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AN ASSESSMENT OF CLIMATE CHANGE IMPACT ON THE LIVELIHOODS OF FARMERS AT DELING VILLAGE IN SOUTHERN BHUTAN

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ABSTRACT

This study was conducted in Deling Village under Chhukha district in Bhutan as a case study to investigate the impact of climate change on farmers livelihoods. Data was collected through a semi-structured interview with farmers (n=8) and government officials (n=3), and field observations. In addition, the study also analysed the climate data such as variability of temperature and precipitation data of the past 26 years (1996-2021) collected from the National Centre of Hydrology and Metrology, and crop production records from District Agriculture Statistics (2004-2021). Analyses revealed that the farmers' practices of new crops and vegetables production in the village, an outbreak of pests and diseases, changes in plant phenology and vegetation, rural-urban migration, the emergence of vector-borne diseases, and macro-parasites in animals were mainly attributed to changes in temperature and rainfall patterns in the region. Therefore, this study suggests that climate variability has brought with its pests and diseases, changes in plant and animal species, the drying up of water sources in lean seasons, and erratic heavy rainfall during monsoons in the region, which has resulted in flash flooding and frequent land erosions in the communities. To cope with the impacts, farmers have developed adaptive strategies in their own ways to cope with it. Thus, the findings of this study are useful to the relevant stakeholders on the impact of climate change at the local level in planning and developing the climate change adaptation process. Therefore, this study suggests a relentless need to address these challenges both from short and long-term policy perspectives.

Keywords: Climate change, livelihood, impacts, and coping mechanism.

1. INTRODUCTION

The Himalayan country of Bhutan is typically an agrarian country, with 57% of the population dependent on agriculture (National Statistics Bureau [NSB], 2016). Bhutanese farmers practice subsistence farming (Katwal *et al.*, 2015), making them vulnerable to food insecurity caused by external shocks such as global climate change challenges and commodity market instability (Chhogyel & Kumar, 2018). The rain-fed nature of farming and the marginality of small farms without adequate access to technical and financial support further expose farmers to the impacts of climate change (Holland *et al.*, 2016; Morton, 2007). The country is located in one of the most climatically vulnerable regions in the world due to its location in the fragile Himalayas (Wester *et al.*, 2019). It has been established that there are approximately 500 million small farmers worldwide whose average land holding per household is less than 2 hectares (Lowder *et al.*, 2016). The average land holding of each Bhutanese farmer is 1.4 hectares which is much lower than the global average (Chhogyel & Ghimiray, 2018). The generalized land-use categories are Kamzhing (dryland), Chuzhing (wetlands) and horticulture (orchards and plantations), accounting for61.90%, 27.86% and 10.24% of the agricultural land (National Soil Service Center, 2011 as cited in Chhogyel & Kumar, 2018). According to NSB (2020), the common agricultural activities in Bhutan include cereals, oil seeds and legumes, vegetables and species, mushrooms, roots and tubers, and fruit cultivation. In 2014, the agriculture sector was the highest contributor to the national economy with 16.77 percent (NSB, 2016). However, the share of agriculture in Bhutan's gross domestic product declined to the third highest in 2019 at 15.82 percent (O'Neill, 2021). This suggests that the impacts of climate change on the agriculture sectors are intensifying, food security is likely to be a major concern, and that minimizing its negative impacts require understanding the ground situations and limiting factors affecting farm resilience to the challenges.

Over the past years, the country has experienced rapid changes in average temperature, precipitation patterns, and increased risks of climate hazards, including excessive rains, flash floods, windstorms, hailstorms, and droughts, causing massive losses and damage to farming households (Chhogyel *et al.*, 2020). The main impact of climate change highlighted by the local farmers across the country is low crop production (Chhogyel *et al.*, 2020; Chhogyel & Kumar, 2018; Suberi *et al.*, 2017). The low production of crops was attributed due to the lack of adequate water, the presence of pests, and the invasion of unwanted weeds (Suberi *et al.*, 2017). The drying of the irrigation sources, periods, and temperature rise was also reported by (Chhogyel *et al.*, 2020). All those studies documented erratic rainfall patterns and rising temperatures as impacts of climate change (Wester *et al.*, 2019; Ismail *et al.*, 2016; Mishra *et al.*, 2014). Likewise, Intergovernmental Panel on Climate Change [IPCC] (2013) also reported events of

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sudden high-intensity rains that wreaked havoc on the farming and livelihood of smallholder farmers. Thus, it is considered the impact of climate change in Bhutan.

