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

# LIVELIHOOD VULNERABILITY AND ADAPTIVE STRATEGIES ASSESSMENT OF FARMERS LIVING IN RAJAPUR MUNICIPALITY, BARDIYA.

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**(P.U. registration number: 2019-1-25-0058)**

**School of Environmental Science and Management (SchEMS)**

**Faculty of Science and Technology**

**Pokhara University, Nepal**

**JULY, 2022**

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**Supervised by Prof. Ram Asheshwar Mandal, Ph.D.**

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Environmental Science and Management.


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# Declaration

I, Prajun Chapagain, hereby declare that this Project paper entitled**, "LIVELIHOOD VULNERABILITY AND ADAPTIVE STRATEGIES ASSESSMENT OF FARMERS LIVING IN RAJAPUR MUNICIPALITY, BARDIYA"** is my original work and has not been submitted anywhere else for any academic award. All literature, data, or works done by others and cited within this report has been given due acknowledgment and listed in the reference section.

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# Recommendation

The thesis attached hereto entitled "**LIVELIHOOD VULNERABILITY AND ADAPTIVE STRATEGIES ASSESSMENT OF FARMERS LIVING IN RAJAPUR MUNICIPALITY, BARDIYA"** was prepared and submitted by **Prajun Chapagain** in partial fulfillment of the requirement for the Degree of Master of Environmental Management under my supervision is hereby accepted.

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# Certification

This thesis entitled **"LIVELIHOOD VULNERABILITY AND ADAPTIVE STRATEGIES ASSESSMENT OF FARMERS LIVING IN RAJAPUR MUNICIPALITY, BARDIYA"** prepared and submitted by **Mr. Prajun Chapagain** has been examined by us and is accepted for the award of the degree of Master of Science (M.Sc.) in Environmental Management by Pokhara University. The thesis in part of 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 Mr. Prajun Chapagain entitled ‘’**Livelihood Vulnerability and Adaptive Strategies Assessment of Farmers living in Rajapur Municipality, Bardiya’’** has been accepted for the partial fulfillment of Master of Science in Environmental Management from Pokhara University.

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**Prajun Chapagain**

**JULY, 2022**

## Abstract

Flood is one of the serious problems in Nepal and annually several people were killed particularly in Terai. However, the study related vulnerability of floods was very limited so far. Thus, this study was objectively carried out to assess the change in rainfall and climate variability, to assess the livelihood vulnerability of farmers against flood, and to assess the adaptive strategies of farmers against flooding in Rajapur**,** Bardiya.

Rajapur Municipality wards 1, 3, 4, and 7 were selected as the study site. The households were categorized into large, medium, and small farmers. Climate data like temperature and rainfall for 30 years were gathered and 160 household survey was conducted. In addition, four focus group discussions and five key informant interviews were conducted to collect data aiming to find the vulnerability and adaptation practices. The climatic data were analyzed using trend analysis and different indices. Similarly, the livelihood vulnerability index was used to analyze the context of vulnerability and descriptive analysis was conducted to analyze the data related to adaptation strategies. The result showed that the annual yearly temperature was increased by 0.0084ºC and a similar trend in temperature was seen in all the seasons except the post-monsoon season. The annual average rainfall was increased by 8.318mm/year. The winter and post-monsoon rainfall trends were found to be decreasing whereas the pre-monsoon and monsoon rainfall was found to be in increasing trend. The overall LVI calculated from the major components indicates that small farmers were the most vulnerable to climate change, followed by medium farmers and the least vulnerable were large farmers. The LVI-IPCC index also showed the same pattern, small farmers were the most vulnerable and large farmers were the least. The adaptation strategies of early warning system, shelter house, elevated tube wells, capacity building training, social networks and embankment construction were found to be significant one against the impacts of floods. This research will be useful for decision-makers and the scientific community to understand the vulnerability context of floods from Rajapur, Bardiya.

**Keywords**: Climate change. Flood hazard. Vulnerability. Adaptation. Farmer's livelihoods. Plainlands. Nepal

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## Abbreviations

| | |
|---|---|
| CBS | Central Bureau of Statistics |
| CCA | Climate Change Adaptation |
| CDM | Clean Development Mechanism |
| COP | Conference of Parties |
| CRED | The Centre of Research on Epidemiology of Disaster |
| DHM | Department of Hydrology and Meteorology |
| DWIDP | Department of Water Induced Disaster Prevention |
| DSA | Daily Subsistence Allowance |
| EM-DAT | Emergency Events Database |
| FGD | Focused Group Discussion |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| GoN | Government of Nepal |
| IPCC | Intergovernmental Panel on Climate Change |
| KII | Key Informant Interview |
| LAPA | Local Adaptation Plans of Action |
| MoFE | Ministry of Forest and Environment |
| MoHA | Ministry of Home Affairs |
| NAPA | National Adaptation Programme of Action |
| NDC | Nationally Determined Contribution |
| OFDA | Office for Foreign Disaster Assistance |
| PMAMP | Prime Minister Agricultural Modernization Project |
| RCP | Representative Concentration Pathway |
| SLA | Sustainable Livelihood Approach |
| UNISDR | United Nations International Strategy for Disaster Reduction |
| UNFCCC | United Nations Framework Convention on Climate Change |
| YONSED | Youth Network for Social and Environmental Development |

## Units and conversions

| | |
|---|---|
| 1 Bigha | 20 Katha |
| 1 Katha | 0.0338 hectare |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Climate change impact is a global issue. The extreme and general impacts are major categories of impacts of climate change. The general impacts are early flowering and fruiting, and variation in the production of the crop. On the other hand, landslides, erosion, flood, and drought are the extreme impacts of climate change. The record showed that about 23.9 million people per year were displaced between 2008 and 2018 because of natural disasters. Flooding caused over 1.4 million fatalities and damage to infrastructure worth $5 billion. Another research showed that there might be 325 million extremely poor people by 2030 (living on less than $1.25 per day) [1].

Floods, tropical cyclones, earthquakes, and droughts are considered four major types of disasters in the world. Out of these disasters, floods have been proven as the most common disaster. Weather, climate, and water hazards caused 50% of all disasters between 1970 and 2019, 45% of all reported fatalities, and 74% of all reported economic losses. [2].

Globally, flood is a serious problem and their effects are worldwide very serious. The countries in East Asia and South Asia are vulnerable to floods. The study report showed that no countries are safe because of the effect of the flood on the world. However, the number of individuals in danger is extremely high in South and East Asia. Approximately 1.36 billion people have affected annually because of floods in these regions. More specifically around 29 million individuals were killed annually in China and around 225 million individuals were killed in  India [3].

A humanitarian crisis is escalating in South Asia. The latest studies showed that more than 9.6 million people were displaced because of monsoon floods across India, Bangladesh, and Nepal. About 550 people have died in India, Bangladesh, and Nepal. In addition, millions of people were forced to flee their homes because of the effect of the severe flood [4].

Climate change is exacerbating the frequency of river floods and droughts [5], [6]. Nepal is considered as one of the world's most vulnerable to natural disasters. Nepal ranks fourth and thirteenth among the twenty poorest nations in terms of the impacts of climate change and flood risk, respectively [7]. Nepal has also been hit by a number of floods, many of which have resulted in significant loss of life and economic damage. The rugged topography of Nepal, haphazard land use, melting snow caps and glacier lake outbursts, and concentrated monsoon rain are a few key causes of water-induced disaster[8]. Flooding and widespread inundation are significant problems in the Terai due to changes in river courses, bank erosion, and erosion in river meanders, as well as the suspended load carried by the rivers. They widen and cut their banks every year[9]. Rain-fed agriculture and subsistence farmers are more vulnerable to climate change and variability. The Terai region has witnessed the most severe climate change in recent decades, with severe drought, extreme and repeated floods, landslides, and other natural disasters. The direct impact on food production and livelihood has been observed [10].

In the upcoming years, it is anticipated that both slow-onset and extreme events will become more frequent, intense, and extensive, especially in the context of a changing climate and shifting land use patterns [5], [11]. Extreme events such as heat waves (very likely), heavy precipitation (high confidence), and slow onset events such as glacial melt and extreme events such as agricultural and ecological droughts are expected to increase in some regions. Heavy rains, both seasonal and unseasonal, have become more common in recent years[12].

More specifically, the catastrophic flood hit South Asia in August 2017 and affected roughly 1.7 million people in Nepal. At least 140 people were killed because of the flood in Terai. The report prepared by the government showed that flood damage was worth about US$ 584.7 million, with a home rehabilitation cost of US$ 375.8 million. About 900 irrigation schemes were destroyed in this incident and the consequence was an effect on agricultural productivity [13].

History showed that around 7,599 people were killed and 6.1 million people were affected, between 1954 and 2018 in Nepal. Every year, on average 100 individuals are killed in Nepal because of the flood [14]. As a result, floods have a significant negative impact on people's lives, livelihoods, and food security, trapping the majority of the population in poverty and making them more vulnerable to disaster risk.

### 1.2 Statement of Problem

Flood is the most common hazard in Nepal. Terai region is more affected. Nepal is the tenth highest country in the world in terms of relative physical exposure to river (fluvial) flooding, exposing possible damage to physical assets as a value equivalent to 1.4% of its GDP [15].

The Karnali transboundary river originates from the Himalayas and flows to West Nepal's steep and hilly terrain. The Karnali River flows to the Terai plains from a narrow gorge at Chisapani, where it splits into the Geruwa and Karnali rivers. This forms an inland delta before joining the Ghagra in India (Zurich 2015). The catchments of the Karnali river are bigger and during monsoon season Terai region of Nepal is particularly susceptible to river floods as they are natural floodplains. Generally, flood is caused by heavy rainfall in the monsoon season from June to September [16].

The Rajapur Municipality is one of the most flood-prone sites ad communities are more vulnerable because of seasonal floods in rivers like Karnali and Geruwa. Several reports showed that the monsoon floods in 2017 were so devastating that the Terai area was heavily affected. Bardiya district is ranked Nepal's $4^{th}$ position in terms of damage and loss of life (NPC, 2017). The people are impacted differently as well as regions. When disaster strikes, poor and marginalized people are typically more severely affected than wealthy people. According to Hallegatte et al., 2016, "the same loss affects poor and marginalized people far more because their livelihoods rely on fewer assets, their consumption is closer to subsistence levels, they cannot rely on savings to smooth the impacts, their health and education are at greater risk, and they may need more time to recover and reconstruct." Natural disasters affect people's well-being, but it also depends on how well they adapt and recover, which depends on the support they get. Social protection frequently provides inadequate coverage for the poor. Additionally, poor people receive less post-disaster assistance than non-poor people do after being hit by a shock. For instance, only 6% of the very poor requested government assistance in response to the floods and landslides in Nepal in 2011, compared to almost 90% of the wealthy (Gentle et al. 2014) [17].

The study area is mainly inhabited by indigenous Tharu people (79.6%) along with 2 % of Dalit people whose main income sources depend upon agriculture having an average land holding size of 0.72 ha. Also, it has the highest agricultural land coverage of 108.97 sq. km which has been directly affected by the frequent flooding that hinders the livelihood of the people. The major impacts of floods have been seen on the settlements, agriculture, and food security that affect the overall livelihood of the people living along the Karnali river basin.

This study connects the livelihood condition of people, their socio-economic status, and coping strategies that have been frequently affected by the flood.

### 1.3 Research questions

The focus of this research is to analyze the climatic variations that cause extreme disaster events making the livelihood of farmers more vulnerable and explore the adaptation mechanism against it. Specifically, this study tries to answer the following research questions.

- What is the climatic condition of the study area?
- What makes farming households vulnerable and how their livelihood is affected?
- How the farmers have been adapting in response to frequent flood events?

### 1.4 Research objectives

1.4.1 General objective**:**

- To understand the climate variability, flood impacts on livelihood, and adaptation mechanism of farmers of Rajapur, Bardiya.

1.4.2 Specific objectives:

- To assess the rainfall and temperature trend of Rajapur.
- To assess the livelihood vulnerability of farmers against flood living in Rajapur, Bardiya.
- To assess the adaptive strategies of farmers against flooding in Rajapur**,** Bardiya.

### 1.5 Rationale of the Study

Poor people are more vulnerable to all types of natural disasters. Their lack of access to capital, education, health care, a means of subsistence, and other life options makes them vulnerable to disaster. The majority of the poor live in substandard housing, have limited access to necessities, and frequently lack food and nutrition. It has been found that poverty makes people more vulnerable to natural disasters.

The majority of people in the Terai region are poor; they rely primarily on subsistence agriculture with limited land holdings. So, the frequent occurrence of hazards such as flood completely shuts down their livelihood, reducing their consumption capacity and damaging crops, threatening food security. The major intention of this assessment is to generate information on the impacts of flooding events that have a significant value to the community groups, policymakers, and other stakeholders for informed decision-making.

The findings of this study will help recognize the vulnerable households, their way of living, and the hardships they have been facing during and after the flood. Also, the findings help the government bodies, international non-governmental organizations, and local authorities in the upliftment of livelihood through social and financial assistance ship, risk-sharing mechanism, policy improvisation and capacity building in case of disaster risk reduction of people living in Rajapur, Bardiya.

This proposed study aims at finding the vulnerability of different social groups in the community and analyzing their adaptive capacity in response to climate-induced disasters (floods). So, this study will be helpful to any institutions, organizations, and individuals related to disaster risk reduction soil and water conservation, and livelihood improvement of people living along the Karnali river basin.

### 1.6 Limitation of the study

The present study has the following limits:

- Only two climatic parameters (temperature and rainfall) were examined to assess the climate change scenario in the study area.
- Temperature data was not available for the study area so, data from nearby Tikapur station was used.
- The indicator-based vulnerability assessment applied in this research provides a customizable approach.
- The LVI differs among the farmers since different households have unequal vulnerability.
- LVI indicators differ across studies; numerical values of LVI can be used to compare the level of vulnerability within a study but cannot be cross-referenced to other studies because the indicators and context differ.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Global Context:

The environment and human society are already under immediate and possibly permanent threat from climate change. In acknowledgment of this, the vast majority of governments worldwide signed the Paris Agreement in December 2015, with the primary goal of limiting global temperature rise to 1.5°C. In doing so, these nations urged the IPCC, under the United Nations Framework Convention on Climate Change (UNFCCC), to submit a Special Report on the implications of 1.5°C global warming over pre-industrial levels and the associated global greenhouse gas emissions trajectory. The Paris Agreement was adopted by 195 nations at the 21st Conference of the Parties (COP21) in December 2015. The landmark agreement, the first of its kind, aims to strengthen the global response to the threat of climate change by "keeping the increase in global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels"[18].

Every inhabited cntinent and the oceans are experiencing the effects of climate change. However, they are not evenly distributed around the planet and various regions of the world experience effects in different ways. In addition to numerous other possible effects, average global warming of 1.5°C increases the chance of heatwaves and heavy rainfall events. While limiting global warming to 1.5°C rather than 2°C will help lower these dangers, the effects the world will ultimately experience will depend on the particular "route" chosen for greenhouse gas emissions.

According to the report prepared by the World Meteorological Organization, 2022, the followings are the findings:

- The global mean temperature in 2021 was around 1.11 ± 0.13 °C above the 1850–1900 pre-industrial average. This is less warm than some recent years due to the influence of La Niña conditions at the start and end of the year. The most recent seven years, 2015 to 2021, were the seven warmest years on record.
- The global mean sea level reached a new record high in 2021, rising an average of 4.5 mm per year over the period 2013–2021.

- The Antarctic ozone hole reached a maximum area of 24.8 million km2 in 2021. This unusually deep and large ozone hole was driven by a strong and stable polar vortex and colder-than-average conditions in the lower stratosphere.
- Greenland experienced an exceptional mid-August melt event and the first-ever recorded rainfall at Summit Station, the highest point on the Greenland ice sheet at an altitude of 3 216 m.
- Exceptional heatwaves broke records across western North America and the Mediterranean. Death Valley, California reached 54.4 °C on 9 July, equaling a similar 2020 value as the highest recorded in the world since at least the 1930s, and Syracuse in Sicily reached 48.8 °C.
- Hurricane Ida was the most significant of the North Atlantic season, making landfall in Louisiana on 29 August, equaling the strongest landfall on record for the state, with economic losses in the United States estimated at US$ 75 billion.
- Deadly and costly flooding induced economic losses of US$ 17.7 billion in Henan province of China, and Western Europe experienced some of its most severe flooding on record in mid-July. This event was associated with economic losses in Germany exceeding US$ 20 billion.
- Drought affected many parts of the world, including areas in Canada, the United States, the Islamic Republic of Iran, Afghanistan, Pakistan, Turkey, and Turkmenistan.
- In Canada, severe drought led to forecast wheat and canola crop production levels being 35%–40% below 2020 levels, while in the United States, the level of Lake Mead on the Colorado River fell in July to 47 m below the full supply level, the lowest level on record.
- The compounded effects of conflict, extreme weather events, and economic shocks, further exacerbated by the COVID-19 pandemic, undermined decades of progress toward improving food security globally.
- Hydro-meteorological hazards continued to contribute to internal displacement. The countries with the highest numbers of displacements recorded as of October 2021 were China (more than 1.4 million), Viet Nam (more than 664 000), and the Philippines (more than 600 000) [19].

The Emergency Event Database (EM-DAT) recorded a total of 432 catastrophic events that occurred in 2021, which is much greater than the 357 catastrophic incidents that occurred annually on average from 2001 to 2020. Floods predominated these events with 223 occurrences, up from an average of 163 occurrences each year between 2001 and 2020. During the monsoon season (June to September), India saw a series of catastrophic floods that claimed 1,282 lives. Similarly, the Henan Flood in China in July, which left 352 people dead, 14.5 million people homeless, and cost $16.5 billion, was particularly devastating. 260 people lost their lives in Afghanistan's Nuristan Floods in the same month. The Central European Floods and associated landslides in July were the second-most expensive disaster, costing the German economy 40 billion US dollars.

In 2021 a total of 10,492 people were killed, 101.8 million people were harmed, and 252.1 billion dollars in economic losses were incurred. Asia was the continent that was hit the hardest, accounting for 40% of all disasters, 49% of all deaths, and 66% of all persons affected. While the number of deaths and people affected was lower than the 20-year average, disaster incidents and economic losses increased in 2021[20].

2.1.1. The global trend of temperature and rainfall:

The Intergovernmental Panel on Climate Change (IPCC) published its sixth evaluation report in August 2021 and the third part of the IPCC has also been published on the 4th of April 2022.

According to the World Research Institute, global temperatures have risen by 1.1ºC so far, which already accounts for an increase in natural disasters such as flooding, hurricanes, and other events around the world.

The Intergovernmental Panel on Climate Change highlighted three specific aspects in the third part of its report. They are as follows:

- **Use of fossil fuels:** The use of fossil fuels should be reduced as soon as possible as a matter of urgency.
- **Changes in our diet habits**: The consumption of meat and dairy products should be reduced as the livestock industry is one of the polluting industries. The consumption of meat and dairy products should be sustainable manner.
- **Greener cities**: Traditional urban planning must shift as soon as possible to more sustainable and environmentally friendly urban planning.

The IPCC report 2022 cautioned that the world is on track to exceed 1.5ºC within the next two decades. The most significant cutbacks in carbon emissions beginning now will help to prevent an environmental disaster[21].

The effects of precipitation on ecosystems and human well-being can be very diverse. Rainfall, snowfall, and snowmelt timing can all have an impact on the amount of surface and groundwater available for drinking, irrigation, and industry. They also have an impact on river flooding and can determine what kinds of animals and plants (including crops) can survive in a given area. Precipitation changes can disrupt a wide range of natural processes, especially if they occur faster than plant and animal species can adapt.

The global precipitation patterns show an increase in overall precipitation from 1901 to 2021, based on rainfall and snowfall measurements from land-based weather stations around the world. More evaporation occurs as average temperatures at the Earth's surface rise which results in the increment of overall precipitation. Such phenomena are expected in many areas as the climate warms[22].

**2.2 Context of Climate Change in Nepal:**

Nepal is a nation with diversified typography, complicated geology, and a climate that varies greatly, making it vulnerable to various natural and man-made disasters. According to the Global Climate Risk Index, which evaluates the effects of meteorological events concerning economic losses and human fatalities, Nepal is ranked fourth in terms of climate risk globally (Eckstein, et al., 2019). Nepal's topography, which ranges from the Himalayan Mountain range and hills to low-lying plains, creates an equally diverse setting for disasters. The Terai plains, for example, are more vulnerable to seasonal floods because of monsoonal rainfall and the current complicated river networks (Dewan, 2015).

Hydro-meteorological hazards, such as droughts and floods, have already resulted in extensive harm, and the loss of livelihoods, lives, and property, but their intensity is predicted to rise in the coming years. Precipitation levels are predicted to rise by 15-20% by the middle of the century (Ministry of the Environment, 2010), which would aggravate the effects of water-related calamities. Because a sizable amount of Nepal's economy and employment depends on climate-sensitive activities, climatic changes have a direct impact on people's quality of life.

According to the Ministry of Science, Technology, and the Environment (2014), 35 percent of the GDP is derived from agriculture and forestry, and any variations in the weather or the production cycle may jeopardize the livelihoods of millions of people [23].

