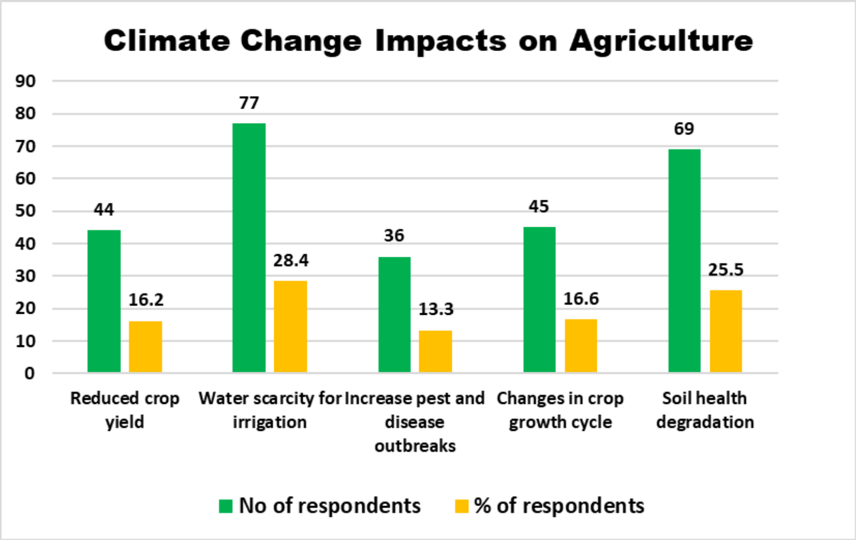

Figure 17: Response on Climate Change Impacts on Agriculture by the respondents

4.1.3.4 Adaptation practices in agriculture

Table 9: Response on Adaptation Practices in Agriculture

Adaptation Practices	**No of respondents**	**% of respondents**
Crop Diversification and crop rotation	43	15.9
Use of improved variety of seeds	49	18.08
Improved water Management technique	55	20.3
Adoption of new farming practices	26	9.6
Use of chemical fertilizer/pesticides/bio fertilizers	67	24.7
Soin conservation and organic farming	19	7.02
Have done nothing	12	4.4
Total	271	100

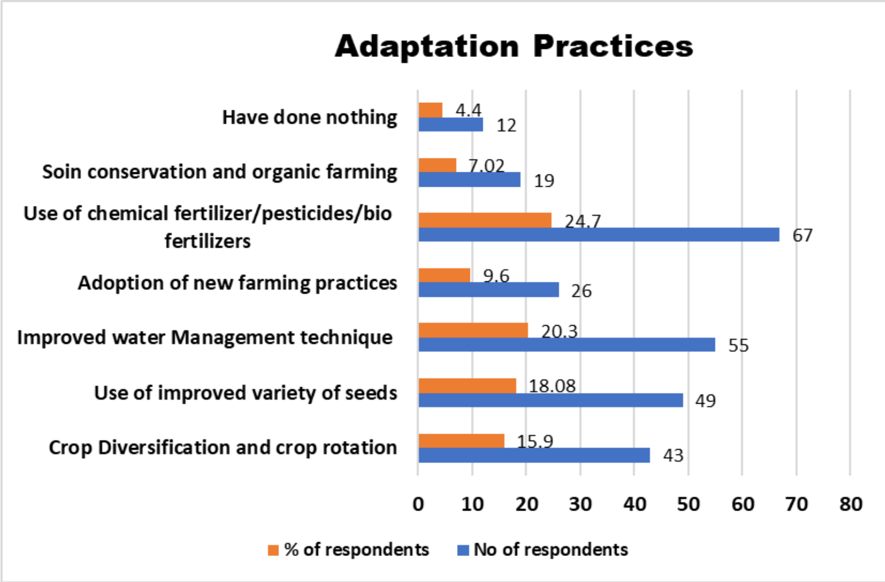

Figure 18: Response on Adaptation Practices adopted by the community

Among the respondents, the highest percentage, 24.7% respondents, mentioned using chemical fertilizers, pesticides, or bio-fertilizers as an adaptation practice in agriculture. Additionally, 20.3% of participants reported implementing enhanced water management techniques. Improved seed varieties were favored by 18.08% of respondents. Crop diversification and rotation stood at 15.9%, followed by 9.6% of respondents adopting new farming practices. Soil conservation and organic farming practices found adoption among 7.02% of participants. Conversely, 4.4% of respondents admitted to not having undertaken any specific adaptation measures.