Local people in Bhutan also indicated the change in snow cover during winter (Suberi *et al.*, 2017). Such climate change impacts have already been well documented in other Hindu Kush regions of the Himalayas as well (Wester *et al.*, 2019). Thus, these changes also contribute to large production losses and food insecurity in the country. Further, the emergence of pests and diseases is another incidence that causes huge losses and ever-increasing sign challenges in food production. In 1996, farmers in the high-altitude areas lost between 80 and 90% of their rice harvest due to a rice blast epidemic in Bhutan. Likewise, the northern corn blight disease outbreak from 2007 caused maize harvest losses of more than 50% at altitudes above 1800 meters (RNR-statistics, 2015). The citrus industry has been devastated by citrus greening, or the Huanglongbing (HLB) disease since 2003 (Donovan *et al.*, 2011). Further, citrus farmers are also affected by the declined fruit production by citrus fruit flies. In the apple orchard in northern Bhutan: woolly aphids, brown rot, collar rots, and apple scab diseases have been reported by Dorji (1999). Similarly, cardamom production has been reduced. Over the last decade, the production of fruits and vegetables have been declined as it is sensitive to climate change (Chhogyel & Kumar, 2018). Further, Chhogyel and Kumar (2018) added that extreme weather such as hail and windstorms destroyed flowering buds and fruits in the orchards. The change in monsoon pattern, all orchards existing in Bhutan are prone to the impacts of climate change and potato production has been reported to decline drastically (Parker *et al.*, 2017). All these climate-related issues signal a grim picture for the future of the agriculture sector in the country.

Therefore, it is imperative to understand the actual dynamics of climate change impact at the lowest levels of the society, such as households, communities and districts (Deressa *et al.*, 2008), and in that way enhance the relevancy of the top-down policy approaches (Ford & Smit, 2004). This study intends to explore the impact of climate change on livelihood of farmers; indigenous knowledge held by the farmers, challenges pose by the climate change, the existing local and institutional coping mechanisms, their viewed from sustainability point of view and regional climate prediction. Although the study focuses on the particular community, the result derived from this study may be useful to many locations of the country as well as other countries with a similar climate and socio-economic structures.

2. OBJECTIVES

The objectives of the study include:

i. Assessment and analysis of historical climate trends in the study area
ii. Investigate the perception of farmers on climate change impact
iii. Examine the challenges that climate change poses to farmers' livelihoods

iv. Identify farming practices used by farmers as a means of climate change adaptation strategy
v. Identify the weather pattern affecting crop production