The Terai area is the most productive but the big challenge of the worst effects of climate change. The projected direct costs of climate change to sensitive industries (including agricultural and energy generation) are anticipated to reach as high as 3% of total GDP by 2050 (Ministry of Science, Technology, and Environment, 2014). Flooding is anticipated to produce 82.93 percent of the Average Annual Loss (AAL) in the future [24].

**2.3 Observed Climate trend analysis of Nepal:**

The observed climate trend analysis, which used gridded temperature and precipitation data for the years 1971 to 2014, shows a considerable upward trend in annual and seasonal maximum temperatures. All Nepal minimum temperature showed a significant positive trend only in the monsoon season. The overall precipitation trend in Nepal does not show any distinct seasonal or annual trends. The annual maximum temperature trend in all of Nepal is noticeably rising (0.05ºC/yr). Although the annual minimum temperature trend in Nepal is positive (0.002oC/yr), it is negligible.

With the exception of the majority of Tarai districts in winter, the positive temperature trend is highly significant in the vast majority of districts (more than 90% of the districts) and in all physiographic regions throughout the year.

At the district level, only a few numbers of districts exhibit significant trends in pre-monsoon and monsoon precipitation, while most districts show insignificant trends in post-monsoon and winter precipitation. In Syangja and Parbat districts during the monsoon season, the significantly largest positive rainfall trend is seen.

The High-Himalayan region only shows a significant negative trend in pre-monsoon precipitation. Precipitation trends in other seasons are negligible across all physiographic regions. Those were the findings from the report published in 2017[25].

2.3.1 The trend of Precipitation in Nepal:

According to Nepal’s Third National Communication to the UNFCCC (2021) (NC3), there have been relatively slight changes to the country's historical annual precipitation rates, which vary regionally and contain both positive and negative moves. The study done by

Bohlinger et al; (2017) shows extreme precipitation events are thought to have become more frequent and intense in some areas (particularly western Nepal)[26]. Another research done by Dahal et al,2015, shows that wet areas are becoming wetter, and dry areas are becoming drier[27].

The report related to climate risk published by World Bank Group and Asian Development Bank remark the following points:

- Warming in Nepal is projected to be higher than the global average. It is projected to warm by 1.2°C–4.2°C by 2080, under the highest emission scenario Representative Concentration Pathway, (RCP) 8.5, as compared to the baseline period 1986–2005. The range in possible temperature rises highlights the significantly lower rates of warming expected in lower 21st-century emissions pathways
- Rises in maximum and minimum temperatures are expected to be higher than the rise in average temperature, likely amplifying the pressure on human health, livelihoods, and ecosystems. The temperature increase is expected to be strongest during the winter months
- Climate change is already having significant impacts on the environment in Nepal. Some of the important examples are species' ranges are shifting to higher altitudes, glaciers are melting, and the frequency of precipitation extremes is increasing.
- Natural hazards such as drought, heat wave, river flooding, and glacial lake outburst flooding are all projected to intensify over the 21st century, potentially exacerbating disaster risk levels and putting human life at risk.
- Modeling has suggested that the number of people annually affected by river flooding could more than double by 2030 as a result of climate change. At the same time, the economic impact of river flooding could triple. The vulnerability of Nepal's communities, particularly those living in poverty, in remote areas, and operating subsistence agriculture, increase the risk posed by climate change.
- Some important adaptation approaches, such as irrigation, water storage, and new crop varieties, may be inaccessible to these communities, and even with adaptation, they are likely to experience damage and loss. Without support for the poorest in Nepalese society, inequalities are likely to widen [28].

### 2.3.2 The trend of temperature in Nepal:

The warming that occurred in Nepal throughout the 20th century may be estimated using data from the Berkeley Earth Dataset. According to projections, Nepal will warm up faster than a typical country. According to the highest emission scenario, RCP8.5, Nepal is predicted to rise by 1.2°C to 4.2°C by the 2080s compared to the baseline period of 1986–2005. The wide range of potential temperature increases draws attention to the much slower rates of warming anticipated on lower-emission paths during the 21st century[29]. Additional studies from Shrestha, U. B., Gautam, S., & Bawa, K. S. (2012), focusing primarily on the Himalayas region (a much wider area than Nepal's national territory), show greater rates of warming, with average temperatures rising by 1.5°C between 1982 and 2006 [30].

## 2.4 Impact of climate change on the livelihood of farmers

According to research conducted by Shaw and Krishnamurthy in 2009, annual flooding has a significant impact on livelihoods since it directly impacts agricultural income. In Nepal, poverty, along with a lack of access to adequate land and jobs, often drives people to reside in areas that are highly exposed and vulnerable to natural disasters (Bajracharya, Shrestha, & Shrestha, 2017). There have been 4631 flood incidents reported in the last 50 years (1970-2019), with 4058 deaths, 45,166,887 impacted people, and 178,833 families displaced (Ministry of Home Affairs, MoHA/DRR Portal, 2019). According to the 2017 Post-Flood Recovery Report, the floods displaced 1.7 million people and affected 46 percent of Nepal's population (NPC Report, 2017). Nepal is ranked 30$^{th}$ in terms of flood risk and vulnerability (Ministry of Home Affairs, MoHA/DRR Portal, 2019).

The economy of Nepal is mostly based on agriculture[31]. Farmers in Nepal have been engaged in agriculture, rearing cattle, and other small-scale productive activities for hundreds of years. The majority of the population relies on agriculture as their primary source of income, accounting for two-thirds of the workforce and one-third of the country's GDP. Paddy is the major cereal crop grown in Nepal followed by wheat, maize, millet, buckwheat, and barley. According to Statistical information on Nepalese Agriculture 2019/20, paddy production in the Bardiya district amounts to 291,139 metric tons with a yield value of 4.15 Mt/ha having an agricultural area of 70,230 ha. The government, donors, and I/NGOs have provided adequate financial aid to expand agricultural production.

However, Nepalese farmers' ability to become productive commercial farmers remains limited[32].

The Government of Nepal (GoN) classifies the rural agricultural population into three categories: small commercial farmers, subsistence farmers, and landless/near landless farmers. The majority of farmers (53%) are landless or almost landless individuals each of whom owns less than 0.50 hectares of land. They make up just 19% of the entire amount of land that is available. Around 27% of farmers practice 'subsistence farming,' with land holdings of 0.5-1 ha, accounting for 28% of the total land available. One-fifth (20%) of rural households are 'small commercial farmers,' with land holdings of 1 to 5 hectares or greater. These farmers own more than half of the available land. The average farm size per household is 0.6 hectares. Agricultural land per capita has also reduced as a result of a combination of reasons such as inheritances, agricultural land loss owing to urbanization, and land degradation[33].

Most farmers cultivate rice, maize, and wheat on a substantial scale. These crops have relatively poor yields when compared to other regions in the country. According to a study done by Samriddhi, almost three-fourths of farmers grow crops for personal consumption. While agriculture is important to the Nepalese economy, insufficient investment in the industry has resulted in comparatively low production when compared to other regions[34].

The agricultural sector, is one of the most affected industries, suffering from and sensitive to climate change. Based on global climate change, Salinger (2005) and Karim, Jahan, and Islam (2014) identified three major variables in the agricultural sector: (1) changes in rainfall patterns, (2) the growth of extreme climate events (floods and droughts), and (3) an increase in air temperature [35].

### 2.4.1 Agricultural Activities in Bardiya

The majority of people's livelihoods and the country's economy heavily depend on rice, which is the most significant staple food crop in Nepal. With a contribution to 15.35% of the AGDP in the fiscal year 2075–76 B.S. (2018–19) and an average productivity of 3.76 mt/ha, it ranks top in terms of area coverage, production, productivity, and preferences[36], [37].

Bardiya district is considered Nepal’s most fertile land and is mostly inhabited by the Tharu community whose major livelihood depends upon agriculture and animal husbandry.

Around 80% of the people are farmers; out of the total area of 202500 ha, the land suitable for farming is 75000 ha which is about 37.03 % out of 100. People have been farming in the land area of 60100 ha (80.13% of available agricultural land). The Prime Minister Agriculture Modernization Project (PMAMP) has declared Rajapur municipality and Geruwa rural municipality in the Bardiya district as rice super zones because of their high agricultural productivity[38]. Agriculture is the main source of income for the people in this area. Frequent flooding may negatively affect agricultural output and threaten food security.

### 2.4.2 Concept of the livelihood vulnerability index

Vulnerability is one of the aspects that determine whether or not individuals face threats to their livelihoods. The IPPC (2007) states that the vulnerability assessment assesses a community's capacity to address hazards and/or safeguard their livelihood. As a result, the index is used to compare communities[39].

The Third Assessment Report of the IPCC (2001) defines climate change vulnerability as the degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. In its most simple form, vulnerability is the tendency to be adversely affected (Kelly and Adger 2000; IPCC 2001; Fussel 2007; Opiyo et al. 2014). Since the primary aim of this study is to understand vulnerability as an outcome, rather than as a factor that shapes an outcome (i.e., risk) (IPCC 2014), we consider the vulnerability of a system within three components:

1. Exposure to a risk or a hazard.
2. Sensitivity to that risk or hazard.
3. Capacity to respond to that hazard either by coping, recovering, or adapting from the situation (IPCC 2001; Smit and Wandel 2006; Reed et al. 2013).

These drivers of vulnerability differ according to geographic location, economic situation, socio-political scenarios, psychological conditions, infrastructural development, institutional capacities as well as individual characteristics such as gender, age, health, and education (Zarafshani et al. 2016)

This vulnerability is influenced by socioeconomic profile, resource use, and other factors. Therefore, not all communities are equally vulnerable [40]. Fussel (2007) defined three approaches to understanding system vulnerability:

1. a risk-hazard approach that considers the risk that a system experiences as a result of exposure to a specific hazard;
2. a social constructivist approach that considers the socioeconomic dynamics that shape a system's ability to respond to any shock; and
3. an integrated approach that combines the earlier two forms to integrate hazard exposure as well as the vulnerability[40].

These classifications are comparable to Turner et al. (2003)'s study, which classified vulnerability into three approaches: risk hazard model, pressure and release model, and enlarged vulnerability mode. Investigating climate change-related vulnerability reveals its importance in the integrated approach (Fussel 2007; Adger 2006) or the enlarged vulnerability model (Turner et al. 2003), both of which take into account the synergy between human and biophysical systems.

Over the last decade, a variety of vulnerability assessment frameworks have been used to give metrics for assessing vulnerability. Preston et al. (2011) conducted a critical examination of 45 vulnerability mapping studies in terms of (1) assessment aims, (2) vulnerability framework employed, (3) technical approaches used for assessing vulnerability, and (4) users, beneficiaries, and participants in the assessment activity. The research revealed that approaches are frequently chosen primarily on the convenience of use rather than the efficacy of the approach due to a lack of agreement on the proper methodology and framework. The authors claim that the effectiveness of the approach utilized depends on the purpose for which the vulnerability assessment is being conducted[41].

Although vulnerability assessment methods are frequently debated, studies focusing on vulnerability agree that exposure to risk, sensitivity to damage, and the capacity to recover are critical components of determining vulnerability [39], [42], [43][44].

The definitions and evaluations of climate change susceptibility are variable, as vulnerability is notoriously difficult to standardize across professions.

According to the Intergovernmental Panel on Climate Change (IPCC) sixth assessment report, vulnerability to climate change is described as the tendency or inclination to be adversely affected, which includes sensitivity or susceptibility to damage and a lack of capacity to cope and adapt. It is also shown as a hierarchical aggregation of three systems: physical, harmful exposure; shock sensitivity; and adaptive coping capacity to the negative consequences.

Vulnerability assessments are typically carried out utilizing an indicator-based approach in the context of sustainable livelihoods. Adger et al. (2003) investigated how many factors interact to significantly explain vulnerability using an indicator-based methodology. According to the authors' conceptual framework, vulnerability cannot be described in terms of a single indicator, nor is it static; rather, it is determined dynamically by the interaction of several factors in a given context. In contrast to the IPCC vulnerability index (LVI-IPCC), which combines the primary components into three contributing variables (exposure, sensitivity, and adaptive capacity), Hahn et al. (2009) established LVI as a composite index comprising all major components and sub-components [45].

The computation of the index is simpler once rainfall and temperature data are available, as it uses primary data from households. Numerous studies have measured vulnerability in the context of natural hazards (for example, Parmesan & Yohe, 2003). The term vulnerability is used in many diverse ways by various intellectual communities such as poverty and food security analysts as well as in natural hazards research and each area conceptualize it differently (Bryan, Deressa, Gbetibouo, & Ringler, 2009). These studies define vulnerability as the extent to which geophysical, biological, and societal systems are prone to, or at risk of, and are unable to deal with the negative effect of climate change and variability.

According to IPCC (2001), climate change vulnerability is the degree to which a system is vulnerable to or unable to withstand the harmful consequences of climatic change and variability. According to FAO (2006), due to the many influencing elements, climate change susceptibility varies through time and geography. The kind, magnitude, and pace of climate change and fluctuation to which the system is exposed, as well as the system's sensitivity and capacity for adaptation, all affect how vulnerable the system is to them (FAO, 2009; IPCC, 2007). Location-specific exposure to climate change is thought to exist. Populations in semi-arid regions, for instance, may be particularly vulnerable to drought, whereas coastal communities would be more vulnerable to sea level rise and cyclones. The degree to which a body is adversely or positively, directly or indirectly, impacted by climate change and fluctuation is known as sensitivity (IPCC, 2007). Due to the cumulative effect on water flows, a tropical environment, for instance, will be less vulnerable to a drop in rainfall than a fragile, dry, or semi-arid one. Additionally, a society that relies on mining is less responsive to shifting rainfall patterns than one that depends on rain-fed agriculture (IPCC, 2007) [46].

### 2.4.3 Adaptation and Mitigation Measures against Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) highlights two approaches to respond to the causes and impacts of climate change: mitigation of climate change by reducing greenhouse gas emissions (GHGs) particularly carbon dioxide and methane; and adaptation by limiting the negative impacts of climate change on social and ecological systems (Klein et al. 2005). In the forest sector implementing adaptation and mitigation policy strategies risk canceling each other. Integrating adaptation and mitigation to exploit win-win opportunities is a policy option. However, climate policy response sets that include both options – adaptation and mitigation – are still receiving less attention in the climate response processes, especially in developing countries. This could be due to the limited knowledge of the commonalities between adaptation and mitigation (Dang et al. 2003).

As more evidence of climate change and its effects becomes available, different countries, particularly those lacking the resources to pursue mitigation strategies, have shifted their focus to developing adaptation strategies (Somorin et al. 2011). Adaptation is the process of altering the human or natural environment to reduce the actual or anticipated effects of climate change. It is classified into three categories (IPCC, 2007):

- Anticipatory or proactive, which occurs before the effects of climate change are felt;
- Autonomous or spontaneous, which occurs unconsciously as a result of changes in natural and human systems; and
- Planned, which occurs after a policy is implemented and conditions have changed or are about to change.

Behavioral, technological, risk management and reduction, conservation, and restoration are all options for adaptation.

To address the issue of adaptation, three key characteristics must be defined: vulnerability, resilience, and adaptive capacity (IPCC 2007). Vulnerability refers to the degree to which a community or region is vulnerable to the effects of climate change and variability and is unable to cope with them.

For example, developing countries, particularly the least developed countries, are the most vulnerable to the effects of climate change due to a lack of financial, social, and technological resources to adapt (UNFCCC 2007). The ability of a community or ecological system to absorb the effects of climate variations and changes while also being capable of self-organization and restructuring is referred to as resilience. It could entail adopting new technologies while preserving traditional knowledge, as well as diversifying livelihoods to better cope with the stress of climate change (UNFCCC 2007). The ability of a system to adjust its characteristics or behavior to expand its coping range under existing climate variability or future change conditions is known as adaptive capacity. One way to strengthen a country's adaptive capacity is to implement policies for disaster risk reduction and climate risk management (UNFCCC 2007).

### 2.4.4 Initiatives against Climate Change in Nepal

Nepal ratified the UNFCCC on May 2, 1994, after signing it in Rio de Janeiro in June 1992. Nepal has been attending Conferences of Parties (CoPs) and other subsidiary meetings regularly since then. It also became a party to the Kyoto Protocol on September 16, 2005, when it submitted its instrument of accession.

Nepal is attempting to develop various Clean Development Mechanism (CDM) projects that promote clean energy and sustainable development in the country to take advantage of CDM as a source of new investment and technology. Nepal's Ministry of Environment recently established the National Designated Authority to approve CDM projects (NAPA\MOE 2009). Nepal's government approved the National Adaptation Plan of Action (NAPA) in 2010, the Climate Change Policy in 2011, and the National Framework on Local Adaptation Plan for Action (LAPA) in 2011 as major policy instruments for mainstreaming climate change activities in general and climate change adaptation, in particular, Youth Network for Social and Environmental Development (YONSED, 2012). Climate change policy emphasizes climate adaptation, low-carbon development, research and development, citizen participation and empowerment, financial resource mobilization, and climate-friendly natural resource management (YONSED, 2012).

Through subsidies and technical assistance, the Alternative Energy Promotion Centre, in collaboration with several NGOs and private companies, is promoting clean energy efficiency technologies such as biogas, micro-hydro, and solar.

Climate Change Network, comprised of representatives from relevant government bodies, NGOs, civil society, and experts, has been established by the Ministry of Environment for information and knowledge management, as well as policy input.

In addition, a national-level disaster relief fund has been established under the chairmanship of the Prime Minister, and a disaster relief committee has been established under the district administrative office to provide immediate relief for climate-induced disasters. Furthermore, government offices such as (the Irrigation office, Soil conservation office, and Water induce Disaster office) and some non-governmental organizations (NGOs) such as Practical Action and Red Cross are involved in district-level climate induce disaster relief activities.

### 2.4.5 Climate Change Policy, 2019 in Nepal

The Government of Nepal issued a Climate Change (CC) Policy in 2019, repealing the 2011 CC Policy to contribute to socioeconomic prosperity by developing climate-resilient societies in the country. The previous 2011 Policy set out seven objectives, including the creation of a Climate Change Centre, the start of climate change adaptation (CCA), the formulation of a carbon trade strategy within a year, the formulation of a low-carbon economic development strategy within three years, and the economic assessment of loss and damage in key development sectors due to carbon change.

The goals of the Climate Change Policy 2019 are to improve Climate Change Adaptation (CCA) capacity, develop ecosystem resilience, promote a green economy by adopting a low-carbon economic development concept, mobilize national and international financial resources, improve information service, mainstream climate change into relevant policy, strategy, plan, and programs, and mainstream gender and social inclusion in climate change mitigation and adaptation programs.

# CHAPTER 3

# MATERIALS AND METHODS

## 3.1 Study Area

Rajapur Municipality of Bardiya District of Lumbini province has been selected as the study area for the research purpose. It is located between two flood-prone branches of the Karnali River and shares borders with Geruwa Rural Municipality to the east, Kailali district and Geruwa Rural Municipality to the west, and the state of Uttar Pradesh to the south. It is like an island, situated between 142m and 154m above sea level, covering an area of 127.08 sq. km, and is physically confined by latitude 28°21'25.16" N to 28°29'43" N and longitude 81°03'25.63" E to 81°12'52" E (Source: LDCRP, 2078). The Karnali River originates in Tibet, flows through Nepal, and finally merges with the Ganges in India.

Out of 10 wards four wards 1, 3, 4, and 7—were chosen because they were located along the branch of the Karnali River, where the previous incident resulted in catastrophic loss and damages.

Most of the land is used for agriculture. Out of the total land, 57.89% of the land is used for agriculture. The average land holding per household is 0.72 hectares. According to the Rajapur Municipality shelter plan 2077, there are 12707 households and a total population of 69873, with 35312 men and 34561 females. People are living in diverse communities, with over 80 percent belonging to the Tharu indigenous tribe and other minorities accounting for 10 percent of the total population.

Agriculture remains a significant activity in this area, with over 70% of families practicing subsistence agriculture. Agricultural land use is dominated by rice, wheat, maize, mustard, and pulses. Besides agriculture, people are engaged in fishing, cattle farming, business, and the service industry, particularly hospitality, which are the most important sources of revenue (Rajapur Municipality, 2019).

Rajapur Municipality is vulnerable to floods. Rivers like Karnali, Babhai, and Geruwa are responsible for flooding during the monsoon season. Frequent flood events have been recorded such as in 1983, 2009, 2013, 2014, and 2021, affecting the livelihood, destructing properties, and making the place more vulnerable to live in. Disasters such as floods, fires, hurricanes, droughts, and wild animal attacks have been recorded in the last 30 years among which the flood is the most significant one.

Furthermore, Rajapur municipality is recognized as a frontrunner in the implementation of Local Adaptation Plans of Action (LAPA), National Adaptation Programs of Action (NAPA), Community Adaptation Plans of Action (CAPA), Nepal Climate Change Support Program (NCCSP), and several other flood-related programs. The locations were chosen because they are regarded to be very flood-prone, with substantial floods practically every year, and because they are mostly inhabited by vulnerable and disadvantaged groups with subsistence ways of farming for livelihood.