4.1.3.5 Barriers to adaptation practices

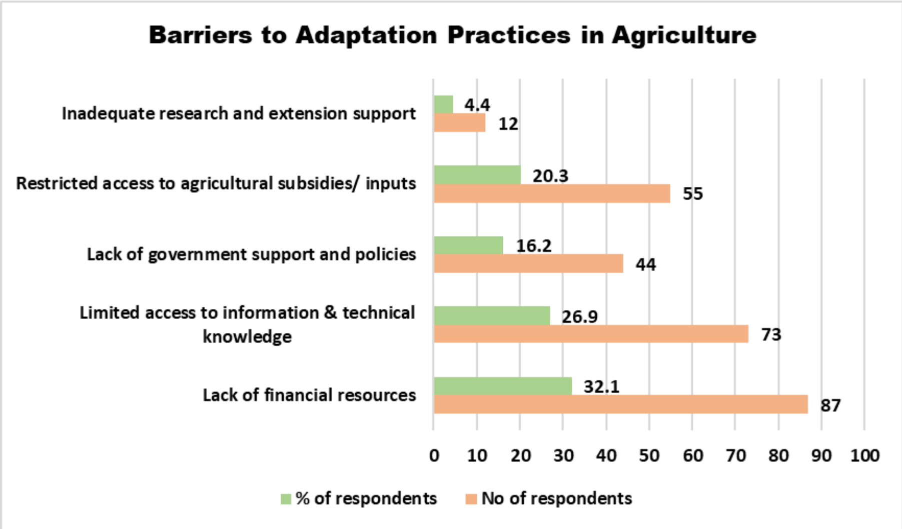

Figure 19: Response on barriers to adaptation practices in agriculture

The survey sought to uncover the primary barriers hindering the adoption of adaptation practices among respondents. The data collected from 271 participants shed light on several key challenges. The most prevalent barrier identified was the lack of financial resources, accounting for 32.1% of responses. The following closely was the barrier of limited access to information and technical knowledge, as reported by 26.9% of respondents. The survey also indicated that 16.2% of respondents identified a lack of government support and policies as a substantial barrier. Similarly, restricted access to agricultural subsidies and inputs was recognized as a barrier by 20.3% of respondents. In contrast, a relatively lower percentage of participants, 4.4%, identified inadequate research and extension support as a barrier.

4.2 DISCUSSIONS

4.2.1 Key Climate Change Indicators

The results of the study provide valuable insights into the long-term trends of annual average maximum and minimum temperatures in the study area over the past three decades. The findings indicate a consistent upward trend in both annual average, maximum and minimum temperatures, with increases recorded at rates of 0.039°C/year, 0.053°C/year and 0.026°C/year, respectively, over the last 29 years. This aligns with the one of the observations of a previous study conducted by another researcher in the Rautahat District, which also reported rising temperatures over a similar period. Specifically, the earlier study revealed that the maximum, minimum, and annual mean temperatures in the Rautahat District had risen by approximately 0.01°C/year, 0.019°C/year, and 0.015°C/year, respectively, over a 28-year period (Dhakal, Sedhain, & Dhakal, 2016). The trend analysis shows that the annual average minimum temperature has also been increasing per year in Kavrepalanchowk district over a period of 27 years (Giri & Dahal, 2021).

However, a more detailed analysis using statistical methods such as the Mann-Kendall test and Sen's slope has provided additional insight into the significance of these trends. The results suggest that while the overall annual mean temperature increase is statistically significant, indicating a clear warming trend in the study area, the upward trends observed in annual maximum and minimum temperatures are not statistically significant at a 95% confidence interval. The lack of statistical significance in annual maximum and minimum temperatures might indicate certain degrees of variability or complex local factors that influence these specific temperature parameters. This observation underscores the importance of considering various local influences, such as microclimates, topography, and land use patterns, that could contribute to temperature variations and potentially mask clear trends.