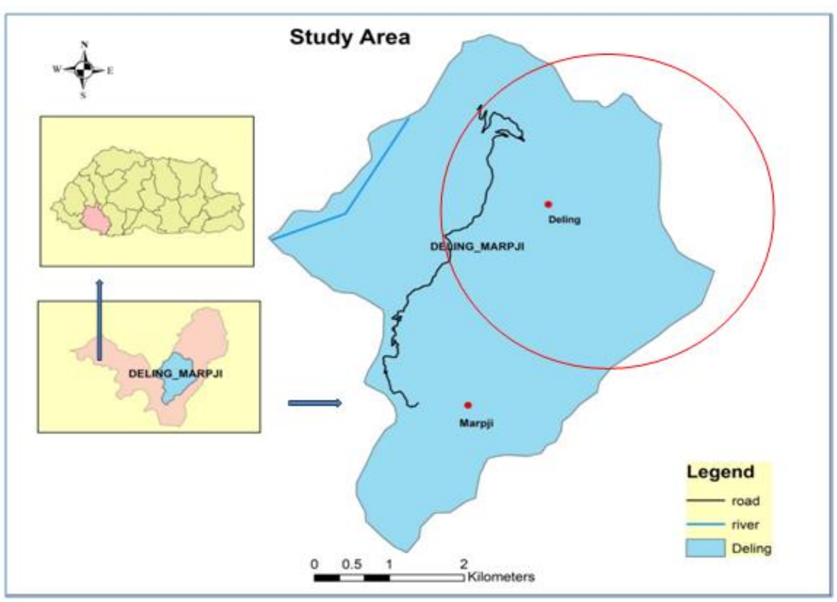
3. METHODOLOGY

This study used a convergent mixed method design wherein both qualitative and quantitative data were collected and analyzed during a similar timeframe. In this single-phase approach, the study compared both qualitative and quantitative results to develop a complete understanding of the results. First, qualitative data was collected through interviews and observations were analyzed into broad themes. Second, quantitative data were analyzed in terms of statistical outcomes. Finally, two databases were integrated to confirm or refute the statistical result (Creswell & Creswell, 2018).

3.1 Study area

This study was conducted at Deling Village under Phuentsholing gewog (block) in Chhukha district, Bhutan. Livestock rearing, agriculture farming and use of forestry products form the daily subsistence of the village. Wheat, Mustard, Millet and Buckwheat are also grown on dry land. Paddy is the main crop in the fertile plain area while Maize is the main crop insloppy areas. Orange, Cardamom, lemon, and Ginger are the main cash crops and sources of cash income. The main forest products are timber and fuelwood. The non-wood products are wild vegetables. In addition, the vegetables and livestock products complement the villagers' sources of income. .

Fig 1: Study area



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3.2 Population and sampling technique

The village consists of 49 households. The head of the family of every household is eligible to be the sample of the study irrespective of gender (Suberi *et al.*, 2017; Senbeta, 2009). The head of the family or any members of the family over the age of 18 were randomly selected from a list of the population (Senbeta, 2009). The selection of a single participant was randomized to avoid research bias (Cohen *et al.*, 2007). Therefore, 16.33% (eight households) of the total population were interviewed for the study.

3.3 Primary data collection

3.3.1 Interview with local households

Primary data on impact, vulnerability, and coping strategies were collected by using household interviews and field observations. In order to get a more comprehensive overview of the study, 16.33% of total households were randomly selected for the interview. The interview questions focused on a broader range of issues, such as socioeconomic status (source of income), the impact of climate change on farmers' livelihoods, coping and adaptation strategies, vulnerability, and aggravating factors (Senbeta, 2009). Accordingly, the researcher used their native language during the interview and later translated it into English. The interview was also conducted face-to-face and an audio recorder was used to avoid information dilution. The interviewees were regarded as "carriers of information," and the researcher took on the role of an "ignorant knower" in order to collect the most relevant information for the study (Cohean *et al.*, 2007).

3.3.2 Interview with Government officials

Interviews with government officials were conducted with the Gewog livestock extension officer, the agriculture officer, and the forest ranger with different semi-structured interview questions. In-depth interviews were conducted with the respective officials to harness and comprehend climatic change trends, impacts, vulnerabilities, and existing stressors.

3.3.3 Field observations

During the field visit, field observations were made in the Deling village, and photographs of crop production were also taken on the impacts of climate change and existing coping mechanisms (Suberi *et al.*, 2017). For each event, the researcher also made short field notes during the conversation (Cohean *et al.*, 2007) and the spatial distribution of the land degradation sites such as landslides, soil erosion, flood-prone areas, etc. were recorded.

3.4 Secondary data collection

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The secondary data on crop production, policy, programs, and activities regarding climate-related risk management and adaptation were collected from government reports and the relevant offices (Suberi *et al.*, 2017; Senbeta, 2009). For this study, climate data was collected from NCHM for the period of 26 years (1996-2021).