Also, the study area is flood-prone that has continued to experience increasing frequency of floods. The people' lives and livelihoods have been severely affected by the flooding. The communities have a long history of agricultural practice, supported by fertile soils in the flood plains. However, the rising flood risk in the area, caused by increased rainfall amount and intensity, poses a significant threat to agriculture-dependent communities. So, the study requires research to be conducted that facilitates, local government, social organizations, planners, and policymakers in minimizing the yearly risk related to flooding that helps to improve the livelihood and adaptation strategies of local communities.

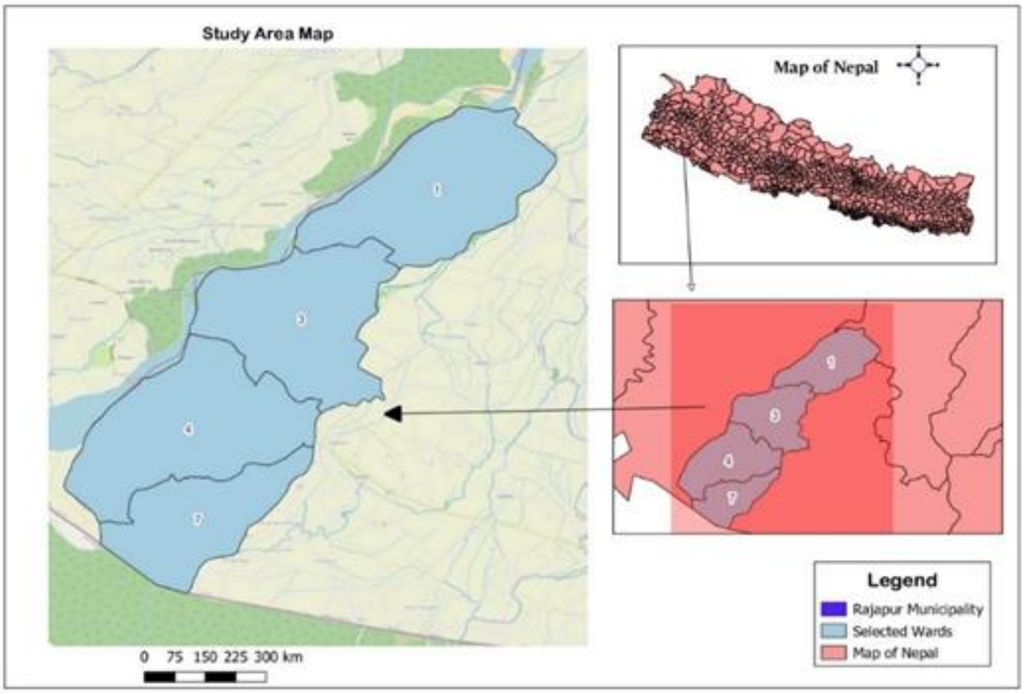



Figure 1 Map of Nepal with the demarcation of the Rajapur municipality

**3.2 Research design:**

The research work was carried out according to the designed conceptual framework in consultation with the supervisor. The study began with the selection of a site based on problems published in articles, journals, and newspapers. The objectives were then set in accordance with the questionnaire that had been prepared. Primary data were collected during the field visit, while secondary data was collected from DHM and other sources. The data was analyzed, and charts, tables, and graphs were prepared to present the findings. Throughout the study, relevant literature was reviewed.

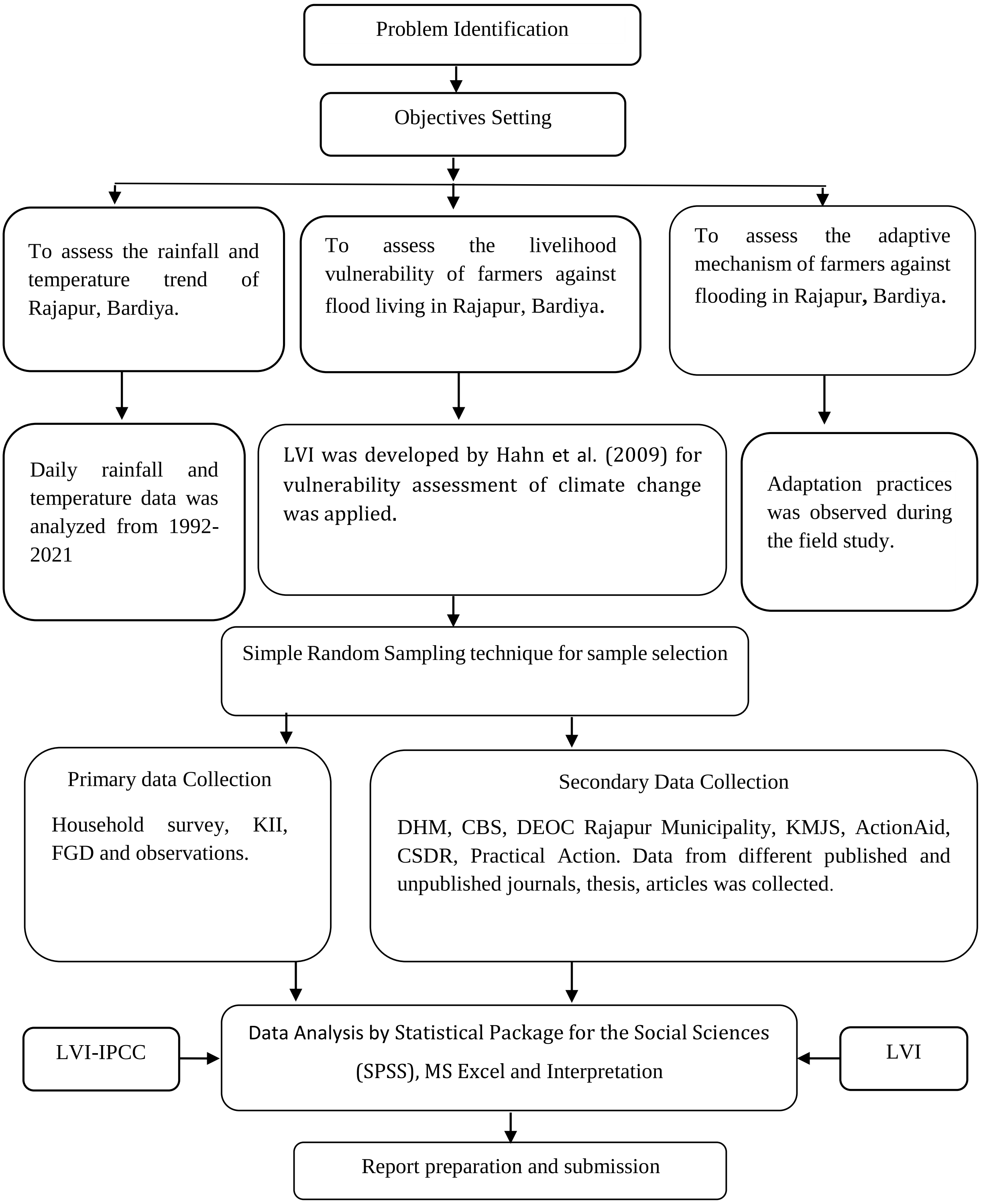



Figure 2:Flowchart of Research Design

### 3.3 Sample size and sampling technique:

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 (0.05)
e= the margin of error (5%)
Modification for the Cochran Formula for Sample Size Calculation in Smaller Populations

$$n= [n_0/(1+((n_0-1)/N)].$$

Where,

$n_0$= Cochran sample size

N= household number

n= sample size

In total 152 household were selected from wards 1, 3, 4 and 7. Required data and information were collected from all these households.

A multistage sampling technique was applied for the collection of samples. In the first stage, a total of 160 samples were collected from 4 different wards based on Cochran formula, 40 in each ward. And in the second stage, all the samples were divided into three farmer's types namely large, medium, and small. Among 160 households, 20 were large farmers, 54 were medium farmers, and 86 were small farmers. The proportion of the large farmers was comparatively lesser than the medium and the small farmers in the study area.

The survey was conducted between the fourth week of March 2022 to the second week of April 2022.

Table 1 Farmers categorization according to land holding size

| S. N | Farmers Category | Farm Size local classifications | GoN Classifications |
|---|---|---|---|
| 1 | Small Farmer | (1-10) Katha | Less than 0.50 Hectare |
| 2 | Medium Farmer | (10-60) Katha | (0.50-1) Hectare |
| 3 | Large Farmer | >60 Katha | (1-5) Hectare & Above |

(Source: GoN Agricultural Department)

### 3.4 Methods of data collection

Both primary as well as secondary method of data collection was applied during the research study.

3.4.1 Primary data collection:

The method employed in this study includes a questionnaire House Hold Survey (HHS), Key Informant Interview (KII), and Focal Group Discussion (FGD) for listing out implementation status and people's perceptions. A semi-structured questionnaire was used to collect data on each topic from the available household family members. The data were collected on the livelihood practices, agricultural system, monthly income–expenditure, local awareness, perception of climate change, and natural disasters. They were asked about their socioeconomic condition such as a number of a family member, their age, gender distribution, educational background, housing condition, occupation, and income level per month. The impacts of natural hazards on shelter, water supply system, sanitation system, health conditions, food the change of intensity of livelihood vulnerability, and percentage of occurrence of various natural disasters were also asked. Through detailed interviews of the respondent, data were collected by using a semi-structured questionnaire in order to obtain precise information.

- House Hold Survey (HHS**):** From the enumerated wards (1,3,4 &7) simple random sampling techniques were applied to gather the data. A semi-structured questionnaire was used to solicit information from the respondents. Mainly household head of the family was considered eligible as a respondent but in absence of senior members, educated adults were also considered eligible respondents. The HH questionnaire survey of 160 households was done. Among them, most of the respondents were senior males as household heads and the rest of other were females. Each interview lasted for about 10-20 minutes. Household surveys aimed to know the livelihood condition, flood impacts on agriculture and settlements, and adaptive strategies applied in response to frequent flooding.
- Focus Group Discussion (FGD): Focal Group Discussion was organized with the coordination and permission of the respective ward chairperson. A total of three groups were formed for the FGD, among which the first was conducted with local farmers. The second FGD was conducted with the stakeholders including the members of wards,

barghars (community heads) as well as flood affected farmers. And the female member's group of KMJS was taken as the third FGD. KMJS is a freed kamaiya women's organization that was founded in 2010. The Kamaiya Mahila (Freed Kamaiya Women), who hold the 0.167ha (5 kattha) of land allocated by the government of Nepal, are significant members of society. Since its founding, KMJS has provided services in Rajapur regarding the management of disaster risk. Additionally, these people are actively involved in rescue and relief efforts during the disasters. Open-ended questions were asked to understand the problems that have been facing by the people during and after the flood. The adaptation strategies, financial aid and other support from the government and I/NGOs were analyzed. The FGD aimed to gather information from the local level with the participation of people from all sectors despite their position and well-being rankings.

- Key Informant Interview (KII): For the key informant interview, a senior citizen, an administrative officer from the Rajapur Municipality, a sub-engineer from the Karnali River Management Committee, a subject matter expert with experience in the Rajapur flood, a representative from an INGO, and the disaster (bipad) focal person from the Rajapur Municipality were all interviewed. From this key informant consultation, major natural disasters and affected groups, livelihood change, change in cropping pattern, the impact of climate change at the local level, its extent, and some local adaptation strategies were collected. The purpose of the study was to know the flood history, its impacts on livelihood, and risk management strategies. Also, the plans and policies related to flood risk management and support people have been receiving from local government social organizations during and after the flood can be analyzed.
- Observations**:** Both covert and overt observations were conducted during the field research period. During meetings and walking tours, pictures and short notes were taken. In some cases, observations served as the main source of information, while in others, they were utilized to triangulate information to assess its reliability. The observations intended to validate the information that was noted from the FGDs and KII.

3.4.2 Secondary data collection:

Secondary data were collected from source of different from published and unpublished articles, documents, reports, thesis, newspapers, and websites. The hydrological and meteorological data were collected from Department of Hydrology and Meteorology (DHM).

Secondary data on flood inundation, its effects on livelihood, and adaptation strategies applied by the house holds for this study were gathered as a supplement to primary data. Additional published and unpublished reports were collected from the Rajapur Municipality, the Department of Agriculture (Rajapur Municipality), the District Emergency Operation Centre (DEOC), and other I/NGOs.

**3.5 Data Analysis**:

The data collected during the fieldwork was classified, and variables were created. Statistical and quantitative analysis were the main methods used for the data analysis. Both qualitative and quantitative data received from diverse sources were processed and evaluated to meet stated objectives.

3.5.1 Analysis of Meteorological Data:

The temperature and precipitation data from the year 1992-2021 were collected from DHM. The collected from DHM were analyzed and interpreted annually, monthly, and on a seasonal basis. The minimum and maximum trend for each season were analyzed. Nepal has four seasons[25] based on the rainfall and temperature pattern namely:

- Winter season (January, February, and December)
- Pre-monsoon season (March, Aril, and May)
- Monsoon season (June, July, August, and September)
- Post-monsoon season (October and November)

MS Excel and Statistical Program for Social Sciences (SPSS) were used to analyze the data and the result obtained are presented in graphs and tables.

### 3.5.2 Livelihood Vulnerability Index Analysis:

The livelihood vulnerability index (LVI) was developed by Hahn et al. (2009) for vulnerability assessment of climate change. It has been designed to provide information to development organizations, policymakers, and public health practitioners to understand climate vulnerability and its related component such as demographic, social, and health (Hahn et al. 2009).

The LVI includes seven major components;

a) Socio-Demographic Profile (SDP),
b) Livelihood Strategies (LS),
c) Social Networks (SN),
d) Health (H),
e) Food (F),
f) Water (W), and
g) Natural Disasters and Climate Variability (NDCV).

Drawing upon the Sustainable Livelihood Approach (SLA) and the Hahn et al. (2009) LVI, the research methodology was modified and refined based on a series of consultations conducted with a panel of local stakeholders, climate vulnerability experts, and researchers. The consultations and ensuing recommendations produced one important modification to the LVI and the research methodology. One more component – Housing and Land Tenure – was added to the LVI as a means of capturing the sensitivity of households to climate change. The temporary structure houses and settlements along the river banks are sensitive to frequent flooding events [44] so it was taken as a major component in this research study.

The LVI uses a weighted average approach (Sullivan *et al*. 2002) where each sub-component contributes equally to the overall index even though each major component is comprised of a different number of sub-components.

In this study, the LVI was calculated by applying a balanced weighted average approach. Each sub-component contributes equally to the overall index even though each major component comprises different numbers of sub-components. The data used in the computation of subcomponents have been measured at different scales, so it is essential to rescale/normalize data

before measuring the vulnerability index (Hahn et al. 2009). For this purpose, the min-max normalization technique (Patro and Sahu 2015) has been applied using the following formula:

$$Index_{s_d} = \frac{s_d - s_{min}}{s_{max} - s_{min}} \qquad \text{[ Eqn 1]}$$

Here $s_d$ is defined as the original value of a variable, $s_{min}$

and $s_{mix}$ reflect the minimum and maximum values of that variable that is determined by the data from the study area. The standardized index was developed by using these minimum and maximum values. A scale ranging from 0 to 100 was used to explore the percentage of some components. Once standardized, the sub-components are averaged by using the following formula:

$$M_{h=} \frac{\sum_{i=1}^{n} index_{shi}}{n} \qquad \text{[Eqn 2]}$$

The value of $M_h$ is equal to one of the main components in the household $h$ [Socio Demographic Profile (SDP), Livelihood Strategies (LS), Social Network (SN), Health (H), Food (F), Water (W), Housing and Tenure Natural hazard and Climate Variability (NDCV)] for the household. The $index_{shi}$ represents the sub-components, indexed by *i*, that make up each major component, and n is the number of sub-components in each major component. Based on these equations, the LVI grades can be obtained by using the following equation:

$$LVI_h = \frac{\sum_{i=1}^{8} W_{M_i} M_{d_i}}{\sum_{i=1}^{8} W_{M_i}} \qquad \text{[Eqn 3]}$$

which can also be expressed as:

$$LVI_h = \frac{W_{SDP}SDP_d + W_{LS}LS_d + W_{SN}SN_d + W_H H_d + W_W W_d + W_F F_d + W_{HLT}LT_d + W_{NDCV}NDCV_d}{W_{SDP} + W_{LS} + W_H + W_W + W_{SN} + W_F + W_{HLT} + W_{NDCV}}$$

[Eqn 4]

where,

$LVI_h$ = Livelihood Vulnerability Index of household

$W_{M_i}$= Weights of each major component

The weights of each major component, $W_{M_i}$ are determined by the number of sub-components that make up each major component and were included to ensure that all sub-components contribute equally to the overall LVI (Sullivan et al. 2002).

### 3.5.3 LVI–IPCC calculation

The LVI–IPCC index is an alternative to evaluate LVI by merging the definition of vulnerability corresponding to IPCC. Vulnerability is an action of a process that exposes and is susceptible to environmental stimuli and their adaptability to negative impacts (Shah et al. 2013). For this analysis, the major components of LVI data were categorized into three groups, these are adaptive capacity, sensitivity, and climate exposure. Exposure represents the nature and degree to which a system is subjected to large climate variations. The exposure of this research population is measured by the average number of natural disasters (floods and drought,) that occurred and was reported by the respondent in the last 10 years. Adaptive capacity denotes the ability of a group or individual to deal with challenges through local knowledge and strategies to adjust. Sensitivity is measured using the facilities of housing & land tenure, available food, health, and water in the study area. Understanding these components can assist to assess the nature and magnitude of the climate change risk together with the recognition of substantial sources of vulnerability.

The eight elements of the LVI-IPCC framework are arranged in the table 2. Equations and the subcomponents listed in the previous table were used to calculate the LVI-IPCC.

Table 2 Category of major components into IPCC contributing factors to vulnerability

| **IPCC contributing factors to vulnerability** | **Major Components** |
|---|---|
| Exposure | Natural disasters and climate variability |
| Adaptive Capacity | Socio-demographic Profile |
| | Livelihood Strategies |
| | Social Networks |
| Sensitivity | Health |
| | Food |
| | Water |
| | Housing and Land tenure |

Source: Hahn, M.B., Riederer, A.M. & Foster, S.O., 2009

After combining the major components, the LVI-IPCC splits from the LVI. Instead of combining the major components into the LVI together at once, they are first merged following the table's categorization scheme using the following equation.

$$CF_h = \frac{\sum_{i=4}^{n} W_{Mi} M_{hi}}{\sum_{i=1}^{n} W_{Mi}} \quad \text{[Eqn 5]}$$

where,

$CF_h$ = Contributing Factor

$W_{Mi}$ = Weight of each major component $Mi$ = Major component indexed by i

n = number of major components in each contributing factor

Once exposure, sensitivity, and adaptive capacity were calculated, the three contributing factors were combined using the following equation:

$$LVI - IPCC = (e - a) * s \quad \text{[Eqn 6]}$$

where,

LVI-IPCC = LVI expressed using the IPCC vulnerability framework

e = exposure

a = adaptive capacity

s = sensitivity

The scale of the LVI-IPCC ranges from -1(least vulnerable) to 1(most vulnerable) **(**Hahn et al. 2009).