The annual average, monsoon, and winter rainfalls have a decreasing trend, as indicated by the negative Tau (τ) values and are statistically significant, but the pre- monsoon, and post-monsoon rainfall is on an increasing trend, as indicated by the positive Tau (τ) value. However, pre- monsoon, post- monsoon and winter rainfalls are statistically insignificant at the 95% confidence level, as indicated by the p-values greater than 0.05 in all cases. Sen's slope method quantified that the monsoon, winter, and average annual and annual total rainfalls are all decreasing at a rate of 14.6 mm/year, 0.307 mm/year, 1.267 mm/year, and 15.2 mm/year, respectively; however, the pre-monsoon, post-monsoon rainfall has been increasing at the rate of 0.255mm/year and 0.413mm/year since 1993. One of the research in Rosi Khola Watershed, western part of Kavrepalanchowk district showed that the annual rainfall in the two stations (Godavari and Dhulikhel) of the study area significantly decreased, with a rate of −10.4 mm/year ($p = 0.006$) in Godavari and −9.1 mm/year ($p = 0.010$) in Dhulikhel over a period of 43 years (Dahal et al., 2018). It's important to recognize that the patterns of climatic factors rely significantly on the timeframes under consideration and whether notable extreme events occurred within those timeframes.

4.2.2 Agricultural Production

Despite decreasing trends of precipitation and increasing trend of temperature, there was a higher yield of major crop types in the study area, and the trend was increasing. Such an increased trend of yield of major crops should have been contributed by a wider use of improved variety of seeds, chemical fertilizers, alternate irrigation to crops through water collected in plastic ponds, soil- cement tank rainwater harvesting, crop diversification and rotation, and other adaptation capabilities adopted by the majority of farmers, as shown in section 4.1.3.4. The yields of major crops including rice, maize, wheat, sugarcane, potatoes, and pulses all showed increasing trends during 1999 to 2014 in Rautahat District (Dhakal, Sedhain, & Dhakal, 2016).

Similarly, Paddy cultivation during the monsoon season shows a moderate positive correlation (0.527) with seasonal rainfall. The p-value of 0.100 suggests that this correlation might not be statistically significant at the 95% confidence level of significance. Maize cultivation displays significant positive correlations with both Pre-Monsoon (0.557) and Monsoon (0.770) rainfall. The low p-values (0.080 and 0.008) indicate that these correlations are likely meaningful. Wheat cultivation has a weak positive correlation (0.255) with post-Monsoon rainfall. However, there is a weak negative correlation (-0.200) with Winter rainfall. Neither of these correlations appears to be significant based on their p-values. Potato cultivation shows a modest positive correlation (0.236) with post-Monsoon rainfall, but it exhibits a strong negative correlation (-0.700) with Winter rainfall. The low p-value (0.021) for the Winter correlation suggests a significant relationship. Mustard cultivation demonstrates a mild positive correlation (0.315) with Pre-Monsoon rainfall, but weak negative correlations with both post-Monsoon (-0.187) and Winter (-0.169) rainfall. None of the correlations have particularly low p-values. This result is similar to the results of Poudel and Shaw , where they found that paddy, maize, and wheat yields were negatively correlated in Lamjung district of Nepal (Poudel & Shaw, 2016). It has to be noted that there can be some influence of data trends while performing correlation, which was not considered in this analysis. It was the view of the majority of respondents that most of the rice- and maize-growing farmers were using hybrid seeds in irrigated fields and getting much higher production compared to the open-pollinated varieties used in the past. The trends of major crop yields found in the present study are similar to the findings for the whole country (Pant, 2012; Joshi et al., 2011).

4.2.3 Community Perception on Climate Change, its impact on agriculture and adaptation practices by the community

4.2.3.1 Demographic Distribution of the Respondents

The survey's findings reveal a diverse demographic and socio-economic landscape among the respondents. A comparison of different categories highlights several noteworthy trends. In terms of caste/ethnicity, Janajati emerges as the most prominent group, comprising 43.9% of respondents, showcasing their significant representation within the study. Brahmin/Chhetri and Dalit groups follow, constituting 28.8% and 27.3% respectively. This distribution signifies a balanced ethnic composition, reflecting the region's diversity. In the context of gender, the survey showcases a slight female majority, with 55.4% females compared to 44.6% males. Age-wise, the largest proportion falls within the 41-50 age (30.6%), closely followed by those aged 51-60 (21.4%). Notably, the data reveals a relatively even distribution across age groups, indicating inclusivity in data collection. Occupation-wise, farmers constitute the largest group (36.5%), underlining the community's strong ties to agriculture. Day laborers (27.3%) and businessmen (24.7%) represent substantial segments as well. Conversely, teachers and government officials constitute a smaller percentage, possibly indicating areas of growth in these sectors. Analysis of farmland size demonstrates a predominance of small land holdings, with 57.9% owning land within the 0-0.3-hectare range, reflecting the prevalence of subsistence farming. On the education front, functional literacy stands out at 40.2%, showcasing a significant effort toward basic education. The distribution across education levels indicates a gradual decline, from primary (22.9%) to secondary education (12.1%) and further to higher education (3.7% with a Bachelor’s degree, and 0.7% with a Post Graduate degree).