3.5 Data Analysis

3.5.1 Recent trend analysis and future prediction of climate change

The analysis work was focused on identifying the most recent trend of variation in each climatic parameter (annual mean temperature, and annual rainfall), in order to comprehend the climate variability and change over the period 1996–2021. For the entire period from 1996 to 2021, the annual rainfall trend over the study area has been determined. By plotting data in Microsoft Excel, trends in maximum, minimum, and rainfall were calculated for each year from 1996 to 2021 using a five-year moving average. The regression equations were created using these five-year moving averages of the annual climatic data.

3.5.2 Investigation of Impacts on crop production

An effort was made to investigate the probable linkage between climate variability and change and the trend of crop production so that the impact on production can be revealed. For this part of the analysis, the production data of four crops—maize, cardamom, ginger, and mandarins—which are the main crops in Deling—were used to identify the trend in crop production in response to annual rainfall and temperature extremes from 1996 to 2021. Then, an attempt was made to investigate any possible correlation between the trend of local climate change and the trend of change in crop production, to realize any types of probable impacts of local climate change on crop production during the specified period.

4. RESULTS

4.1 Livelihood of the farmers

As in most parts of Bhutan, mixed farming dominates the livelihood of farmers in the study area. Land is an important household commodity for growing crops and raising livestock. Based on data from household interviews, crop production is one of the most important livelihood capitals for the people of Deling Village in Phuentsholing Gewog under Chhukha district. Qualitative analysis based on the farmers' interview data showed that the people living in the village primarily rely on crop productions ranging from vegetable cultivation to livestock rearing for their daily subsistence. Field observation data also revealed that crop production was the main economic activity in the village. The most commonly grown crops in the village include spinach, broccoli, beans, cauliflower, corianders, cabbage, and ginger. In addition, some farmers derive

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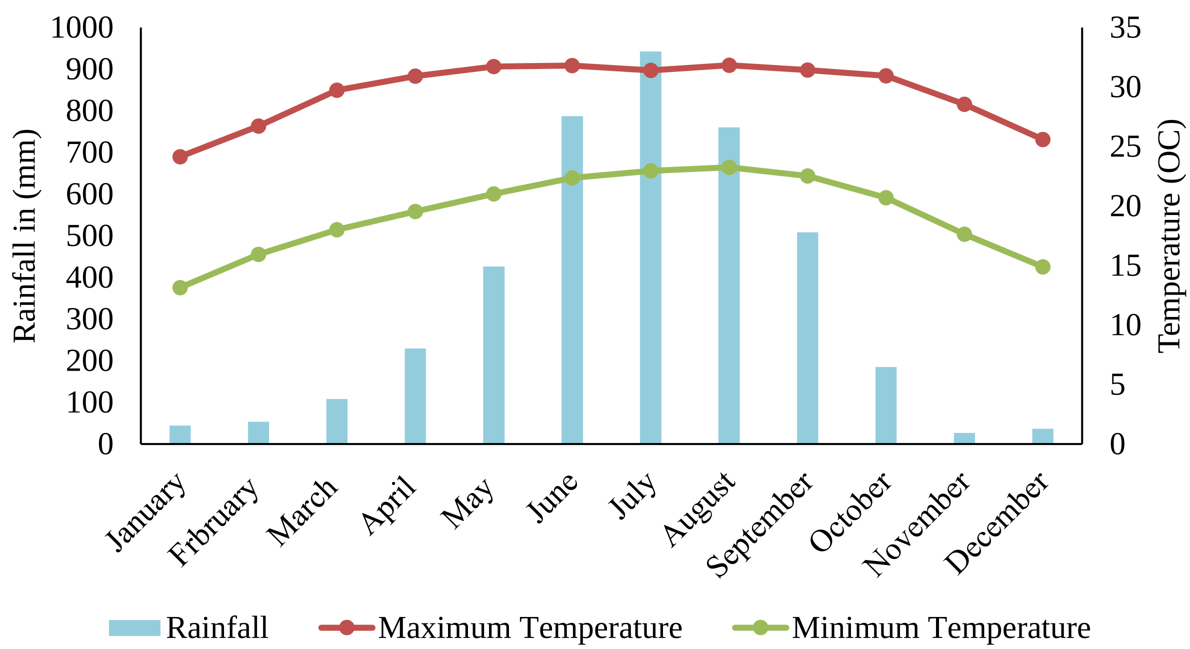
income from other sources such as dairy, poultry, fisheries, sheep, and goat farming. Most of the dairy products have been used for self-consumption and their byproducts (e.g. manure) are used for crop production and the rest goes to the market. Oxen were used as the main engine for plowing fields. Similarly, poultry, fisheries, sheep, and goats were raised commercially to bolster their family source of income. Other sources of income for the farmers are Non-Wood Forest products such as ferns, mushrooms, bamboo shootsand peppers. Some farmers also go to the cities seasonally to work as day laborers as there are more opportunities to make money in the city. This result strongly suggested that the failure of agricultural production had triggered the rural-urban migration and the urban part-time wage earner had been the usual alternative for other source of income in the village.