Table 3 Major components, sub-components, data sources, and their functional relationship with vulnerability

| **Major Components** | **Subcomponents** | **Status in LVI** | **Explanation of Subcomponent** | **Data Source** | **Functional Relationship** |
|---|---|---|---|---|---|
| Socio-demographic profile | 1. Dependency ratio | | Dependency Ratio (65 years) | Survey | A higher percentage reflects less capacity to adapt |
| | 2. % Of female-headed household | | Percentage of households where the primary adult is female. If a male head is away from the home for>6 months per year the female is counted as the head of the household | Survey | Women typically have the less adaptive capacity (Mainly and Tan 2012) Most households in Nepal are male-headed; female-headed means males are outside home |
| | 3. Avg. age of female-headed household | | Average age of female headed household above dependency level | Survey | A higher age of female headed households means more vulnerable |
| | 4. % Of illiterate household heads | Modified | Percentage of households where the head of the household reports that they have attended 0 years of school | Survey | Education makes people more aware and able to adjust to changes in environmental condition |
| | 5. % Of Household with members needing dependent care | New | | Survey | Care needed means more sensitive |
| Livelihood Strategies | 6. % Of Household with family members working outside the community | | Percentage of households that report at least 1 family member who works outside of the community for their primary work activity | Survey | Income diversification increases adaptive capacity |

| | | | | | |
|---|---|---|---|---|---|
| | 7. % Of Households mainly income dependent on agriculture | Modified | Percentage of households that report only agriculture as a source of income. | Survey | Dependency on Agriculture is more vulnerable to climate change |
| | 8. Avg. agricultural livelihood diversity index | | The inverse of (the number of agricultural livelihood activities +1) reported by a household, e.g., A household that farms, raise animals, and collects natural resources will have a Livelihood Diversification Index = 1/ (3 + 1) = 0.25. | Survey | More diversification in agriculture, less vulnerable |
| | 9. % Of households without nonagricultural livelihood income contribution | New | % Of Households reporting livelihoods other than agriculture as the main source of income | Survey | Higher values increase adaptive capacity |
| Social Network | 10. Avg receive: give the ratio | Modified | The ratio of (the number of types of help received by a household in the past month + 1) to (the number of types of help given by a household to someone else in the past month + 1) | Survey | Higher Receive: Give ratio, more socially sound relation |
| | 11. Avg borrow: lend ratio | Modified | The ratio of a household borrowing money in the past month to a household lending money., If a household borrowed money but did not lend money, the ratio = 2:1 or 2 and if they lent money but did not borrow any, the ratio = 1:2 or 0.5. | Survey | Higher Receive: Give ratio, more socially sound relation |
| | 12. % Households seeking government assistance even after post-flood | Modified | A percentage of households reported that they still needed their local government for livelihood assistance. | Survey | Lower local government support means higher vulnerability |
| Food | 14. % Of households that cultivate on other farms | New | Percentage of households that have to lease/rent other farms for food sufficiency | Survey | High sensitivity because of not having personal land |

| | | | | | |
|---|---|---|---|---|---|
| | 15. % Of household dependents on family farm food | New | Percentage of households that get their food primarily from their farms. | Survey | High sensitivity because of the limited source of food |
| | 16. Average no. of months household struggle to find food | New | The average number of months households struggle to obtain food for their family | Survey | More months imply more sensitivity |
| | 17. Average Crop Diversity Index | | The inverse of (the number of crops grown by a household +1). e.g., A household that grows pumpkin, maize, beans, and cassava will have a Crop Diversity Index = 1/ (4+ 1) = 0.20. | Survey | More diversification in crops means less sensitivity |
| | 18. % Of households that do not have seeds from year to year | | Percentage of households that do not save crops from each harvest. | Survey | A lower level implies higher sensitivity |
| | 19. % of households that do not sell/barter crops | | | | A lower level implies higher sensitivity |
| Water | 19. % Of households' access to drinking water | New | Percentage of households obtaining water from handpumps, rainwater, and springs, other than the public system | Survey | A lower level implies higher sensitivity |
| | 20. Avg days without clean drinking water | New | Average day households have to suffer for clean and safe drinking water | Survey | More days implies more sensitivity |
| | 21. % Of households with water-related infections during monsoon days | New | Percentage of households reported illness due to unsafe and unhygienic drinking water | Survey | A higher level implies more sensitivity |
| Housing & Land Tenure | 22. % Of a house with weak flood- | New | Percentage of houses that will be unable to withstand a severe climatic event (e.g. floods, winds) | Direct Observation | Temporary houses are more sensitive to disasters |

| | | | | | |
|---|---|---|---|---|---|
| | resistant construction | | | | |
| | 23. % Of houses not elevated to avoid floods | New | Percentage of houses that cannot withstand severe storm surges and floods | Direct Observation | No elevated means higher sensitivity to damages |
| | 24. % Of households without ownership of the land they live in | New | Percentage of households that can be removed from the lands on which they presently reside | Survey | No legal papers mean higher sensitivity |
| | 25. % Of houses near the river | New | Percentage of houses/settlements that can be directly affected by riverine flash floods | Direct Observation | Higher sensitivity because of locations |
| Health | 26. Average time to the health facility | | Time taken to reach the nearest available health post/hospital | Survey | More time means more sensitive |
| | 27. % Of Household members suffering from chronic illness | | Percentage of households that report at least 1 family member with chronic illness. Chronic illness was defined subjectively by respondent | Survey | Family with illnesses are more sensitive |
| | 28. % Of Household missed work/school due to illness | | Percentage of households that report at least 1 family member who had to miss school or work due to illness in the last 2 weeks | Survey | This is to assess how illness is impacting the family; a higher percentage implies higher sensitivity |
| Natural disasters and climate vulnerability | 29. Average no. of floods, droughts & storms in the past 10 years | | Total number of floods, droughts, and storms that were reported by households in the past 6 years | Survey | More reflects higher exposure |
| | 30. % Of households that did not receive a warning about the pending natural disasters | | Percentage of households that did not receive a warning about the most severe flood, drought, and storms event in the past 10 years | Survey | More reflects higher exposure |

| | | | | | |
|---|---|---|---|---|---|
| | 31. % Of households with an injury or death by flood in the last 10 years | | Percentage of households that reported either an injury to or death of one of their family members as a result of the most severe flood, drought, or cyclone in the past 6 years | Survey | More reflects higher exposure |
| | 32. Mean standard deviation of daily average maximum temperature by month | | The standard deviation of the average daily maximum temperature by month between 1992 and 2021 was averaged for the study area | DHM | A higher standard deviation means more exposure to climate variability |
| | 33. Mean standard deviation of daily average minimum temperature by month | | The standard deviation of the average daily minimum temperature by month between 1992 and 2021 was averaged for the study area | DHM | A higher standard deviation means more exposure to climate variability |
| | 34. Mean standard deviation of daily average maximum precipitation by month | | The standard deviation of the average daily maximum precipitation by month between 1992 and 2021 was averaged for the study area | DHM | A higher standard deviation means more exposure to climate variability |

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 The trend of temperature and rainfall in Bardiya District

The temperature and rainfall data from 1992 to 2021 was analyzed. The trend of temperature and rainfall of annual, monthly, and seasonal variations of 30 years of data was analyzed and interpreted separately according to years, months and seasons.

### 4.1.1 The trend of annual temperature:

The analysis of annual temperature from 1992 to 2021 showed an increasing trend of maximum and average temperature while it was decreasing in the case of minimum temperature in Bardiya district. It was increased by 0.04 $^0$C in maximum temperature while this was decreased by - 0.024 $^0$C in minimum temperature. The annual average temperature was increased by 0.0084ºC.

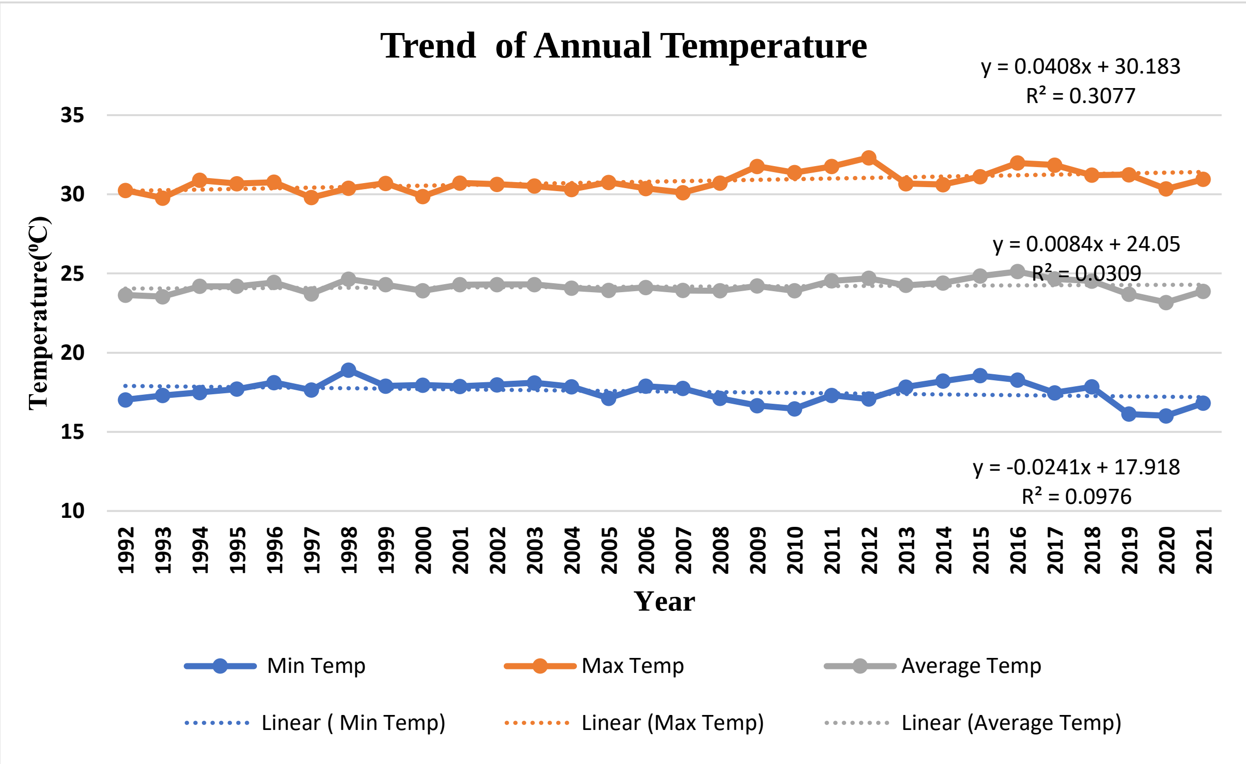



Figure 3 Annual maximum and minimum temperature trend

### 4.1.2 Monthly Trend of Temperature

The analysis of 30 years of temperature data for the period 1992 to 2021 shows that the average maximum temperature was found to be highest at 37.80°C in May and the average minimum temperature was lowest at 7.15°C in January.

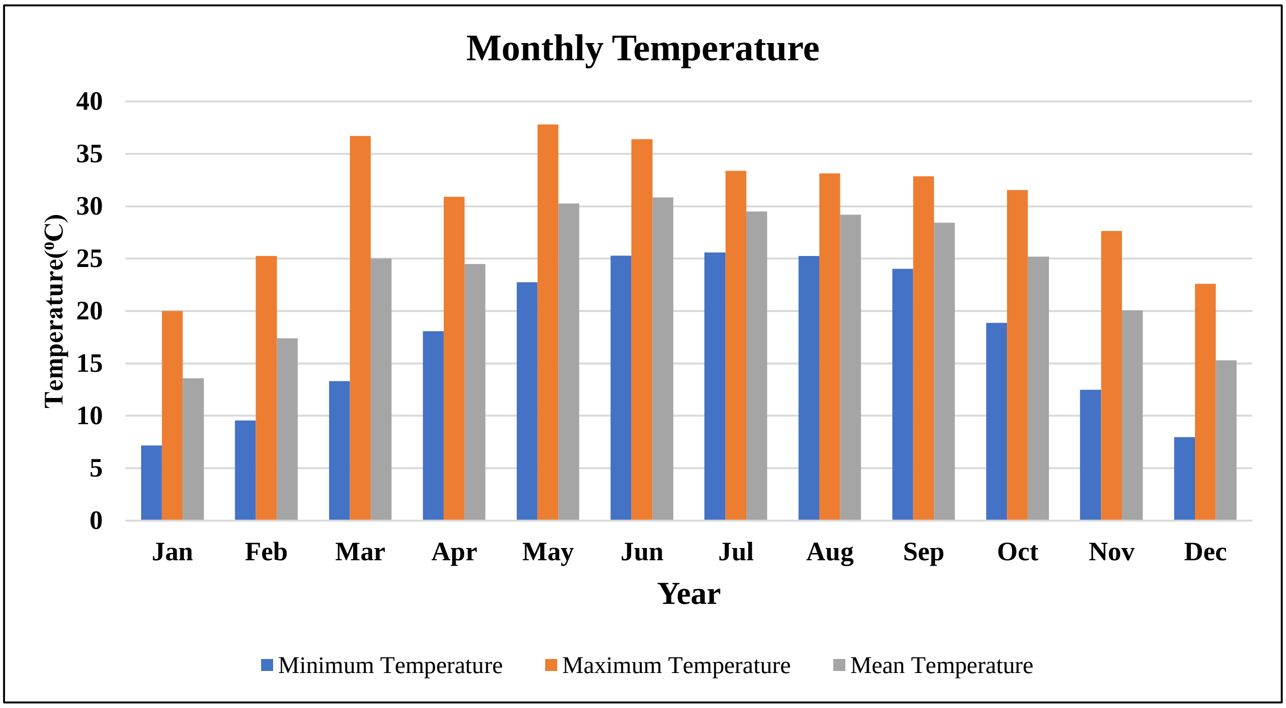



Figure 4 Monthly temperature trend

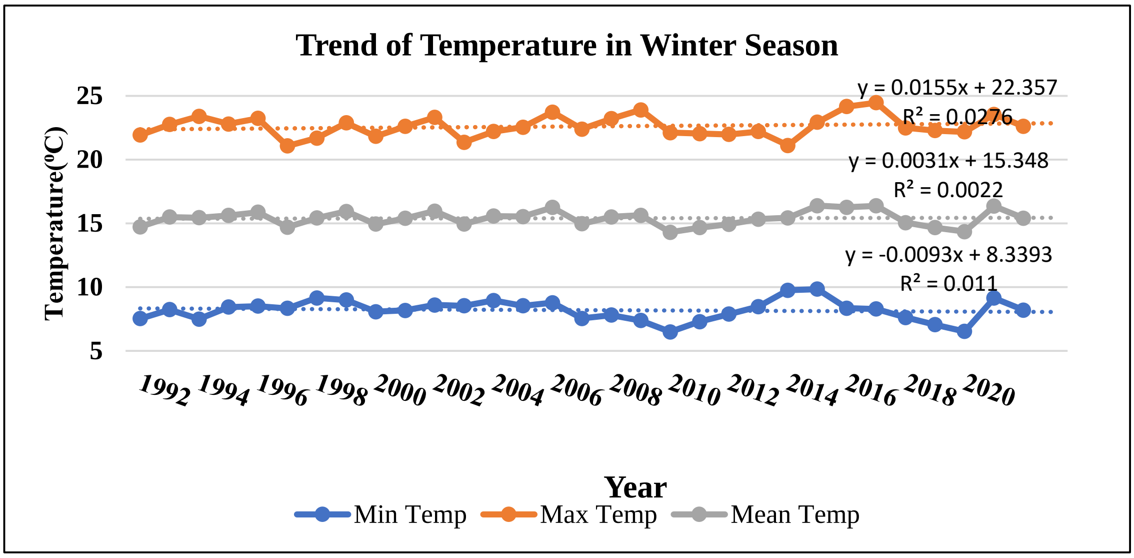



Figure 5 Winter minimum, maximum & mean temperature trend

### 4.1.3 The trend of temperature in the winter season

The trend of temperature was varying in the winter season from 1992 to 2021. The trend of maximum temperature in winter was increasing by 0.015°C/year. A similar trend was recorded for average temperature by 0.0031°C/year while this trend was negative of minimum temperature with -0.0093°C/year. The highest and lowest temperature of maximum temperature was recorded in the years 2017 and 1997 with 24.45 and 21.064°C respectively. The highest mean temperature was recorded at about 16.38°C in 2015 and the lowest record was 14.29°C in 2010.

The highest record of minimum temperature was about 9.836 °C in 2015 while it was the lowest in 2010 at 6.48°C. The winter means temperature was in an increasing trend with 0.0031°C/year from 1992 to 2021.

#### 4.1.4 The trend of temperature in pre-monsoon season:

There was an increasing trend in pre-monsoon temperature from 1992 to 2021. The result showed that the trend of increasing temperature was 0.0335, 0.0239, and 0.0143 $^0$C in maximum, average, and minimum respectively in the pre-monsoon season. The highest maximum temperature was recorded at about 37.335 $^0$C in 2010 was the lowest was around 33.013 $^0$C in 1993.

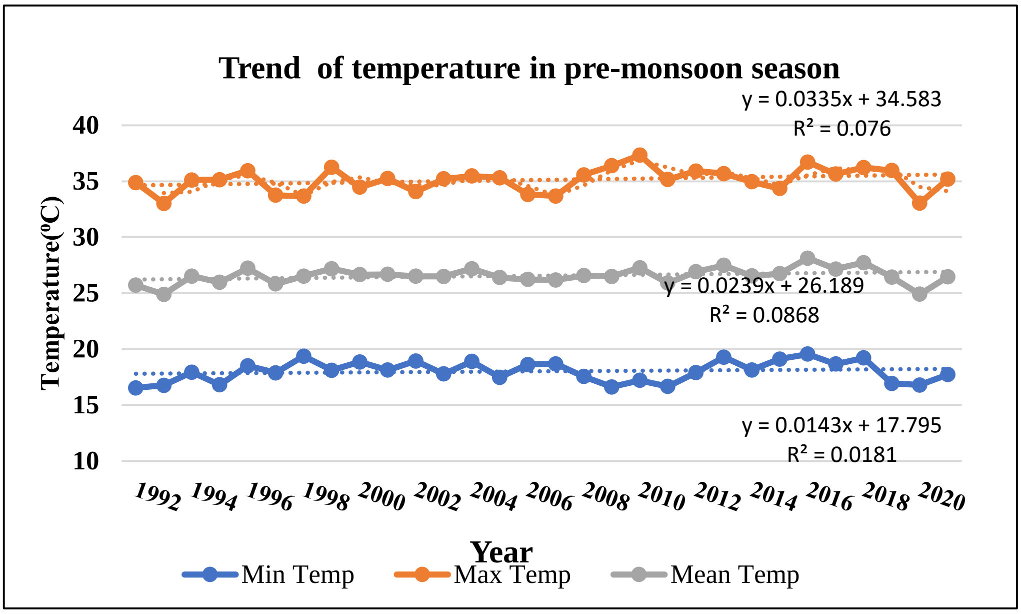



Figure 6 Pre-Monsoon minimum, maximum & mean temperature trend

#### 4.1.5 The trend of temperature in the monsoon season:

The trend of temperature was varying in the monsoon season from 1992 to 2021. The trend of maximum temperature in monsoon was increasing by 0.042°C/year. A similar trend was recorded for average temperature by 0.008°C/year while this trend was negative of minimum temperature with -0.025°C/year. The highest and lowest temperature of maximum temperature was recorded in the years 2009 and 2000 with 35.18°C and 32.45°C respectively. The highest mean temperature was recorded at about 30.49°C in 2012 and the lowest record was 28.79°C in 1993. Similarly, the highest and lowest temperature of minimum temperature was recorded in the year 2012 and 2020 at 25.95°C and 23.18°C respectively.

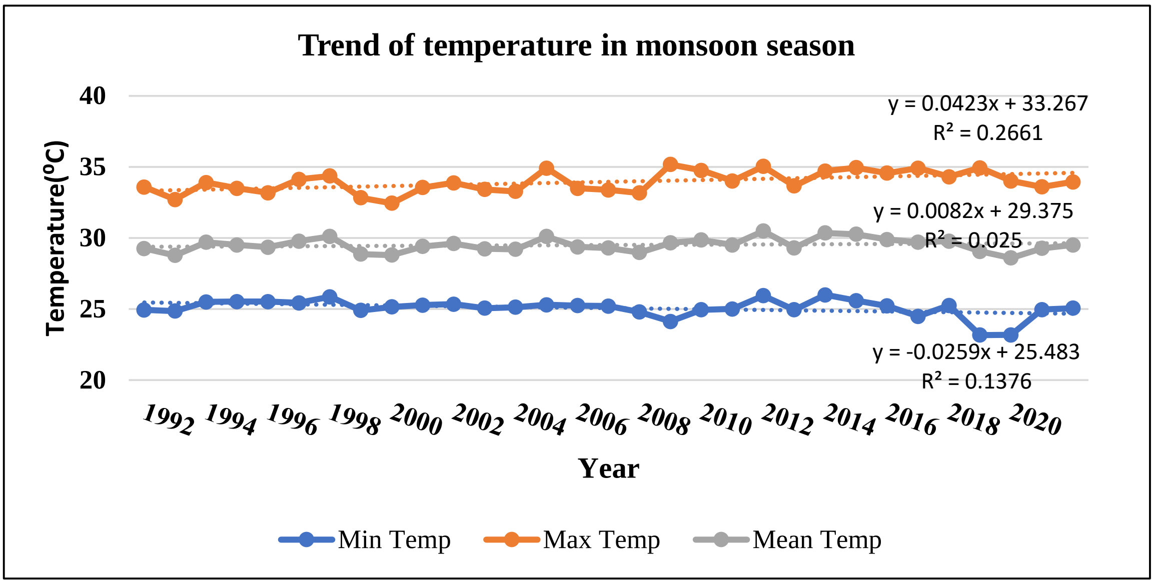
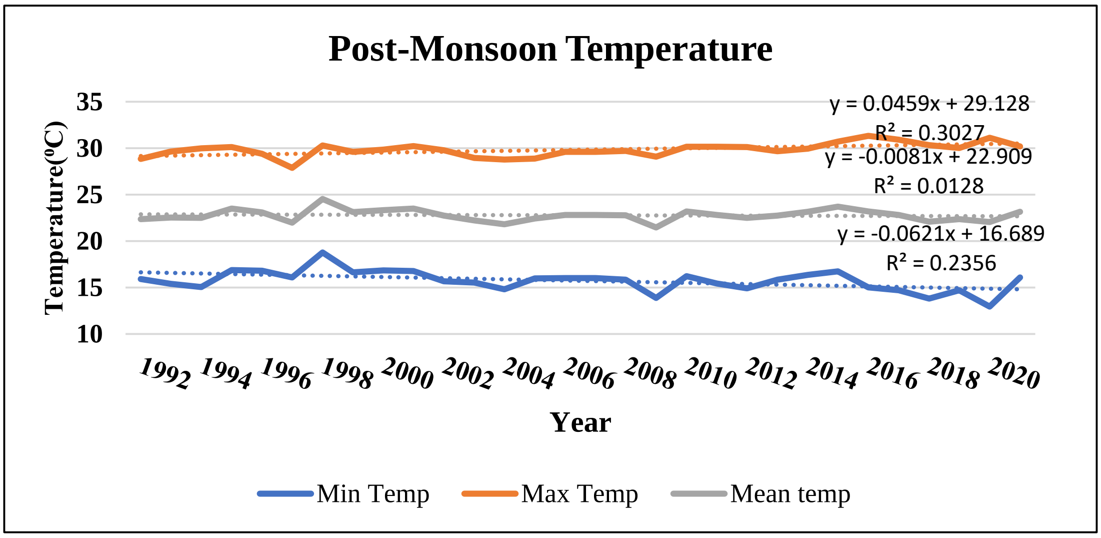