4.2.3.2 People’s perception on climate change, rainfall and temperature

The results obtained from the household survey (HHs) provide valuable insights into the awareness and perceptions of respondents regarding climate change and its impacts. The data collected indicates that a significant majority of respondents, approximately 83%, are well-informed about climate change and have personally witnessed its adverse effects over the last decade. This highlights a growing awareness and recognition of the environmental shifts that have taken place. However, it is noteworthy that 17% of the respondents still lack awareness about climate change, indicating a need for continued education and awareness campaigns to reach a wider audience.

When examining the specific impacts of climate change that respondents have observed, it becomes evident that increased temperatures have gathered the most attention. Around 83% of those who noticed changes in the climate reported that rising temperatures have been a prominent impact. This aligns with the global trend of rising temperatures and suggests that the phenomenon is not only a distant concept but a tangible experience for many individuals. In contrast, 11% of respondents perceived a decrease in temperature over the past decades, showcasing a smaller yet significant proportion that has experienced a contrary trend. Additionally, 6% of respondents reported no change in temperature at all.

A similar pattern emerges when analyzing perceptions of rainfall patterns. Among the respondents, 83% noted a decrease in rainfall over the past decades, indicating a widespread perception of changing precipitation patterns. This is consistent with the understanding that climate change often leads to altered precipitation patterns, with some regions experiencing increased drought conditions. Conversely, 11% of respondents observed an increase in rainfall, possibly indicative of localized variations or shifts in weather patterns. Notably, 6% of respondents did not notice any change in rainfall patterns.

These findings resonate with the conclusions drawn in section 4.1.1 of the study, reaffirming the consistency and reliability of the results. The alignment between different sections of the study reinforces the robustness of the data and the credibility of the conclusions drawn. It is evident that the majority of respondents have recognized and experienced the impacts of climate change, particularly in terms of rising temperatures and altered rainfall patterns.

A survey was conducted in Banepa Municipality, Kavrepalanchok district, involving 200 households to assess the historical and current trends in annual precipitation and temperature variations. Regarding annual precipitation changes, 11% of respondents noted an increase, 76% observed a decrease, and 13% saw no change. Similarly, concerning annual temperature variations, 81% of participants perceived an increase, 10% noticed a decrease, and 9% detected no significant change (Giri & Dahal, 2021). This finding resembles with our current study in Namobuddha Municipality, Kavrepalanchowk district.

4.2.3.3 Climate change impact on agriculture

The provided survey data reveals a clear consensus among participants regarding the influence of climate change on agriculture. An overwhelming 77% of respondents have directly observed this impact, highlighting its significant presence in the agricultural sector. This finding aligns with the survey that was conducted with 125 farmers in the mid-hills of central Himalaya revealed that among 125 farmers, 124 (99%) claimed that they have been experiencing the impact of climate change on agriculture (Dahal et al., 2022).

Notably, a substantial portion of those surveyed in Namobuddha Municipality rely on rainfed agricultural systems, which are particularly sensitive to climate fluctuations. The data also categorizes the impact into five distinct parameters, with the largest group (28.4%) identifying water scarcity for irrigation as a primary concern. This is followed closely by worries about soil health deterioration (25.5%), altered crop growth cycles (16.6%), reduced crop yield (16.2%), and increased occurrences of pests and diseases (13.3%). Such detailed categorization underscores the multifaceted nature of challenges posed by climate change. Collectively, these findings underscore the urgent need for targeted interventions to address the diverse impacts of climate change on agriculture, especially for rainfed systems that seem to be disproportionately affected. Another study also reported that decrease in soil moisture increased the need for water for irrigation, an increase in insect pests and diseases, and weed infestation resulting in low crop production and even crop failure are the biggest impacts of the changing climate on agricultural activities (Dahal et al., 2022).

4.2.3.4 Adaptation practices in agriculture

The data reveals a diverse range of adaptation practices employed by respondents in the agricultural sector. Chemical fertilizers, pesticides, and bio-fertilizers emerged as the most prevalent strategy, with a substantial 24.7% of respondents employing these measures. It was interesting to know that majority of the farmers with small land holdings are switching from chemical fertilizers to bio-fertilizer known as 'Jholmal'. This suggests a strong reliance on technological solutions to address agricultural challenges.