4.2 Trend of Climate Variability - Rainfall and Temperature Data

4.2.1 Monthly Analysis

Analysis of maximum and minimum temperature data of the study area reveals its highest from March to October whilst they were at their lowest from November to February (see Fig 2). The rainy season occurred mostly in summer starting in March and ending in October. The peak rainfall month was in July and the least amount of rainfall was experienced in winter (November and December).

Fig 2: Average monthly maximum and minimum temperatures and rainfall of the study area over the period of 26 years (1996-2021).



4.3 The trend of annual temperature and rainfall patterns (1996-2021)

Analysis of the climate variability data (e.g. temperature and rainfall patterns) of the past 26 years (1996-2021) revealed thatthe five-year moving average of the annual mean temperature had a decreasing trendover the years (see figure 2), and the change was statistically significant (R^2=0.569). Similarly, the trend of an annual rainfall was slightly increasing (see figure 3), however, the change was insignificant (R^2=0.0052).

Fig 3: Five years of moving average of annual mean temperature (1996-2021)

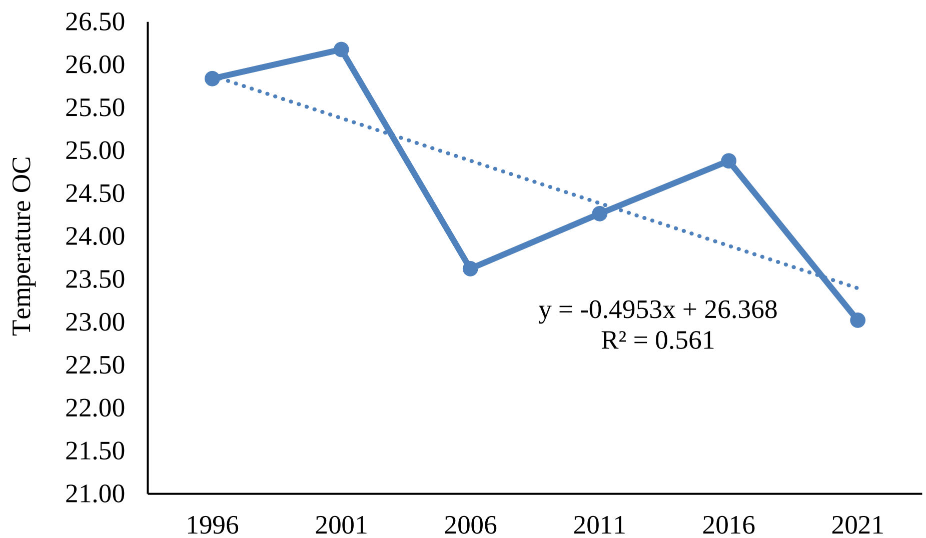
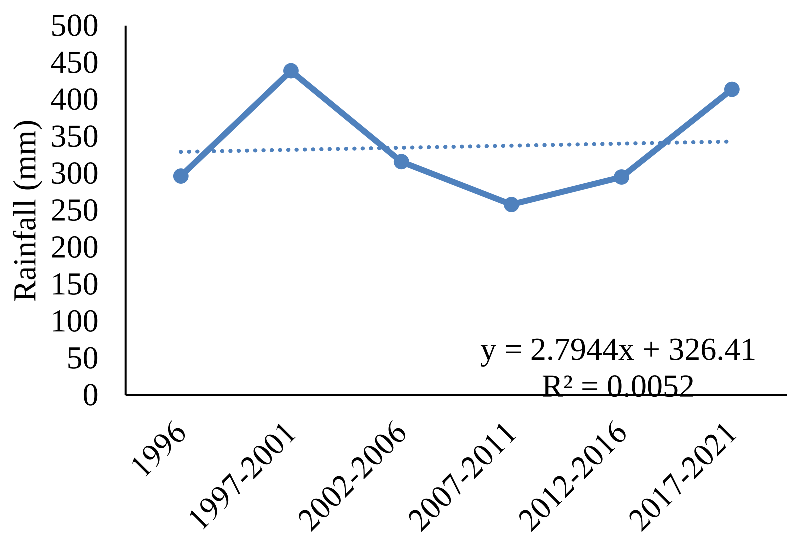