Figure 7 Monsoon minimum, maximum & minimum temperature trend

4.1.6 The Trend of temperature in post-monsoon season:

The trend of temperature was varying according to season. It was found that there was an increasing trend in the average maximum temperature of 0.0459°C /year. This trend was decreasing in the case of the mean and minimum temperature of this season with 0.0081and 0.0621 °C respectively. The analysis of temperature recorded in post-monsoon maximum showed that the highest average maximum temperature was 31.3°C in 2016 i.e., and the



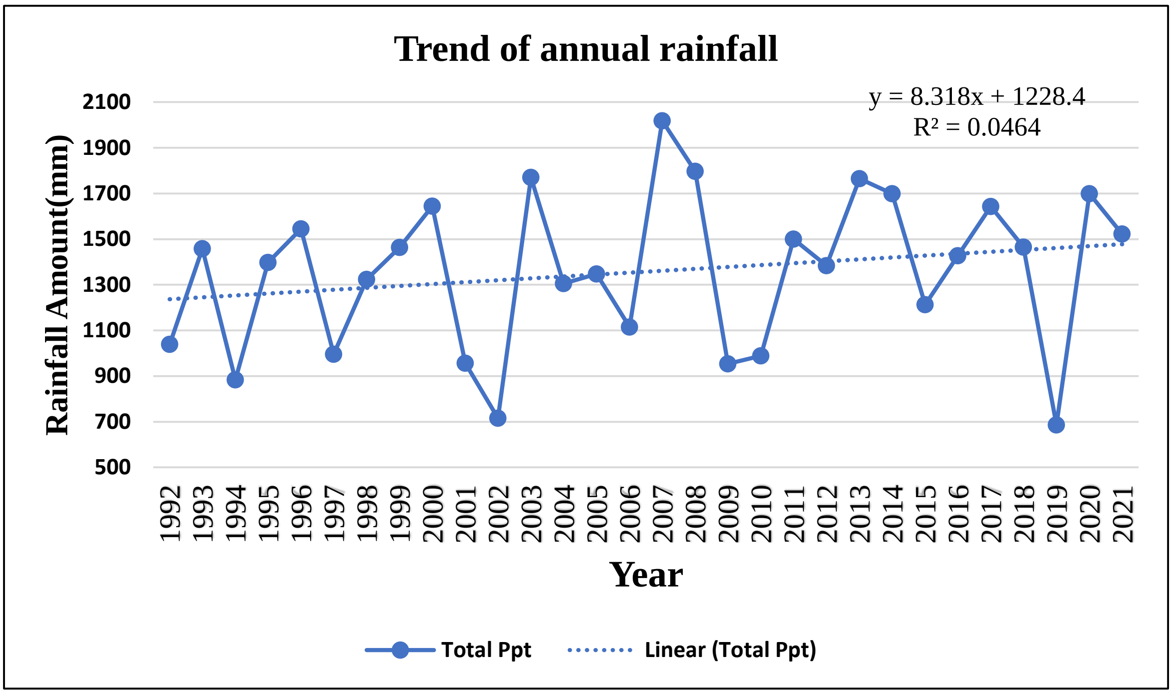

average minimum temperature was 27.9°C in 1997.

**Figure 8 Post-monsoon minimum, maximum & mean temperature trend**

4.1.7 The trend of annual rainfall

The amount of rainfall every year varied, reaching an unpredictable maximum of 2017.7 mm in 2007 AD and a minimum of 686.2 mm in 2019 AD. The trend of annual precipitation showed that there was an increase in total annual rainfall. The trend was about 8.318 mm annually from 1992 to 2021.

Figure 9 Annual rainfall trend




4.1.8 The trend of monthly rainfall:

The monthly precipitation was fluctuating showing erratic maximum precipitation in August i.e., 401.04 mm, and minimum in November i.e., 0.920 mm recorded from the year 1992 to 20221. However, figure 9 shows the increasing trend of precipitation with 6.1195 mm monthly.

Most of the rainfall was recorded in June, July, August, and September. There was less rainfall for the rest of the months while the highest rainfall was in August at 400 mm and followed by 380 mm in July.

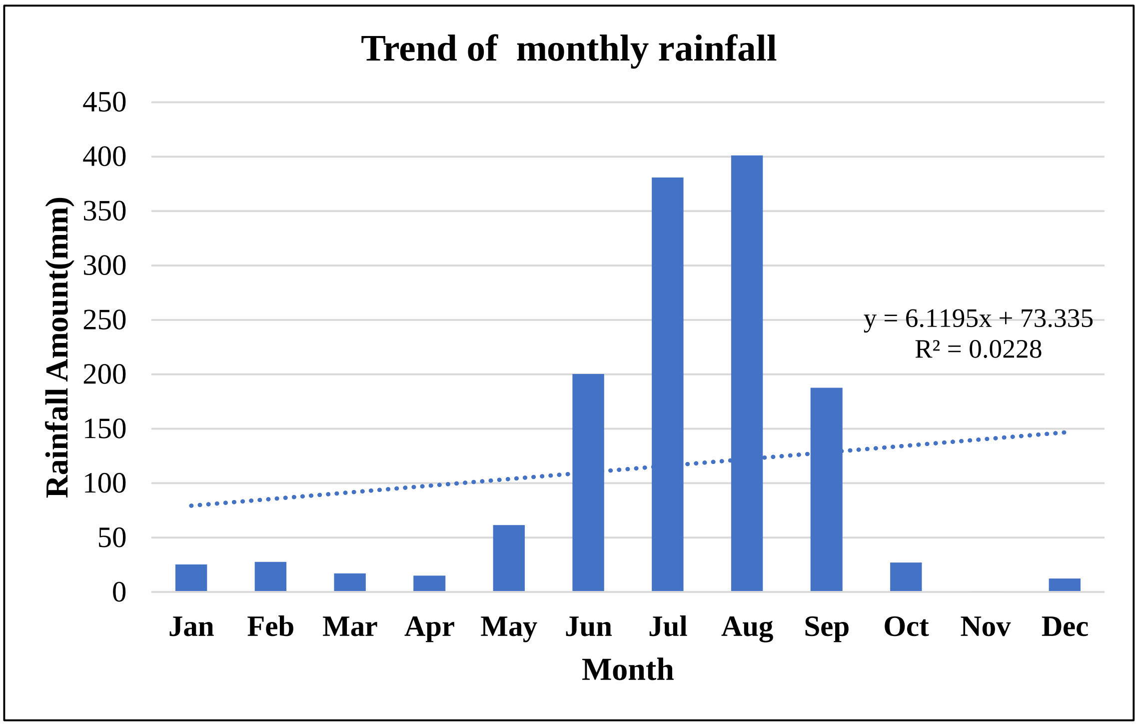



Figure 10 Monthly rainfall trend

4.1.9 The trend of rainfall in the winter season**:**

The rainfall in the winter season was varying between 1992 to 2021. This trend was decreasing with -0.7204 mm/yr. The difference between the highest (1997) and lowest (2008) rainfall was 228.4 mm/yr.

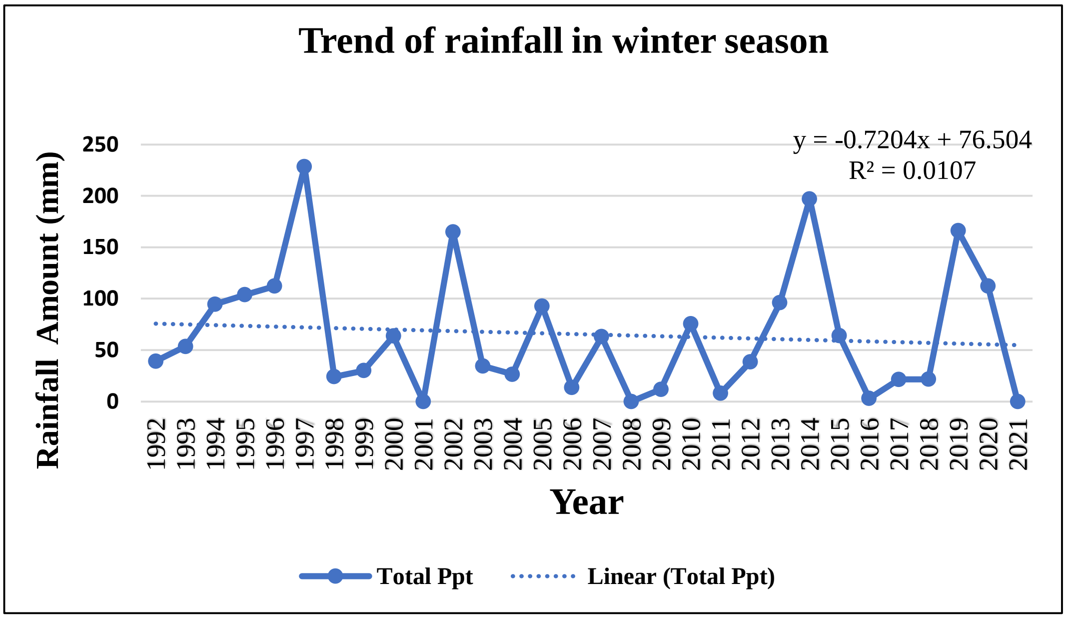



Figure11 Winter rainfall trend

4.1.10 The trend of rainfall in the pre-monsoon season:

The rainfall in the pre-monsoon season was fluctuating between 1992 to 2021. This trend was increasing by 1.8147 mm/yr. The highest rainfall was recorded in 2009 and the lowest in 2013 with 188.4 mm and 18.1 mm respectively. The difference between the highest and lowest rainfall was 170.3 mm.

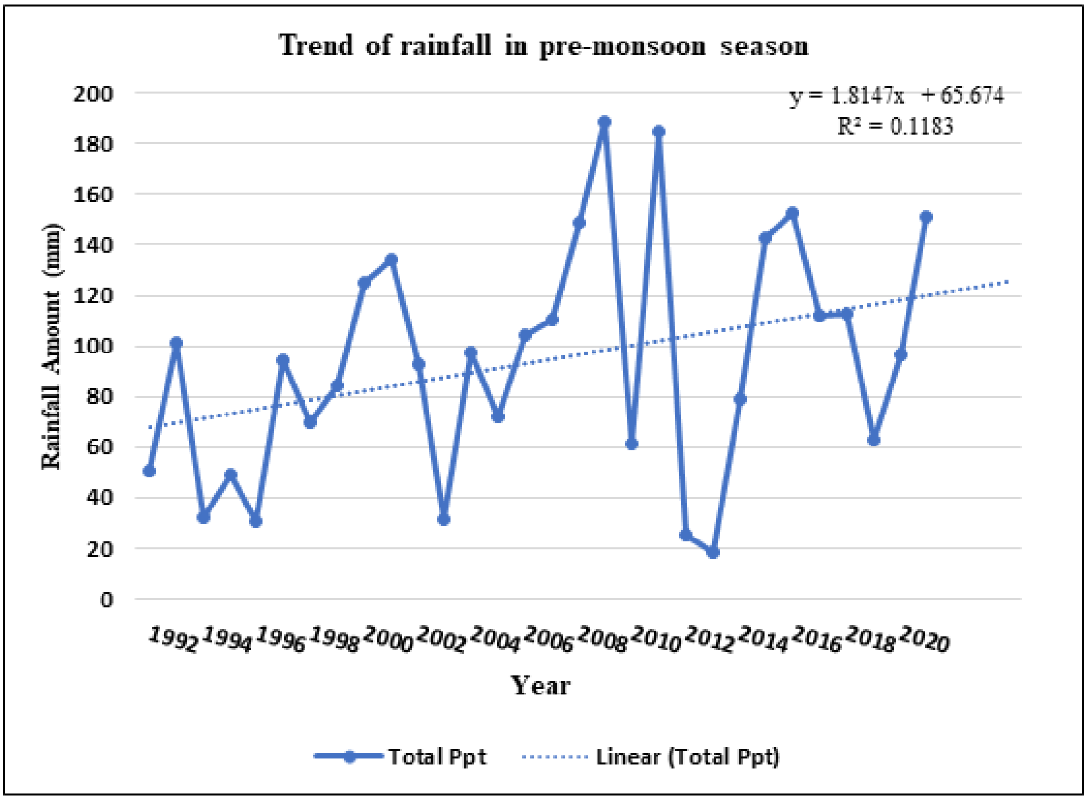



Figure 12 Pre-monsoon rainfall trend

4.1.11 The trend of rainfall in the monsoon season:

The trend of rainfall in the monsoon season was varying between 1992 to 2021. This trend was increasing by 7.4129 mm/yr. The highest rainfall was recorded in 2007 and the lowest in 2002 with 1839.1 mm and 446.6 mm respectively. The difference between the highest (1997) and lowest (2008) rainfall was 1392.5 mm/yr.

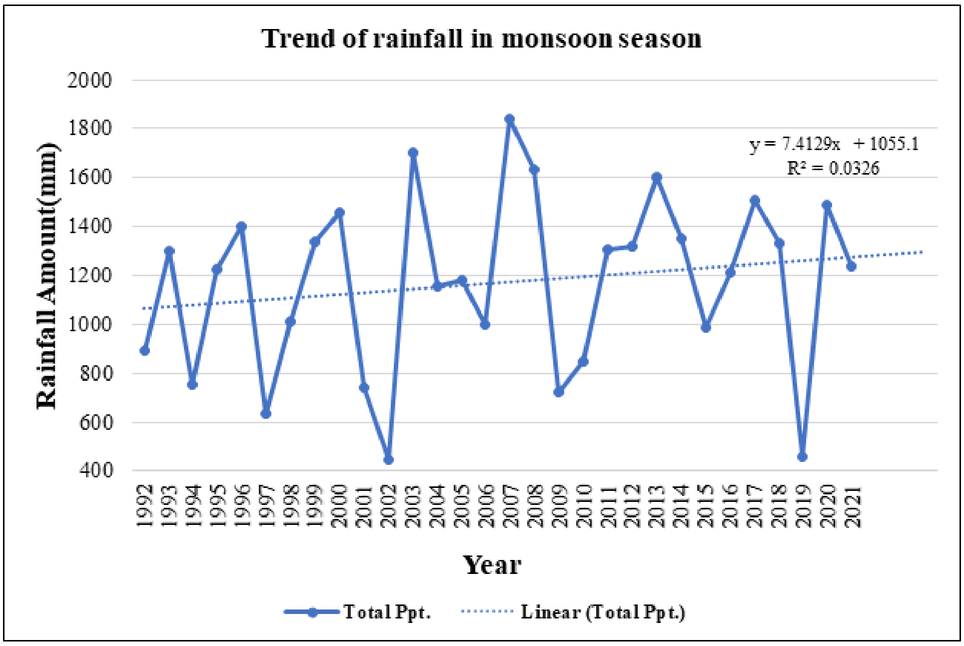



Figure 13 Monsoon rainfall trend

4.1.12 The trend of rainfall in post-monsoon:

The trend of rainfall in the post- monsoon season was varying between 1992 to 2021. This trend was decreasing with -0.1892 mm/yr. The highest rainfall was recorded in 1998 with 220 mm while in most of the year no rainfall was recorded.

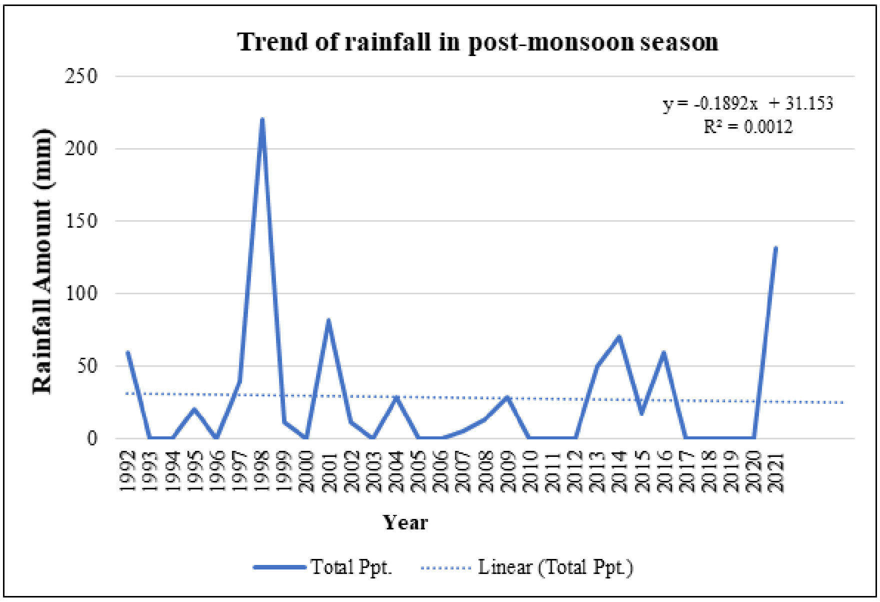



Figure 14 Post-monsoon rainfall trend

## 4.2 Livelihood Vulnerability Index

The livelihood vulnerability index at the household level from the survey was tabulated, and the standardized and overall average value of each major component of the small, medium, and large farmer was calculated separately.

### 4.2.1 Overall Household LVI of Small, Medium & Large Farmers

The overall livelihood vulnerability index of the small, medium and large farmers varied. The estimated highest livelihood vulnerability index was 0.456 for small farmers, followed by medium farmers with 0.362 and it was the lowest at about 0.309 for the large farmer. Specifically, the main components of the livelihood vulnerability index were Socio-Demographic Profile, Livelihood Strategy, Social Network, Food, Water, Housing and Land Tenure, Health and Natural Disaster, and Climate Variability, the values of these were 0.325, 0.385, 0.455, 0.539, 0.440, 0.698, 0.330 and 0.474 respectively (Table 4).

Table 4: Actual Values, Indexed of Sub-component and average of components of the small farmer

| Main Component | Sub Component | Unit | Small Farmer | | Average of Sub-components | Max Value | Min Value |
|---|---|---|---|---|---|---|---|
| | | | Actual Value | Standard Value | | | |
| **Socio-Demographic Profile** | Dependency Ratio | **Ratio** | 0.745 | 0.248 | **0.325** | 3 | 0 |
| | % of Female-headed household | % | 34.884 | 0.349 | | 100 | 0 |
| | Avg. age of female-headed household | 1/yrs. | 47.619 | 0.534 | | 70.0 | 22.00 |
| | % of illiterate household heads | % | 43.023 | 0.430 | | 100 | 0 |
| | % of Household with members needing dependent care | % | 6.522 | 0.065 | | 100 | 0 |
| **Livelihood Strategy** | % of Household with family members working outside the community | % | 73.217 | 0.732 | **0.385** | 100 | 0 |
| | % of Households mainly income dependent on agriculture including livestock | % | 34.000 | 0.340 | | 100 | 0 |
| | Avg. agricultural livelihood diversity index | 1/no. of livelihood | 0.571 | 0.077 | | 5 | 0.2 |
| | % of households without nonagricultural livelihood income contribution | % | 39.130 | 0.391 | | 100 | 0 |
| **Social Network** | Avg receive: give the ratio | Ratio | 1.8478 | 0.300 | **0.455** | 5 | 0.5 |
| | Avg borrow: lend ratio | Ratio | 1.641 | 0.761 | | 2 | 0.5 |
| | % Households seeking government assistance even after post-flood | % | 30.532 | 0.305 | | 100 | 0 |
| **Food** | % of the household that rents and cultivates on other farms | % | 38.043 | 0.380 | **0.539** | 100 | 0 |
| | % of households dependent on family farm food | % | 41.463 | 0.415 | | 100 | 0 |
| | Average no. of months household struggle to find food | 1/no. of months | 4.505 | 0.501 | | 7 | 2 |
| | Average Crop Diversity Index | 1/no. of Crops | 0.282 | 0.273 | | 0.5 | 0.2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | % Of households that do not sell/ barter crops | % | 89.535 | 0.895 | | 100 | 0 |
| | % of households that do not have seeds from year to year | % | 76.744 | 0.767 | | 100 | 0 |
| **Water** | % of households' access to drinking | % | 92.000 | 0.920 | **0.440** | 100 | 0 |
| | Avg days without clean drinking water | 1/no. of days | 5.804 | 0.201 | | 9 | 5 |
| | % of households with water-related infections during monsoon days | % | 20.000 | 0.200 | | 100 | 0 |
| **Housing and Land Tenure** | % of houses with weak flood-resistant construction | % | 80.435 | 0.804 | **0.698** | 100 | 0 |
| | % of the house not elevated to avoid floods | % | 85.870 | 0.859 | | 100 | 0 |
| | % of the household without ownership of the land they live in | % | 34.783 | 0.348 | | 100 | 0 |
| | % of a house near the river | % | 78.261 | 0.783 | | 100 | 0 |
| **Health** | Average time to Health Facility | min | 19.348 | 0.467 | **0.330** | 30 | 10 |
| | % of Household members suffering from chronic illness | % | 13.043 | 0.130 | | 100 | 0 |
| | % of Household missed work/school due to illness | % | 39.130 | 0.391 | | 100 | 0 |
| **Natural Disaster and Climate Variability** | Average no. of floods events in the past 10 years | Counts | 6.096 | 0.699 | **0.474** | 7 | 4 |
| | Average no. of drought events in the past 10 years | Counts | 2.691 | 0.564 | | 4 | 1 |
| | % of households with an injury or death by flood in last 10 yrs. | % | 7.609 | 0.076 | | 100 | 0 |
| | Mean S.D of daily avg. max temp by month | | 5.559 | 0.580 | | 40.568 | 17.355 |
| | Mean S.D of daily avg. min temp by month | | 6.935 | 0.560 | | 27.323 | 5.039 |
| | Mean S.D of daily avg. max precipitation by month | | 4.714 | 0.365 | | 12.862 | 0.029 |
| **LVI of Small Farmer** | | | | | **0.456** | | |

Similar components were considered to estimate the livelihood vulnerability index of medium farmers which were Socio-Demographic Profile, Livelihood Strategy, Social Network, Food, Water, Housing and Land Tenure, Health and Natural Disaster, and Climate Variability, the values of these were 0.289, 0.421, 0.329, 0.346, 0.456, 0.374, 0.272 and 0.441 respectively (Table 5).