Notably, 20.3% of participants emphasized the importance of enhanced water management techniques, reflecting a recognition of the growing significance of water scarcity in farming. Majority of the farmers have adopted water-smart technologies such as soil-cement tanks, rainwater harvesting, plastic ponds, micro-sprinkler irrigation, drip-irrigation and so on. 24 farmers of Namobuddha Municipality have adopted soil cement tank among which 18 have adopted this technology at subsidized rate bearing 15% of the total cost while 6 of them have adopted independently (Nhemhafuki, 2021).

The adoption of improved seed varieties, favored by 18.08% of respondents, underscores the value placed on genetic advancements to enhance crop resilience. Interestingly, 15.9%

of respondents opted for crop diversification and rotation, indicating a shift towards sustainable farming practices.

The relatively lower percentage (9.6%) of respondents adopting new farming practices might indicate the slower adoption rate of innovative methods. Encouragingly, 7.02% of participants showed commitment to soil conservation and organic farming practices, highlighting a growing awareness of environmental sustainability. On the other hand, the 4.4% of respondents who admitted to not undertaking any specific adaptation measures indicate a potential gap in awareness or resources among a subset of farmers.

A previous survey conducted in the Banepa municipality of the Kavrepalanchok district revealed specific trends in local agricultural adaptation practices somehow similar to our current findings. The findings indicated that 23% of the community members were engaged in altering their crop varieties, while an overwhelming 96% were utilizing improved seeds. Additionally, 47% of the respondents had made changes to their cropping patterns, and 64% were practicing intercropping. As for land management techniques, 58% of the participants reported adopting such technologies, while terracing was being employed by 53%. Notably, a significant majority of 93% were found to be using chemical fertilizers and pesticides extensively. It was also observed that there was an absence of water harvesting systems in place (Giri & Dahal, 2021).

4.2.3.5 Barriers to adaptation practices

The survey's findings shed valuable light on the primary barriers that impede the widespread adoption of adaptation practices among the surveyed participants. With data gathered from 271 respondents, a comprehensive picture of the challenges emerged. Notably, a significant 32.1% of respondents highlighted the lack of financial resources as the foremost barrier, underscoring the importance of economic considerations in implementing adaptation measures. Following closely, at 26.9%, was the challenge of limited access to crucial information and technical expertise, indicating that addressing knowledge gaps is integral to fostering effective adaptation strategies. The survey further underscored the impact of policy and institutional support, as 16.2% of participants emphasized the absence of government backing as a substantial hindrance. Additionally, restricted access to agricultural subsidies and inputs emerged as a noteworthy barrier, voiced by 20.3% of respondents. Interestingly, a relatively smaller percentage, 4.4%, identified insufficient research and extension support as a limiting factor.

One of the previous findings also revealed that there are limits to adaptation, which are caused by barriers of available technology, knowledge and institutional frameworks (Regmi & Bhandari, 2013).

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study focused on important indicators of climate change, specifically the variations in temperature and rainfall over the past 29 years within the study area. The analysis showed a clear trend of increasing temperatures, although the annual maximum, minimum, and mean temperatures showed statistically insignificant changes at the 95% confidence level. Rainfall patterns demonstrated fluctuations, with some months experiencing higher rainfall, while an overall decrease was observed during the studied period. Notably, agricultural production exhibited positive growth, as the yields of major crops consistently increased from 2011 to 2021.

However, the relationships between seasonal rainfall and crop yields displayed varying degrees of correlation, highlighting the complex nature of these interactions.

The assessment of community perceptions highlighted that many respondents were aware of the impacts of climate change, particularly regarding rising temperatures and shifting rainfall patterns. The survey indicated that a majority of participants noticed direct effects of climate change on their agricultural practices, citing challenges like water scarcity, changes in crop growth cycles, and decreased yields. To address these challenges, farmers adopted various adaptation practices, including using better seed varieties, employing water management techniques, and using chemical inputs. However, barriers to adopting these practices were also identified, including financial limitations, limited access to information and technical knowledge, and a lack of government support and policies.

This study provides valuable insights into the changing climate dynamics within the study area and their implications for agriculture. The findings underscore the importance of targeted adaptation strategies that address specific barriers and leverage local knowledge. As climate change continues to impact our environment, combining scientific analysis, community perceptions, and adaptive practices becomes crucial in developing resilient agricultural systems capable of facing future challenges.

5.2 Recommendations

1. The 17% of respondents lacking awareness about climate change indicate a need for continued educational campaigns to reach a wider audience. Government and non-governmental organizations should collaborate to raise awareness about the changing climate, its impacts, and adaptation strategies through workshops, seminars, and community engagement programs.