Fig 4: Five years of moving average of annual rainfall (1996-2021)



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4.4 Perception of farmers on impacts of the climate change

The perception of climate change to the farmers at Deling village meant unseasonal and heavy rainfall, drought, and the emergence of pests and diseases. Participant 3 (P3) shared that:

> These days, the weather pattern has changed drastically. We are experiencing extreme cold during winter and hot summer. Rainfall has shifted to the pre-monsoon season or toward the late monsoon season. In winter, we have started receiving frost and snow on nearby mountains. I felt that this could be one reason that brings cold in winter and dry or absence of rain in summer could be one reason for getting warm.

Similarly, P 5 also added:

> The rain has become erratic compared to past years. It rains suddenly without any warning. Before, it takes time to fall, even if there are strong thunders. These days, as soon as the sun is covered by clouds, rain falls like pouring water out of a jar. Indeed, the intensity of rainfall is increasing that causing landslides, soil erosion, flashflood and blocking Farm Feeder Road in the village.

Further P7 articulated,

> In recent years, we are experiencing more rainfall as it is very evident in our village. In 2016, our village witnessed a severe flashflood due to heavy rainfall. It washed away suspension bridge that connects the village and our farms and also damages our agriculture land and crops. Similarly, the temperature is getting warmer every year. Before, there is no fan at home. Now, it is becoming almost mandatory due to more heat.

Similar to farmers' interviews, government officials interview also opined that the impacts of climate change meant heavy rainfall, landslides, disease outbreak, and damage to crops and livestock. Data indicated that "Unseasonal rainfall results in premature falling of fruits, crop desiccation delay, and harvested crops spoilage and deprives the farmers' livelihood. So, it damages maximum in the field", Government Official 1(GO1) from Phuentsholing Gewog.

Consistently, some farmers viewed that plant phenology has changed over the years due to irregular rainfall and increasing temperature. As a consequence, it invites pests and diseases into the field. For instance: participant P6 states that

> Before, there is no disease and pests on crops, and yield used to be good. We need not have to use pesticides, insecticides, or guard the field day in and out in the past, animal or insect pests were very minimum and the weather was good. These days, everything has changed. We faced lots of challenges to protect our crops from pests and diseases.

> Animals such as deer, peacock, bear, monkey, wild bores and birds are the craziest creatures that encroach in the field.

The above findings such as temperature increasing and getting warmer in summer, whilst annual rainfall was also increasing in the recent years were in line with the quantitative findings of this study. For instance, it was evident from quantitative data analysis that revealed temperature reaches a maximum of 31.83, 31.8 and 31.74 ^{O}C during August, June and May respectively. Similarly, the annual rainfall increases from 2016 to 2021

On contrary, a few farmers reported no changes in weather conditions. For example, according to P5, state that "I don't feel changes in temperature and precipitation pattern'. P8 further echoed that they were not aware of the impact imposed by the weather conditions, as they were accessed with climate-resilient seeds and better medical facilities. P8 expressed that,

> We are privileged that the community has access to all the resources necessary to counteract climate change. Through routine vaccination and other clinical guidance to farmers, foot and mouth disease, which was once widespread in the area among cattle, was eradicated. The other is hybrid seeds, which offer disease resistance and high yielding varieties that are advantageous to many farmers. Recently, gewog agriculture extension official also given trainings on land management, grafting and cropping calendar.