Table 5 Actual Values, Indexed of Sub-component and Average of components of medium farmer

| Main Component | Sub Components | Unit | Medium Farmer | | Average Value | Max Value | Min Value |
|---|---|---|---|---|---|---|---|
| | | | Actual Value | Standard Value | | | |
| Socio-demographic Profile | Dependency Ratio | **Ratio** | 0.326 | 0.217 | 0.289 | 1.5 | 0 |
| | % Of Female-headed households | % | **14.815** | 0.148 | | 100 | 0 |
| | Avg. age of female-headed household | 1/yrs | **47.625** | 0.505 | | 60.00 | 35.00 |
| | % Of illiterate household heads | % | 48.148 | 0.481 | | 100 | 0 |
| | % Of Household with members needing dependent care | % | **9.259** | 0.093 | | 100 | 0 |
| Livelihood Strategy | % Of Household with family members working outside the community | % | 3.704 | 0.037 | 0.421 | 100 | 0 |
| | % Of Households mainly income dependent on agriculture including livestock | % | 92.593 | 0.926 | | 100 | 0 |
| | Avg. agricultural livelihood diversity index | 1/no. of livelihood | 0.412 | 0.648 | | 0.5 | 0.25 |
| | % Of households without non-agricultural livelihood income contribution | % | 7.407 | 0.074 | | 100 | 0 |
| Social Network | Avg receive: ratio | Ratio | 1.769 | 0.507 | 0.329 | 3 | 0.5 |
| | Avg borrow: lend ratio | Ratio | 1.011 | 0.341 | | 2 | 0.5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | % Households seeking government assistance even after post-flood | % | 13.890 | 0.139 | | 100 | 0 |
| **Food** | % Of the household that rents and cultivates on other farms | % | 11.666 | 0.117 | **0.346** | 100 | 0 |
| | % Of household's dependent on family farm food | % | 83.333 | 0.833 | | 100 | 0 |
| | Average no. of months household struggle to find food | 1/no. of months | 2.370 | 0.474 | | 5 | 0 |
| | Average Crop Diversity Index | 1/no. of Crops | 1.336 | 0.346 | | 1.5 | 1.25 |
| | % Of households that do not sell/barter crops | % | 14.815 | 0.148 | | 100 | 0 |
| | % Of households that do not have seeds from year to year | % | 15.847 | 0.158 | | 100 | 0 |
| **Water** | % Of households that utilize natural water resources for irrigation | % | 96.29 | 0.9629 | **0.456** | 100 | 0 |
| | Avg days without clean drinking water | 1/no. of days | 4.500 | 0.3750 | | 7 | 3 |
| | % Of households with water-related infections during monsoon days | % | 3.000 | 0.0300 | | 100 | 0 |
| **Housing and Land Tenure** | % Of houses with weak flood-resistant construction | % | 62.963 | 0.630 | **0.374** | 100 | 0 |
| | % Of the house not elevated to avoid floods | % | 39.435 | 0.394 | | 100 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | % Of the household without ownership of the land they live in | % | 18.715 | 0.187 | | 100 | 0 |
| | % Of a house near the river | % | 28.675 | 0.287 | | 100 | 0 |
| **Health** | Average time to Health Facility | min | 19.815 | 0.491 | **0.242** | 30 | 10 |
| | % Of Household members suffering from chronic illness | % | 7.447 | 0.074 | | 100 | 0 |
| | % Of Household missed work/school due to illness | % | 15.957 | 0.160 | | 100 | 0 |
| **Natural Disaster and Climate Variability** | Average no. of floods, events in the past 10 years | Counts | 6.096 | 0.699 | **0.441** | 7 | 4 |
| | Average no. of drought, events in the past 10 years | Counts | 2.778 | 0.389 | | 4 | 2 |
| | % Of households with an injury or death by flood in last 10 yrs. | % | 5.287 | 0.053 | | 100 | 0 |
| | Mean S.D of daily avg. max temp by month | | 5.559 | 0.5796 | | 40.568 | 17.355 |
| | Mean S.D of daily avg. min temp by month | | 6.935 | 0.5596 | | 27.323 | 5.039 |
| | Mean S.D of daily avg. max precipitation by month | | 4.714 | 0.3650 | | 12.862 | 0.029 |
| **LVI of Medium Farmer** | | | | | **0.362** | | |

Likewise, the components used to calculate of livelihood vulnerability index of small and medium farmers, same components were used for large farmers as well. These components were Socio-Demographic Profile, Livelihood Strategy, Social Network, Food, Water, Housing and Land Tenure, Health and Natural Disaster, and Climate Variability having the values of these were 0.193, 0.526, 0.270, 0.258, 0.395, 0.189, 0.219 and 0.435 respectively (Table 6).

Table 6: Actual Values, Indexed of Sub-component and Average of components of a large farmer.

| Main Component | Sub Component | Unit | Large Farmer | | Average Value | Max Value | Min Value |
|---|---|---|---|---|---|---|---|
| | | | Actual Value | Standard Value | | | |
| Socio-Demographic | Dependency Ratio | **Ratio** | 0.513 | 0.373 | **0.193** | 1.375 | 0 |
| | % Of Female-headed households | % | 2.326 | 0.023 | | 100 | 0 |
| | Avg. age of female-headed household | 1/yrs. | 35.500 | 0.500 | | 40.000 | 31.000 |
| | % Of illiterate household heads | % | 4.651 | 0.047 | | 100 | 0 |
| | % Of Household with members needing dependent care | % | 2.320 | 0.023 | | 100 | 0 |
| Livelihood Strategy | % Of Household with family members working outside the community | % | 40 | 0.400 | **0.526** | 100 | 0 |
| | % Of Households mainly income dependent on agriculture including livestock | % | 100 | 1.000 | | 100 | 0 |
| | Avg. agricultural livelihood diversity index | 1/no. of livelihood | 0.201 | 0.453 | | 0.25 | 0.16 |
| | % Of households without non-agricultural livelihood income contribution | % | 25.000 | 0.250 | | 100 | 0 |
| Social Network | Avg receive: give the ratio | Ratio | 1.1250 | 0.250 | **0.270** | 3 | 0.5 |
| | Avg borrow: lend ratio | Ratio | 0.4286 | 0.429 | | 1 | 0 |
| | % Households seeking government assistance even after post-flood | % | 15.000 | 0.150 | | 100 | 0 |
| Food | % Of the household that rents and cultivates on other farms | % | 8 | 0.080 | **0.258** | 100 | 0 |
| | % Of household's dependent on family farm food | % | 100 | 1.000 | | 100 | 0 |
| | Average no. of months household struggle to find food | 1/no. of months | 0.150 | 0.075 | | 2 | 0 |
| | Average Crop Diversity Index | 1/no. of Crops | 0.283 | 0.393 | | 0.33 | 0.25 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | % Of households that do not have seeds from year to year | % | 0.000 | 0.000 | | 0.00 | 0 |
| | % Of households that do not barter/sell crops | % | 0.000 | 0.000 | | 100 | 0 |
| **Water** | % Of households' access to drinking water | % | 94.000 | 0.940 | **0.395** | 100 | 0 |
| | Avg days without clean drinking water | 1/No. of days | 2.211 | 0.211 | | 3 | 2 |
| | % Of households with water-related infections during monsoon days | % | 3.480 | 0.035 | | 100 | 0 |
| **Housing and Land Tenure** | % Of houses with weak flood-resistant construction | % | 21.426 | 0.214 | **0.189** | 100 | 0 |
| | % Of the house not elevated to avoid floods | % | 2.174 | 0.022 | | 100 | 0 |
| | % Of the household without ownership of the land they live in | % | 2.172 | 0.022 | | 100 | 0 |
| | % Of the house near the river | % | 50 | 0.500 | | 100 | 0 |
| **Health** | Average time to Health Facility | min | 20 | 0.500 | **0.219** | 30 | 10 |
| | % Of Household members suffering from chronic illness | % | 7.630 | 0.076 | | 100 | 0 |
| | % Of Household missed work/school due to illness | % | 8.200 | 0.082 | | 100 | 0 |
| **Natural Disaster and Climate Variability** | Average no. of floods events in the past 10 years | Counts | 5.786 | 0.393 | **0.435** | 7 | 5 |
| | Average no. of drought events in the past 10 years | Counts | 2.714 | 0.714 | | 3 | 2 |
| | % Of households with an injury or death by flood in last 10 yrs. | % | 0.000 | 0.000 | | 100 | 0 |
| | Mean S.D of daily avg. max temp by month | | 5.559 | 0.580 | | 40.568 | 17.355 |
| | Mean S.D of daily avg. min temp by month | | 6.935 | 0.560 | | 27.323 | 5.039 |
| | Mean S.D of daily avg. max precipitation by month | | 4.714 | 0.365 | | 12.862 | 0.029 |
| **LVI of Large Farmer** | | | | | **0.311** | | |

Table 7 Statistical comparison of LVI among small, medium, and large farmer

**One way ANOVA test**

VAR00002

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | .087 | 2 | .043 | 3.575 | .046 |
| Within Groups | .254 | 21 | .012 | | |
| Total | .341 | 23 | | | |

POSTHOC=BTUKEY ALPHA (0.05).

Post Hoc Test
Homogenous Subsets:
VAR00002

Tukey B

| VAR00001 | N | Subset for alpha = 0.05 | |
|---|---|---|---|
| | | 1 | 2 |
| 3.00 | 8 | .3106 | |
| 2.00 | 8 | .3622 | .3622 |
| 1.00 | 8 | | .4558 |

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 8.000.

Here,1= Small Farmer

2= Medium Farmer

3= Large Farmer

One-way ANOVA showed that there was a significant difference in LVI index values among small, medium, and large farmers at a 95 % confidence level. Turkey's B test also shows that there were significant differences in vulnerability index values between small, medium, and large farmers between the values of LVI at a 95% confidence level. At a 5% level of significance, the significance value (P) was found to be 0.046.

4.2.2 Spider diagram of major components of LVI**:**

The spider diagram showed the variation of values of components of LVI according to the categories of the farmers (Figure 2). The scale of the diagram ranges from 0 (less vulnerable) at the center of the web, increasing to 0.7 (most vulnerable) at the outside edge, in 0.1-unit increments. The results showed that the most vulnerable component was housing and land tenure with 0.698 for the small farmer. This value was followed by natural disaster and climate variability (0.474) and vice versa for social networks with 0.455 with livelihood strategy (0.385), water (0.374), health (0.330), and social demographic profile (0.325).

The results showed that the most vulnerable component was water with 0.456 for the medium farmer. This value was followed by natural disaster and climate variability (0.441) and vice versa with livelihood strategy (0.385), housing & land tenure (0.374), food (0.346), social network (0.329), social demographic profile (0.289), and health (0.242). But in the case of the large farmer, the results showed that the most vulnerable component was livelihood strategy with 0.526. This value was followed by natural disaster and climate variability (0.435) and vice versa with water (0.395), food (0.258), health (0.219), social demographic profile (0.193), social network (0.27), and housing & land tenure (0.189).

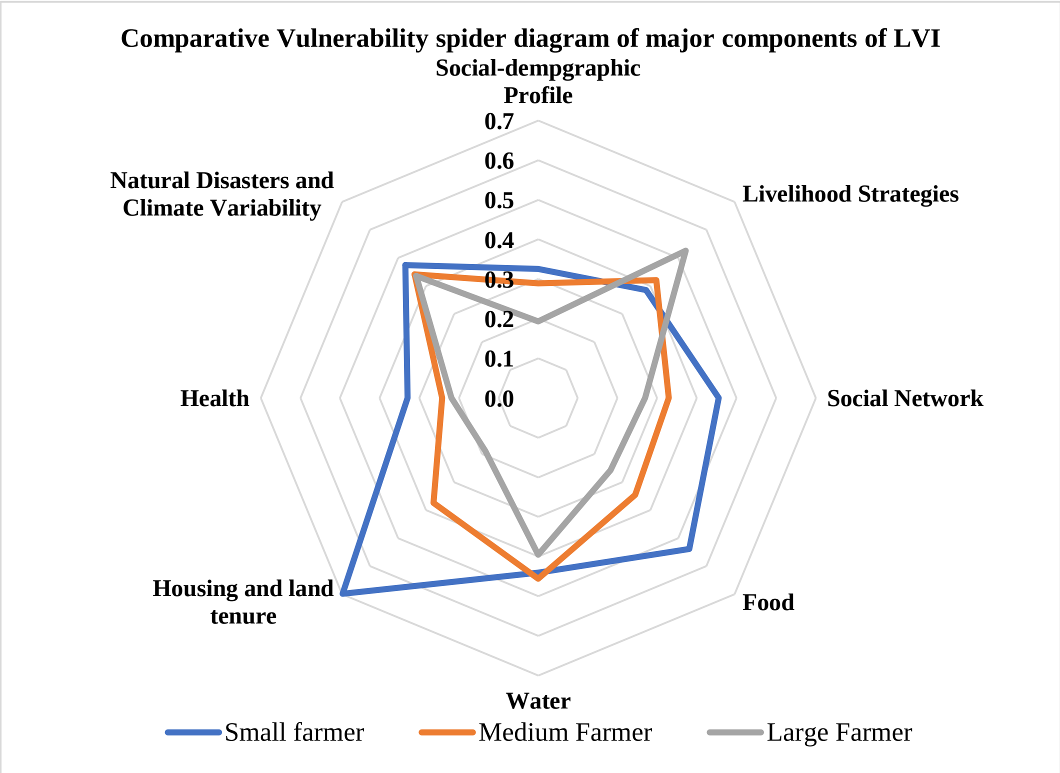



Figure 15 Comparative Vulnerability spider diagram of the major components of the LVI

### 4.2.3 Vulnerability Assessment of Rajapur using the LVI-IPCC Approach

The results of IPCC–LVI was varying levels of vulnerability experienced by small, medium, and large farmers and are shown in Table 8, 9, and 10 respectively. The overall IPCC–LVI values for each of the farmer's categories are given in Table 11.

The result showed that the overall value of LVI-IPCC was the highest at 0.04 for small farmers, followed by 0.034 for the medium farmer and 0.028 for the large farmer (Table 10). Specifically, the highest value of exposure was recorded at about 0.474 for the small farmer, it was followed by 0.441 for the medium farmer and 0.435 for the large farmer.

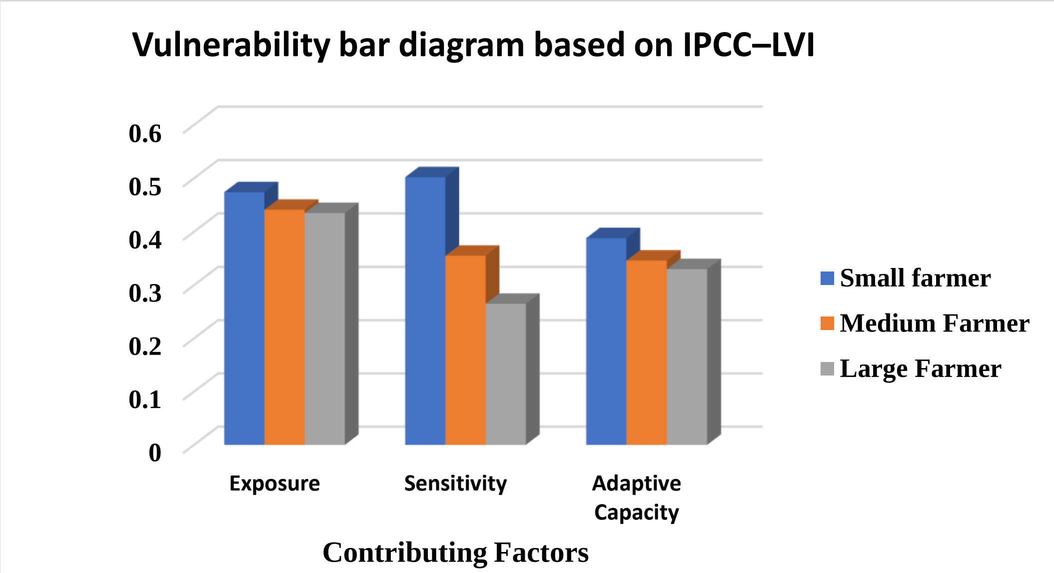



Figure 16 Vulnerability bar diagram of the small, medium, and large farmers based on IPCC–LVI

Table 8 Calculation of LVI-IPCC values for small, medium, and large farmers:

| Contributing Factors | Major Components | Major Components Value | No. of Sub-Components | Contributing Factors Value | LVI-IPCC Value |
|---|---|---|---|---|---|
| **LVI-IPCC value of the small farmer** | | | | | |
| **Adaptive Capacity** | Social-demographic Profile | 0.325 | 5 | 0.388 | **0.043** |
| | Livelihood Strategies | 0.385 | 4 | | |
| | Social Network | 0.455 | 4 | | |
| **Sensitivity** | Food | 0.539 | 5 | 0.502 | |
| | Health | 0.33 | 3 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Water | 0.44 | 3 | | |
| | Housing and Land Tenure | 0.698 | 4 | | |
| **Exposure** | Natural Disasters and Climate Variability | 0.474 | 6 | 0.474 | |
| **LVI-IPCC value of the medium farmer** | | | | | |
| **Adaptive Capacity** | Social-demographic Profile | 0.289 | 5 | 0.346 | **0.034** |
| | Livelihood Strategies | 0.421 | 4 | | |
| | Social Network | 0.329 | 4 | | |
| **Sensitivity** | Food | 0.346 | 5 | 0.355 | |
| | Health | 0.242 | 3 | | |
| | Water | 0.456 | 3 | | |
| | Housing and Land Tenure | 0.374 | 4 | | |
| **Exposure** | Natural Disasters and Climate Variability | 0.441 | 6 | 0.441 | |
| **LVI-IPCC value of the large farmer** | | | | | |
| **Adaptive Capacity** | Social-demographic Profile | 0.193 | 5 | 0.33 | **0.028** |
| | Livelihood Strategies | 0.526 | 4 | | |
| | Social Network | 0.27 | 4 | | |
| **Sensitivity** | Food | 0.258 | 5 | 0.265 | |
| | Health | 0.219 | 3 | | |
| | Water | 0.395 | 3 | | |
| | Housing and Land Tenure | 0.189 | 4 | | |
| **Exposure** | Natural Disasters and Climate Variability | 0.435 | 6 | 0.435 | |

From the calculation, it is found that the small farmers were found to be the most vulnerable among medium and large farmers. The LVI-IPCC values of the small, medium, and large farmers were 0.043, 0.034, and 0.028 respectively indicating small farmers were the most and large farmers the least vulnerable.

## 4.3 Types of Adaptation Strategies Adopted by Farmers

### 4.3.1 Housing Structure:

The household survey showed that the adaptation strategies differed according to farmer types. The result showed that About 80% of small farmers adopted a temporary structure as a small farmer while these values were 62.93% and 21.36% for medium and large farmers respectively. The elevated house was another important adaptation strategy adopted by the farmers, the result showed that about 15%, 37.03%, and 97.82% adopted these practices by small, medium, and large farmers respectively. Also, the permanent structure house was one of the adaptation strategies adopted by the farmers. The results showed that about 78.57%, 37.03%, and 20% adopted these practices by large, medium, and small farmers respectively.