2. The substantial percentage of respondents identifying limited access to information and technical expertise as a barrier underscores the need for accessible knowledge platforms. Extension services, workshops, and technology dissemination should be prioritized to empower farmers with the necessary tools and information to adapt effectively.

3. Recognizing the financial constraints faced by farmers, governments and relevant institutions should provide targeted financial support and subsidies to facilitate the adoption of climate-smart agricultural practices. This could involve reduced costs for inputs, machinery, and technologies that enhance resilience.

4. Encouraging collaboration among farmers, local communities, researchers, governmental bodies, and NGOs can facilitate the exchange of best practices, experiences, and innovations in climate adaptation.

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APPENDICES

Appendix A: Sample size calculation for each ward

Total Households of Namobuddha Municipality: 6,584 (CBS, 2011)

Total sample size: 271 (From Cochran's Formula at 90% confidence Interval)

Ward	Ward Households	% of households per ward (Ward Households/total households *100)	Sample size for Household Survey per ward (% of Household*271/100)	
1	466	7.077764	19.18074	19
2	739	11.22418	30.41753	30
3	580	8.809235	23.87303	24
4	475	7.214459	19.55118	20
5	922	14.00365	37.94988	38
6	332	5.042527	13.66525	14
7	750	11.39125	30.87029	31
8	645	9.796476	26.54845	26
9	577	8.76367	23.74954	24
10	498	7.563791	20.49787	20
11	600	9.113001	24.69623	25

Appendix B Questionaries for the Household Survey

A. <u>Demographic Information:</u>

Name of the respondent:	Ward:

1. What is your age?
   a. less than 40
   b. 41-50
   c. 51-60
   d. Above 60
2. What is your gender?
   a. Male
   b. Female
   c. Others

3. What is your caste?

    a. Brahmin/Chhetri

    b. Janajati

    c. Dalit

    d. Others

4. How many members are there in your household?

    a. 2-4

    b. 4-6

    c. 6-8

    d. 8-12

5. What is the highest level of education you have completed?

    a. No schooling

    b. Functional literacy

    c. Primary Schooling

    d. Secondary Schooling

    e. Graduate (Bachelor's)

    f. Graduate (Master's)

6. What is your occupation?

    a. Farmer

    b. Day Laborer

    c. Businessman

    d. Teacher

    e. Government Officials

    f. Others: Please specify

7. How much farmland you own?

a. 0-0.3 hectare
b. 0.4-0.6 hectare
c. 0.7-0.9 hectare
d. 1-3 hectare

B. <u>Climate Data Trends:</u>

8. Do you know/ heard about climate change and its impact?

a. Known

b. Unknown

9. Has rainfall over the past decades?

a. Increase

b. Decrease

c. No change

10. Has temperature over the past decades?

a. Increase

b. Decrease

c. No change

11. Are you aware of any official climate data collected in your area?

a. Yes
b. No

C. <u>Impacts on Agriculture:</u>

12. Have you experienced any challenges or impacts on your agricultural activities due to climate change?

a. Yes
b. No

13. If yes, please specify the impacts you have observed. (Select all that apply)

a. Reduced crop yields

b. Water scarcity for irrigation

c. Increased pest and disease outbreaks

d. Changes in crop growth cycles

e. Soil health degradation

f. Other (please specify)

14. Have these impacts affected your household income or food security?

- Yes
- No

D. <u>Adaptation Practices:</u>

15. Have you implemented any adaptation practices to cope with climate change in your agricultural activities?

- Yes
- No

16. If yes, please specify the adaptation practices you have adopted. (Select all that apply)

a. Crop diversification and crop rotation
b. Improved water management techniques
c. Use of improved variety of seeds
d. Adoption of new farming practices
e. Use of chemical fertilizers/pesticides/bio fertilizers
f. Soil conservation and organic farming
g. Have done nothing

17. Have these adaptation practices helped in reducing the negative impacts of climate change on your agriculture?

- Yes
- No

E. <u>Barriers and Support:</u>

18. What are the main challenges you face in implementing adaptation practices? (Select all that apply)

a. Lack of financial resources
b. Limited access to information and technical knowledge
c. Lack of government support and policies
d. Restricted access to agricultural subsidies/inputs
e. Inadequate research or extension support

Appendix C: Photographs

Data collection through Household Survey across various wards of Namobuddha Municipality


Focus Group Discussions


Soil Cement Tanks


Drip Irrigation System

Plastic Pond