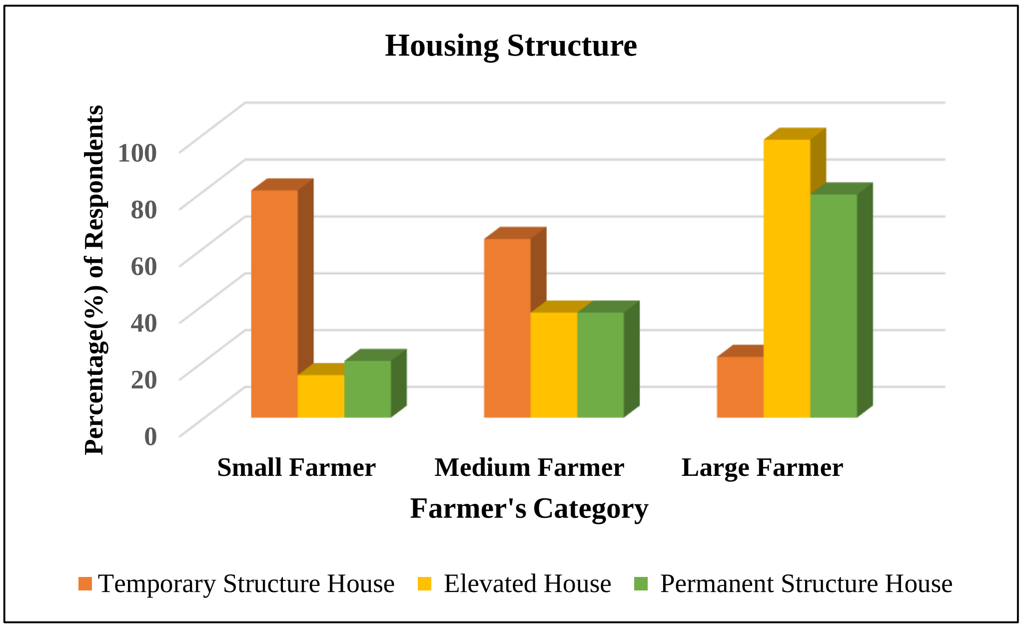



Figure 17 Housing Structure of small, medium, and large farmers

### 4.3.2 Farmland and food status

The household survey showed that about 79% of small farmers have their farmland, and 38% rented other lands for crop cultivation. The majority of the small farmers i.e., 37.5 % reported food deficiency for an average of 5 months. The medium and large farmers also rented the land for cropping and it was found to be 11.66% and 15% respectively. The seed unavailability was found to be 77% which is the highest in the case of small farmers followed by medium farmers i.e., 16%. All the large farmers mentioned that they have enough seed availability for next year.

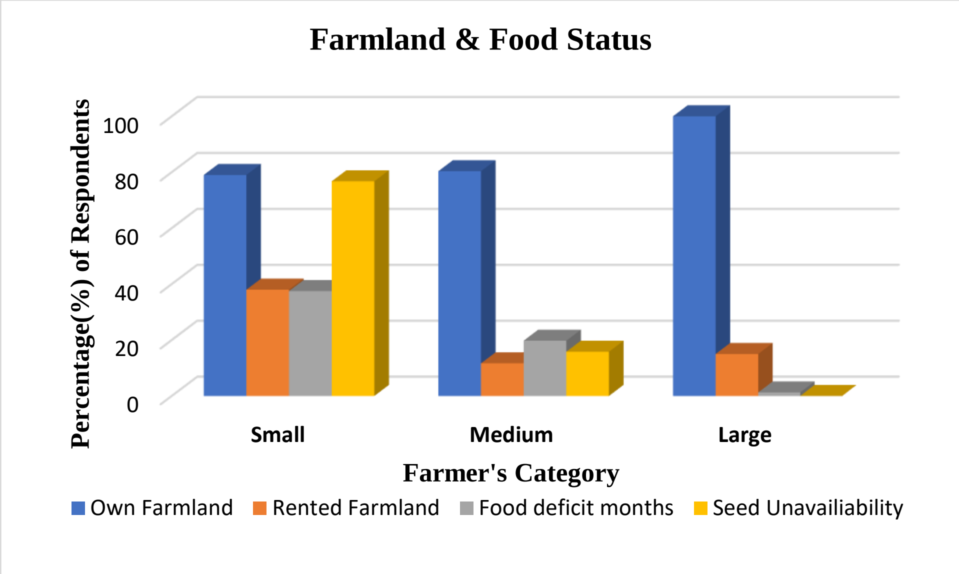



Figure 18 Farmland and food status of small, medium, and large farmers

#### 4.3.3 Diversification of income of farmers:

It was about the highest percentage (79.06%) of small farmers dependent on wages for income generation, it was followed by 33.33 % of medium farmers and least only 5% of large farmers. The involvement of medium farmers in the private job was found to be the highest percentage (27.77%) followed by large and small farmers with 25% and 9.52%. But in the case of remittances, the highest percentage was found in the small farmers with 37.21 %, followed by large farmers with 15%, and least with 9.26% of medium farmers. The income from the business was found to be the highest in large farmers with 75% followed by 23.21% in medium farmers and the least with 1.16 % in small farmers.

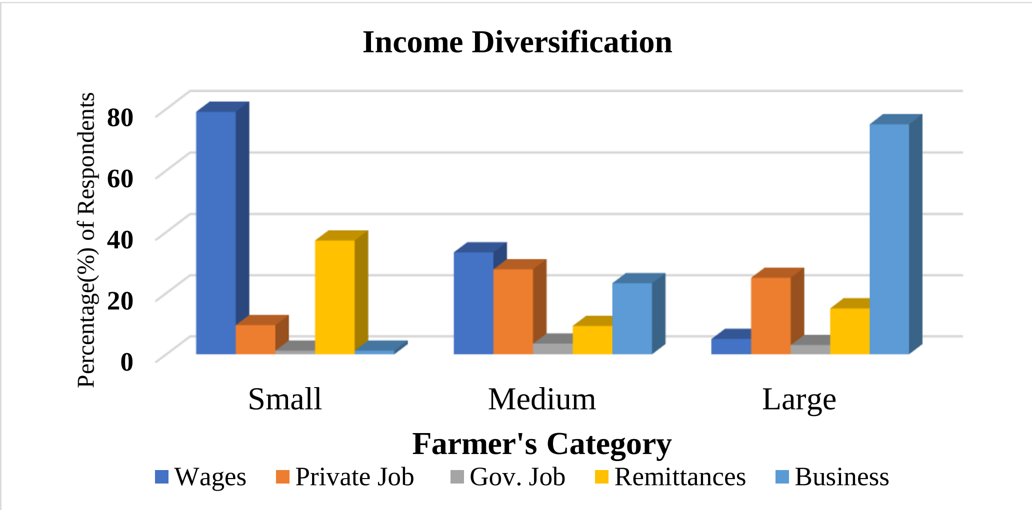



Figure 19 Income diversification of small, medium, and large farmers

### 4.3.4 Accessibility of Drinking Water

The result showed that, elevated pumps for the availability of drinking water. It was about 100% elevated handpumps available for all categories of farmers. The farmers responded that they have to face difficulty in getting clean drinking water during monsoon days and among the categorized group of farmers the highest percentage about 5.804 % of small farmers and the least of large farmers with 3.48%. Also, water-related infections were found to be in the highest percentage of small farmers with 20%, followed by the medium and large farmers with a similar percentage.

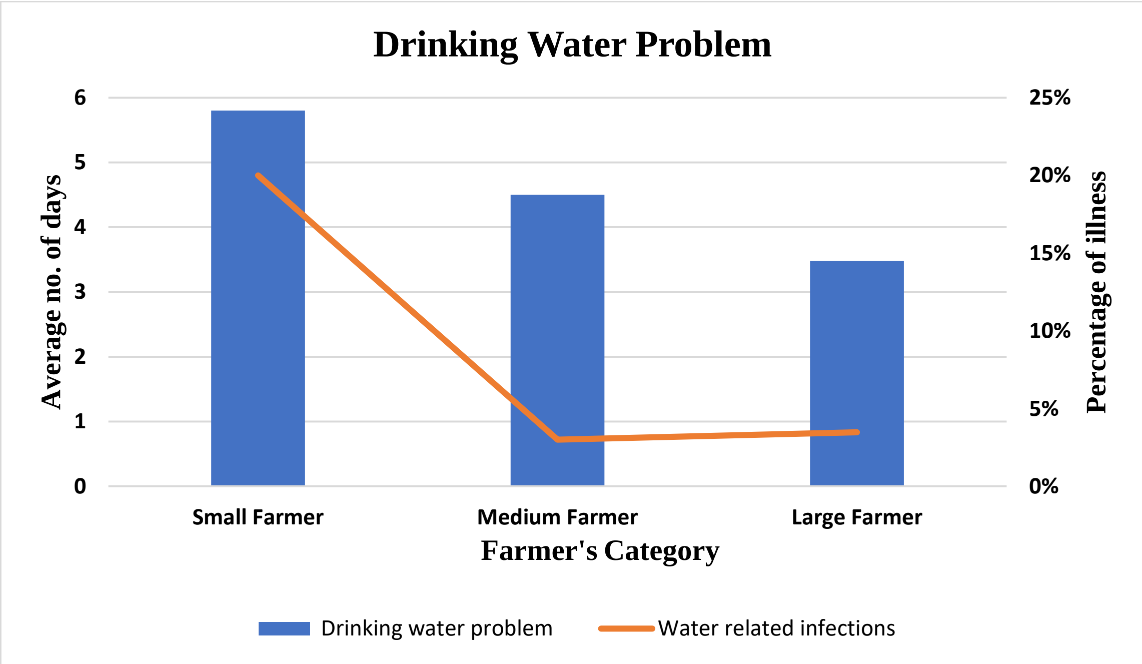



Figure 20 Drinking Water Accessibility

### 4.3.5 Available Social Network to Farmers:

The social network was varying among small, medium, and large farmers. Food and aid, lend, give, a loan taken, and additional assistance needed. The household survey showed that about 58% of small farmers received food and aid during the flood event it was followed by 32% of medium farmers and 1% of large farmers. The lend-borrow ratio was found to be highest in small farmers (0.76%), followed by the large farmer (0.43%), and least with 0.34% in medium farmers. In the case of the give-receive ratio, the highest % was found in small farmers (0.54%) followed by medium and large farmers with 0.51% and 0.08% respectively. Similarly, in the loan taken percentage, it was found that the smaller farmer with the highest about 91.25% of loan accessibility followed by the medium farmer with

79.62%, and the least with 35% for large farmers. The highest percentage of about 30.53% of small farmers needed additional assistance, followed by the medium farmer with 13.89% and the least with 2.42 5 of large farmers.

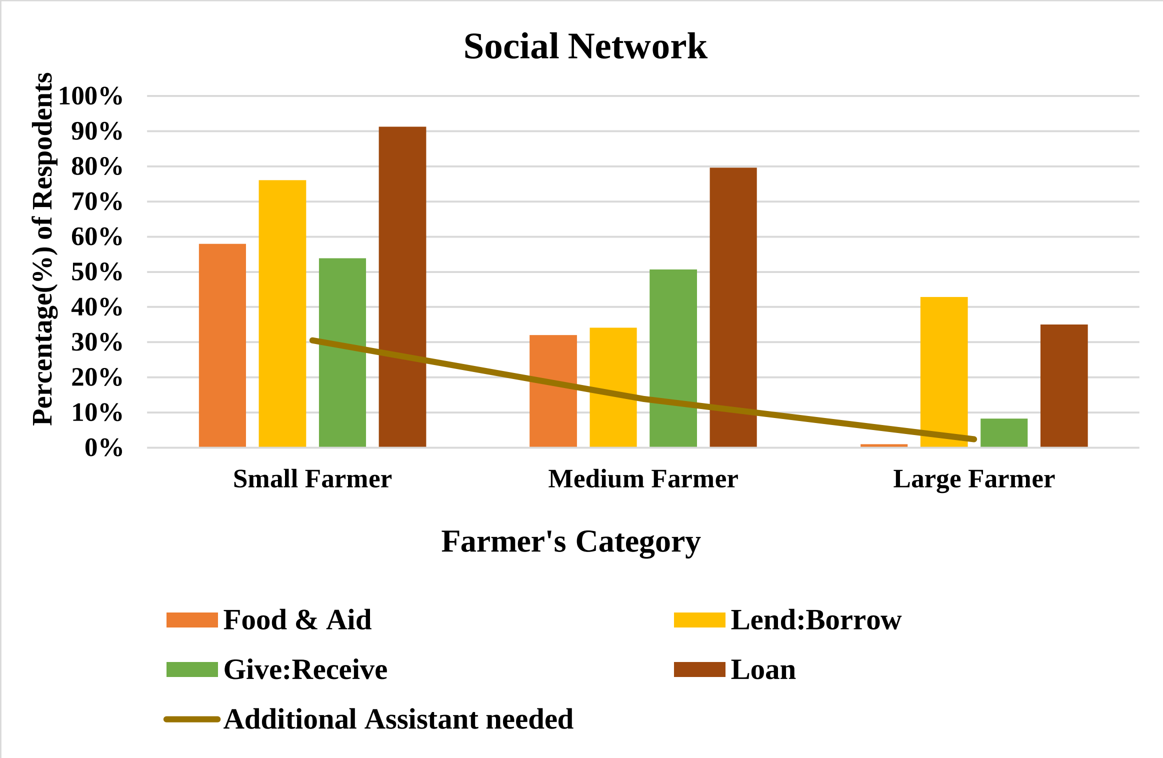



Figure 21 Social network of the small, medium, and large farmers

### 4.3.6 Migration strategy for better earnings:

The household survey showed that farmers migrated to nearby markets, urban areas, and abroad for better earnings. Specifically, it was found the highest migration about 31.40% of small farmers, followed by 30.36% of medium and only 15% of large farmers to nearby markets. The migration percentage to urban areas was found to be highest in medium farmers (26.78%), followed by small farmers (23.36%), and least in large farmers with 10%. The abroad migration percentage was found to be highest in small farmers with 29.07 %, followed by the large farmer with 10% and least of medium farmers with 7.41%. The abroad migration in this study was found to be nearby neighboring country India for labor and wages.

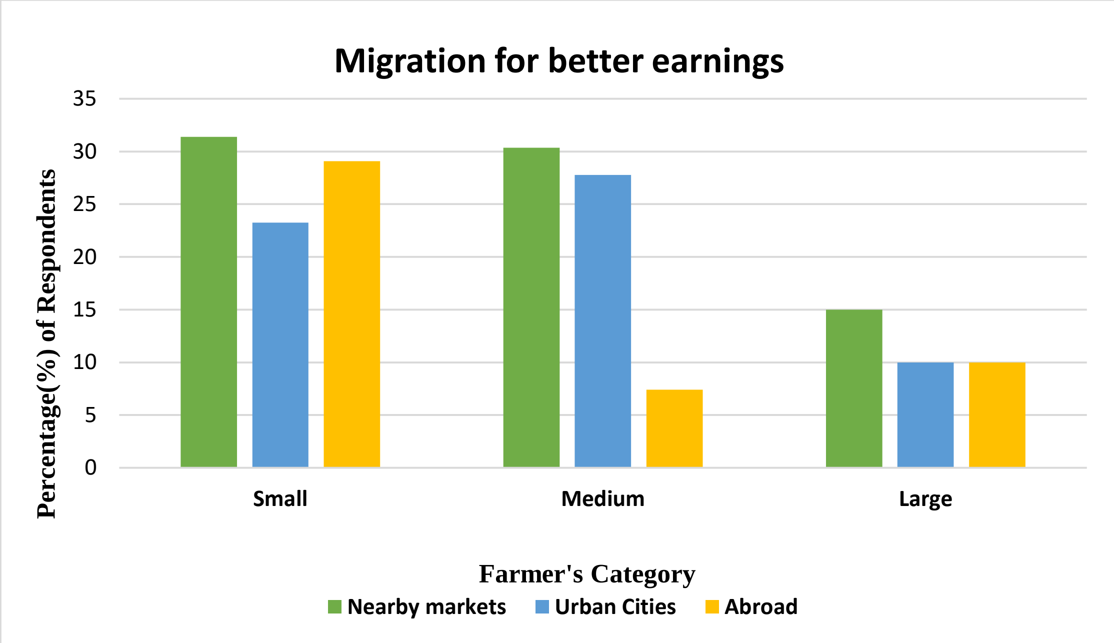



Figure 22 Migration for better earning

4.3.7 Early warning system and Shelter house:

The result showed that, strategies of the early warning system, siren and miking as well as shelter house was adopted by the farmers. The early warning system was adopted by about 100% of medium and large farmers but it was 90% by small farmers. The siren and miking were other strategies against the flood which were about 100% in practice for all categories of farmers. The use of shelter houses was found to be highest at about 70% by small farmers, followed by 50% of medium and least by large farmers with 15%.

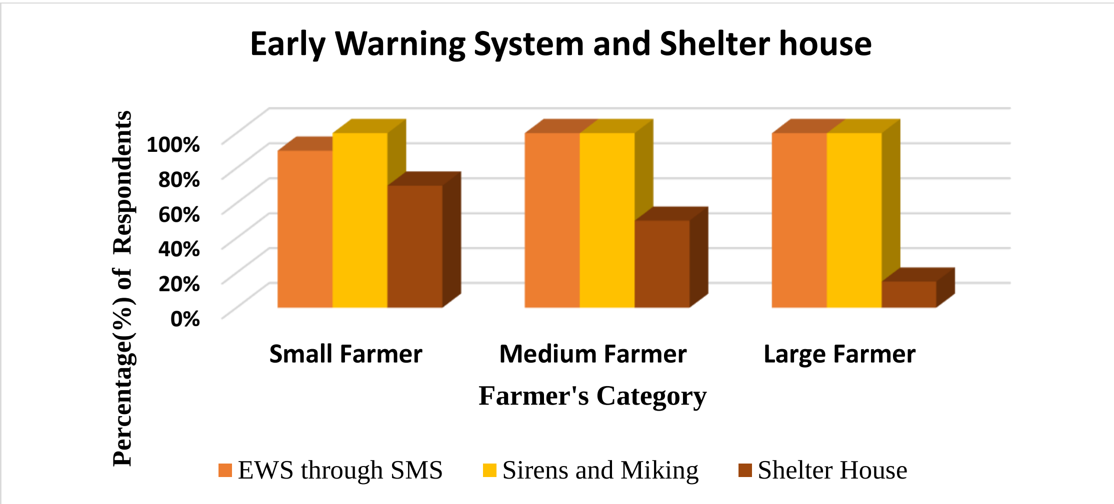



Figure 23 Early Warning System and Shelter House

4.3.8 The strategy of the embankment as a mitigation measure:

The repair and maintenance were reported by the small, medium, and large farmers with 60.47%, 46.30%, and 30% respectively. Besides that, concrete embankment will be an effective mitigating measure, as mentioned by 46.51 % of the small farmer, 64.81% of the medium farmer, and 80% of the large farmer.

The small farmers are the most exposed and sensitive so they feel insecure in the case of livelihood and their demand for relocation was found to be highest at 32.56%.

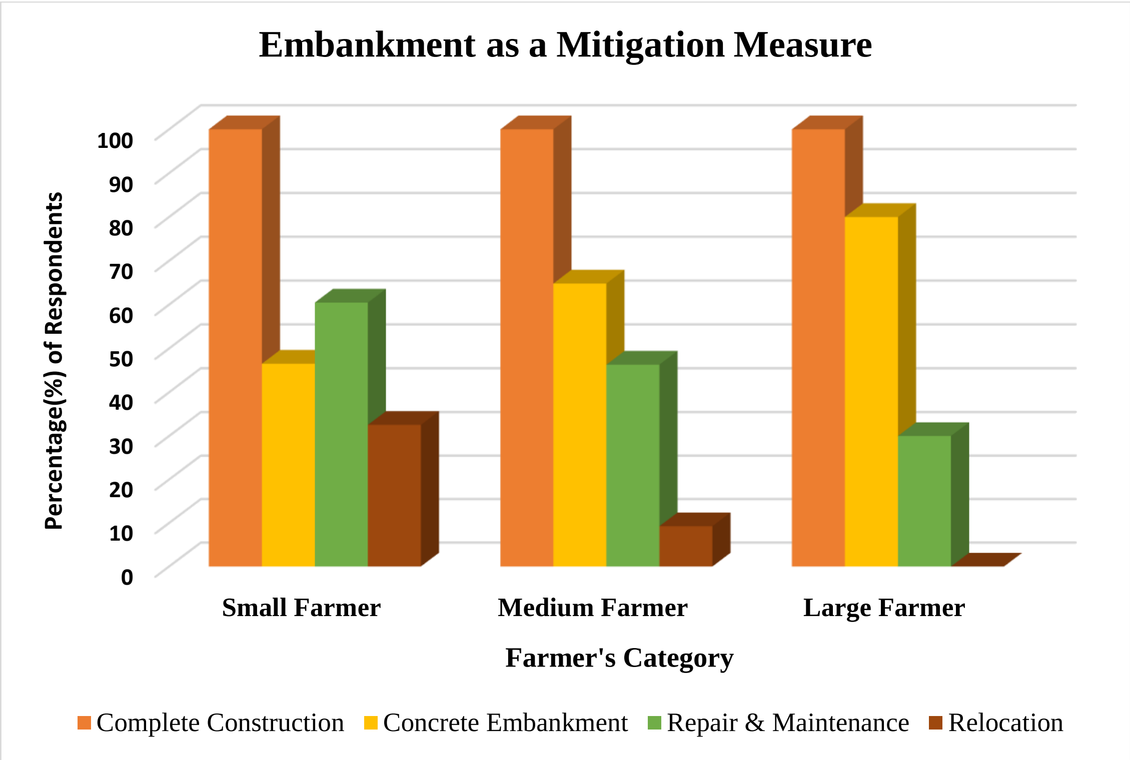



Figure 24 Embankment as a Mitigation Measure

#### 4.3.9 Capacity Building

The capacity-building strategy includes training on Disaster Risk Reduction (DRR), income generating skills, and agriculture subsidy. It was varying according to the small, medium, and large farmers. The highest percentage (38%) of DRR training was received by small farmers which were followed by 28% by medium farmers and only 15% by large farmers. Also, the small farmers with highest percentage (13%) participated in income generating skills which were followed by 11% of medium and only 5% of large farmers. Similarly, the highest percentage (7%) in agricultural subsidy was found to be in small farmers which were followed by 4% of medium and only 2% of large farmers. However, the farm machinery tools were not seen incase of small farmers despite the government's subsidy provisions.

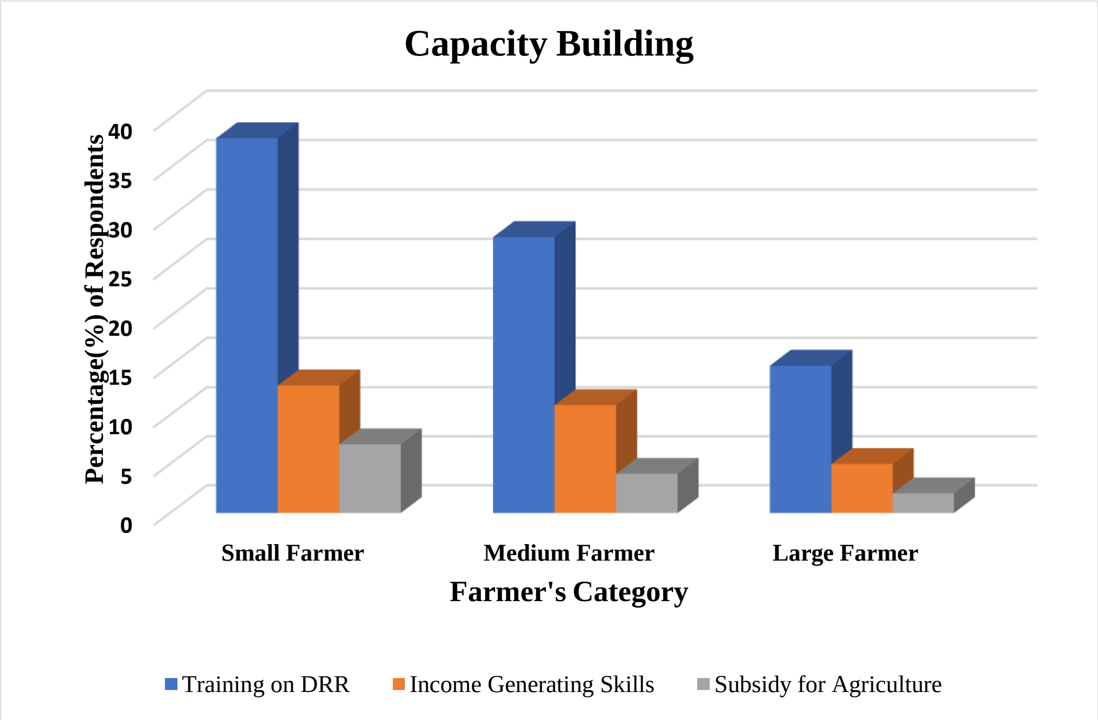



Figure 25 Capacity building

# CHAPTER 5

# DISCUSSION

## 5.1 Temperature:

The variation in minimum temperature, maximum temperature, and rainfall, was analyzed on a yearly, monthly and seasonal basis. This study shows annual positive trends in Rajapur maximum temperature and negative trends in minimum temperature. The average maximum temperature of 37.80ºC was recorded in May and the average minimum temperature was observed to be 7.ºC in January.  The analysis of temperature in all four seasons shows the increasing trend of maximum temperature while the trend for minimum temperatures indicates a decrease in below-average minimum temperatures during the winter and post-monsoon season. The average annual maximum temperature for the study region was determined to be more than 30ºC, which is consistent with the report[25].

## 5.2 Precipitation:

The precipitation trends of Rajapur varied in terms of rainfall frequency and intensity which shows the total annual increase in rainfall of 8.318 mm each year. The winter and post-monsoon precipitation trends are found to be in decreasing trend whereas the pre-monsoon and monsoon are found to be increasing. The findings are also consistent with the Local Disaster and Climate Resilience Plan (LDCRP) book published by the Rajapur municipality in the year 2078.

Rising temperatures, more erratic rainfall, and shifts in the commencement and length of the rainy season are among the most widely reported changes. Farmers' assessments of climate change were largely consistent with historical climatic data for the region, which show considerable increases in mean and maximum temperatures across Rajapur but less clear trends in rainfall patterns. Most farmers (92.2%) also reported having been affected by at least one extreme weather event during the last decade, and many considered that the frequency and intensity of extreme weather events were increasing, as is also suggested by projections from climate models.

### 5.3 Livelihood Vulnerability of farmers

The main focus of this study was the vulnerability of farming households to floods, along with climate-driven natural disasters and climate variability. The primary data obtained from the household survey to assess the livelihood vulnerability approaches, i.e., LVI and LVI-IPCC of a rural farming household was used.

LVI identifies the important components and sub-components that are the most important drivers of vulnerability in the studied area, whereas LVI-IPCC identifies the studied community's adaptive capacity, sensitivity, or exposure, which could be useful for developing planning for the reduction of livelihood vulnerability to changing climate and related hazards. Relevant indicators or significant IPCC contributing factors (exposure, sensitivity, and adaptive capacity) were used to assess this vulnerability, which was also taken into account by Hahn et al. (2009) and Tran et al (2020). For adaptation and mitigation planning at the household level, livelihood components capable of utilizing adaptive capacity and sensitivity should be included. As a result, computing both indexes concurrently have been beneficial. Furthermore, vulnerability is measured using specific indicators that we discovered to be appropriate for agricultural households. Such indicators show the susceptibility of an individual, a group, or a system to specific risks[47]. At first inspection, it appears that the vulnerability variations between small, medium, and big farmers were negligible. However, detailed analyses revealed several small yet significant differences between these farmer categories. In the overall analysis of the study, the small farmers are found to be the most vulnerable among the medium and large farmer categories.

#### 5.3.1 Socio-demographic profile:

The socio-demographic index of the small farmer is highest i.e., 0.325 in comparison between the medium and large farmers. Women make up 34.88 percent of family heads in small farming households, while 14.81 % and 2.32% in medium and large farming households. The absence of a male for more than six months in most of the cases was found and female was considered in the households. Compared to males, women are more vulnerable to natural disasters, especially during and after floods. This is because women are more involved in household tasks including gathering water and burning wood, cooking, managing food, and caring for children. Due to long-standing gender differences, they could also experience violence and other issues (Nasreen, 2010) [48]. According to this indicator, female-led households are more susceptible than male-led households. However, the in-depth analysis was out of the research objective. Further studies and deep exploration need to be conducted regarding the vulnerability of female-headed households.

## 5.4 Livelihood strategy

About 90.21% of small farmers have at least one family member working outside the community to support the basic needs of the family while the percentage is extremely lower in the case of medium and large farmers**.** The livelihood strategy of small farmers shows that the majority of the households depend upon the nonagricultural livelihood income and for income diversifications people have been migrating outside the community for better opportunities. The non-agricultural income includes wages, private jobs, government jobs, business, and remittances. The reason for non-agricultural livelihood is because of limited land holding size for agricultural activities, poverty, and frequently occurring hazards that destroy the major cereal crop.

Livestock rearing was found to be negligible so it was included in the agricultural activities without considering it as a source of income. The livestock rearing was found to be decreasing due to infection of disease after the flood and insufficient fodder availability.

### 5.4.1 Social network

Social organizations and community-based institutions are less accessible to vulnerable social groups than to other groups [49]. Participation in a social structure improves adaptive capacity, according to other studies[50]. In our study, this applies especially to the small farmers, whose limited involvement in local institutions and organizations and lack of political participation is a cause of their low adaptive capacity. The involvement of small farmers in at least one social organization was found to be in a very smaller proportion with 0.17%. This study shows that small farmers have a greater borrow-lend ratio than medium and big farmers, and instead of making profitable investments, they borrow money at a high-interest rate from a moneylender to satisfy their basic needs. This demonstrates how borrowing money and paying high-interest rates increases the vulnerability of small agricultural households and the same case implies more vulnerable social communities. Similar findings have been reported by Sujakhu et. al 2019 [51]. Besides lending and borrowing, the majority of the small farmers (91.25%) had taken loans from small financial cooperatives to run their livelihood which demonstrates their hardship of living with just a limited source of income from daily wages and are forced to migrate for better earnings.

About 30.53% of small farmers said they have not attended any training and needed additional assistance to boost their livelihood that including income-generating skills, agricultural assistantship, adequate fertilizers for cultivation, and risk-sharing provisions from the government level. If provided they won't have to move away from the community most of the months for employment that was mentioned by all the farmers in the FGD.

### 5.4.2 Food

According to the survey report, large farmers obtain 100 percent of their food mostly from their farms, while medium farmers get 83 % and small farmers get 41.43 %. The agricultural yield is insufficient year-round so the practice of sharecropping accounts for 38% in the case of the small farmers. Such agriculture practices are carried out mainly to fulfill the household food requirements from farms, and the loss of major crops may worsen food insecurity[52]. Besides sharecropping, farmers in Rajapur have begun cultivating Spring season rice (choice dhan), which has a better yield than main season rice and is supported by the PMAMP initiatives that help to minimize the food scarcity for small farming households. The study demonstrates that small farmers had the lowest crop diversity index as well as the lowest rates of crop sale and seed preservation. Similar findings have been reported in [53][54].

### 5.4.3 Water

From the household survey, it was found that 39% of small farmers reported, they missed work due to illness, 13% reported water-related infections during flooding with an average of 5 days problem in getting clean drinking water whereas the medium and large farmers data was minimum when compared to the small farmer. Almost all the surveyed households have the facility of drinking water whereas few reported that the water is contaminated with Arsenic. The report households with no drinking water fall under the small category of farmers whereas contaminated Arsenic water was found in the household of large farmers.

### 5.4.4 Housing and land tenure

The study shows that the majority of the houses of small farmers are comparatively nearer to the Karnali rivers, the houses are constructed with the local resources available that are weak in structure and cannot provide shelter during extreme flooding events. In past, there used to be more elevated houses and the forest resources were available abundantly but these days the resources are limited and it cost too much to make an elevated house that was the outcome of the FGD with the involvement of farmers, along with representatives of village head (Barghars). The percentage of weak structure houses was found to be 80%, 62%, and 21% among small, medium, and large farmers, respectively. According to the report, 78 percent of small farmers have constructed settlements along the river, and living near rivers was generally recognized as a result of poverty: poor people, particularly tenants, cannot afford to live in safer areas. Poor people are less likely to own property and are more likely to live in makeshift shelters that may be swept away each year. The findings were similar to the study done by L. Emma, et, al(2019) [55].

### 5.4.5 Health

Human capital is crucial when considering how livelihoods are affected by climate change, especially when considering health. Health problems impair labor's ability to work and shorten the number of workdays (Hahn et al. 2009). According to the household survey, 39 percent of small farmers reported missing work due to illness, with 13.04 percent mentioning at least one family member suffering from chronic disease and requiring daily care. The percentage of medium and large farmers reporting chronic illness and missed work was lower, but the average time to reach a health facility was almost the same in all three categories of farmers.

### 5.4.6 Natural disaster and climate vulnerability:

The index number of natural disasters and climate variability in the small farming household is 0.456; which is the highest among the medium (0.362) and large farming households (0.311). Small farmers are highly vulnerable to flooding due to their proximity to the Karnali river and the highest number of injuries reported by households during flooding events in the past 10 years.

Besides the household surveys, the available secondary literature, and DHM data were used to examine the trend of flood incidents in Rajapur Municipality during the last 30 years.

According to the findings, the flood happened in the following years: 1995, 1998, 1999, 2000, 2003, 2007, 2008, 2009, 2012, 2013, 2014, 2017, 2020, and 2021. Due to recurring floods, the livelihoods of people have been severely affected. It was found that the frequency and intensity of flood incidents are increasing, and a similar flood trend was discovered in other research[56][57][58][59]. So, flood is considered the major hazard in the case of this study area.

### 5.4.7 Livelihood Vulnerability Index- Intergovernmental Panel on Climate Change approach

The livelihood vulnerability index/LVI-IPCC is a measure of the vulnerability of farming households in disaster-prone areas that includes three measuring indicators: exposure, sensitivity, and adaptive capability.

By analyzing all the major components of LVI with LVI-IPCC, the study demonstrates the small farmers with the highest vulnerability. The contributing factors were analyzed and it shows that the small farmers were most exposed and sensitive to frequent flooding and climate variability despite their higher adaptive measures among the medium and large farming households. Water, food, health and housing, and land tenure were the major components that were found to be most sensitive in the case of small farmers. Among the four sensitive components, the housing and land tenure status was found to be the poorest in the case of small farmers with the majority living under the weak structure house and having farmland that does not yield sufficient crop year-round. Small farmers were found to be the most vulnerable due to their direct exposure to floods, settlements near river banks, and higher sensitivity to floods, despite their highest adaptive measures being applied. Regardless of location, households with weak adaptation ability are more exposed to and sensitive to climate change and catastrophic occurrences, according to Piya et al. (2012). No matter where they are, households with low incomes and little access to resources are highly vulnerable[60].Similar findings were reported in [61][53] [45], [54], [62]–[65].

# CHAPTER 6

# CONCLUSION AND RECOMMENDATION

## 6.1 Conclusion

The current study examined the vulnerability of farming households to climate change in the Rajapur municipality of Nepal by employing the Livelihood Vulnerability Index. Primary and secondary data were employed in the investigation. The primary data was based on 160 agricultural households and was complemented by secondary data on rainfall and temperature from 1992 to 2021. A comparative analysis was carried out for Rajapur's small, medium, and big farmers. Small farmers were found to be the most vulnerable followed by medium and large farmers in terms of main components such as social-demographic profile, livelihood strategies, social network, housing and land tenure, food, health and natural disasters, and climate variability.

The overall LVI calculated from the major components indicates that small farmers were the most vulnerable to climate change, with an index of 0.456 compared to 0.362 for medium farmers and 0.311 for large farmers. The LVI-IPCC index also showed that small farmers in Rajapur municipality were the most vulnerable, with an index of 0.043, followed by the medium and large farmers, with indexes of 0.034 and 0.028, respectively. According to the study's findings, the climate and precipitation pattern is changing in Nepal's Rajapur region, and it suppresses the farmers' livelihoods.

## 6.2 Recommendation

To develop intersectional strategies for vulnerability reduction and resilience-building in policy and programming, this study proposes the following recommendations:

- Since, this research could not integrate the gender-based vulnerability and household level vulnerability of minority populations against flood, the provision of classification of various types of vulnerabilities based on socioeconomic circumstances and access to resources may be useful tool to develop the effective adaptive strategies at national and local level.
- The lives and livelihood of small farmers are in the direct threat as the settlements have been made near by the river banks. Small farmers are most exposed, sensitive and have limited land with adaptation limits. Since the small farmers are highest in number and their practice of sharecropping is compulsion for their livelihood. So, when disaster hits, they are the biggest sufferers. Looking at this scenario it is recommended to provide adequate trainings, skills and knowledge that helps in capacity building of rural farmers in disaster prone areas.
- The basic needs of human's food, water and shelter should not be compromised and it is the duty and responsibility of government to secure these needs of vulnerable people. Significant positive impact can be seen through the implementation of action-oriented activities on mean time that helps to build the trust against government policies and frameworks.
- This study shows that forced migration ratio due to climatic disaster had already begun and it is expected to increase exponentially in near future. This will create additional pressure on urban infrastructure and services undermining economic growth. The fertile agricultural land is left barren and people lack interest in agricultural practices due to higher risk from frequent flooding. So, it is recommended to introduce risk sharing mechanism and provide adequate technical as well as financial assistance to farmers particularly the smaller ones as they are the ones with higher migration.
- The major LVI components namely adaptive capacity, exposure and sensitivity were used to assess the vulnerability index caused by flood, this tool can be used for other causes of vulnerability as well.

- It is recommended to conduct further study to integrate the resilience-building of the local people in order to reduce the vulnerability
- The incomplete construction of embankment and its breakage puts the farmers of Rajapur into serious threat. Also, the economic and non-economic loss and damages is enormous on a single disaster event. As the proposed date for the complete construction of embankment had already passed out much priority should be given for the complete construction as soon as possible that helps to protect the lives and properties. This supports for the economic upliftment of inhabitants of Rajapur near future.
- It is recommended to encourage farmers and local people to adopt natural based solutions. Some of the natural approaches for managing flood risk include bio-engineering, planting along riverbanks and around farmland.
- It is recommended to provide on-time compensation to the farmers in case of loss and damages because the farm products reach every household that does not farm. Those hardworking farmers must be appreciated.

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## APPENDICS

**Appendix I:** Average minimum, maximum, and mean temperature data from Tikapur station

| Year | Average Minimum Temperature (⁰C) | Average Maximum Temperature (⁰C) | Average Mean Temperature (⁰C) |
|---|---|---|---|
| 1992 | 17.02 | 30.25 | 23.64 |
| 1993 | 17.30 | 29.77 | 23.53 |
| 1994 | 17.49 | 30.89 | 24.19 |
| 1995 | 17.71 | 30.68 | 24.19 |
| 1996 | 18.11 | 30.77 | 24.44 |
| 1997 | 17.64 | 29.79 | 23.72 |
| 1998 | 18.91 | 30.39 | 24.65 |
| 1999 | 17.89 | 30.70 | 24.29 |
| 2000 | 17.95 | 29.87 | 23.91 |
| 2001 | 17.87 | 30.72 | 24.29 |
| 2002 | 17.98 | 30.63 | 24.31 |
| 2003 | 18.10 | 30.52 | 24.31 |
| 2004 | 17.85 | 30.32 | 24.08 |
| 2005 | 17.12 | 30.76 | 23.94 |
| 2006 | 17.89 | 30.37 | 24.13 |
| 2007 | 17.75 | 30.11 | 23.93 |
| 2008 | 17.12 | 30.72 | 23.92 |
| 2009 | 16.66 | 31.77 | 24.21 |
| 2010 | 16.45 | 31.37 | 23.91 |
| 2011 | 17.31 | 31.76 | 24.54 |
| 2012 | 17.08 | 32.32 | 24.70 |
| 2013 | 17.84 | 30.68 | 24.26 |
| 2014 | 18.20 | 30.62 | 24.41 |
| 2015 | 18.55 | 31.13 | 24.84 |
| 2016 | 18.28 | 31.98 | 25.13 |
| 2017 | 17.47 | 31.85 | 24.66 |
| 2018 | 17.84 | 31.21 | 24.53 |
| 2019 | 16.13 | 31.25 | 23.69 |
| 2020 | 16.01 | 30.34 | 23.18 |
| 2021 | 16.81 | 30.95 | 23.88 |

**Appendix II**: Annual Precipitation data from 1992 -2021

| **Year** | **Total Precipitation(mm)** |
|---|---|
| 1992 | 1039 |
| 1993 | 1458 |
| 1994 | 884 |
| 1995 | 1398.1 |
| 1996 | 1545.2 |
| 1997 | 995.6 |
| 1998 | 1323.1 |
| 1999 | 1463.2 |
| 2000 | 1645 |
| 2001 | 956.3 |
| 2002 | 715.1 |
| 2003 | 1770.3 |
| 2004 | 1305.3 |
| 2005 | 1347.6 |
| 2006 | 1114.4 |
| 2007 | 2017.7 |
| 2008 | 1797.5 |
| 2009 | 953.2 |
| 2010 | 988.4 |
| 2011 | 1499.5 |
| 2012 | 1383.3 |
| 2013 | 1765.1 |
| 2014 | 1699.5 |
| 2015 | 1212.5 |
| 2016 | 1427.5 |
| 2017 | 1642.7 |
| 2018 | 1465 |
| 2019 | 686.2 |
| 2020 | 1699.6 |
| 2021 | 1522.37 |

**Appendix III**: Photographs from household survey

## Some Photographs

Houses as seen on Rajapur villages

- **Sheds and Elevated Handpump**

**Livelihood activities**

- Farming
- Animal husbandry
- Fishing

- Victims of bank erosion
- Inundation water level mark on the tree


Shelter House such houses are used during flooding.

- Those houses were built by different INGOs in collaboration with local government.

## KII

With Mr. Arjun Subedi Sir,

Administrative officer of Rajapur Municipality.


FGDs with 3 different groups of people