Thus, some interviewees were unable to make out the impact and changes levied by climate change

4.5 Impact of climate change on the crop production and livestock

The present study showed that global climate change has affected the livelihoods of farmers in Deling village in different ways. The main source of their daily subsistence in the village was agriculture and livestock production. Specific data analysis reveals the impacts of climate change on crop production and livestock were; growth of new crops and vegetables, an outbreak of pests and diseases, changes in plant phenology and vegetation, rural-urban migration, the emergence of vector-borne diseases, and macro-parasites in animals. A comprehensive analysis of these claims are presented in the following sub-headings:

4.5.1 Outbreak of pests and diseases

All participants reported an increasing in the incidence of pest and disease on their crops. Insect pests such as aphides, army wombs, cutworm, grasshopper, leaf miner, pod bug, whitefly and many other unidentified pests were reported by the majority of respondents. Government Official 1 (GO1) also articulated an incident of a white moth outbreak in a maize field during the shooting stage. It is also called shoot borrowers which affect the fruiting and yield of the plants. Similarly, birds and animals were another larger pests reported by the household. For instance, P1 expressed "this time, we are facing serious challenges of wild animals encroaching to our field such as wild bores, monkey, bear, deer, rabbits and birds". In the researcher's observation, larger bird pests had been recorded throughout the village and were mostly fed on broccoli, cauliflower, spanish, beans, and chili. In addition to Bulbul species, there were other unidentified bird species that damaged green and leafy vegetables.

Fig 3: Broccoli damaged by birds (Bulbul sp) in the field.

4.5.2 Growth of new crops and vegetables

The majority of farmers in the village articulated the effect of climatic change on their farming activities. For example, P5 articulated,

> Before, we use to cultivate few crops such as ginger, cardamom, oranges, beans, spinach, radish, buckwheat, and wheat. I now cultivate many new crops such as tomatoes, cabbage, cauliflowers, watermelon, chili, and many others. These crops I never cultivate before, because it does not suit our place. Now, due to climate change, we experience both warm and cold seasons that fit these crops.

Further, P3 added, "…now I cultivate litchi and areca nut that I never grow before". These results indicated that farmers were also bestowed with the opportunity to grow new crops and vegetables.

Consistently, some farmers also observed phenological changes in plants and crops. For instance, P1 shared that: "These days, it is quite surprising to observe that flowering time of some plants

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has changed. For instance; peach, oranges and many other, it flowers early and also get early mature". Similarly, early maturity of crops was also reported by the GO interviews due to inconsistent precipitation and temperature pattern. However, early maturity of crops was associated with an emergence pest and diseases. For instance, GO1 observed that "early mature crops are mostly attracted by the pests where the probability of disease outbreak is very high". The findings pointed out that early maturity of crops associated with an outbreak of disease.

4.5.3 Rural-Urban migration

The findings revealed that rural-urban migration is the consequences of climate change impacts. According to P3:

> In 2014 to 2016, when the production of cardamom and ginger was good, many educated youths have taken up agriculture as a part of their employment in the village. At the initial phase, most of the youth entrepreneurs were successful and very happy with their work As their annual agricultural production began to decrease each year, they gradually began moving to towns in search of better opportunities. Now, I am the only educated farmer left in the village after graduation.

This finding has been reconciled with quantitative findings that crops production trends have also been declining in the recent years. The following graph showed a recent trend of crop production in the district of study area. The graph depicted a declining trend of maize, cardamom and mandarin's production. The mandarins fruit bearing trees were drastically declined over the 18 years of observed periods. However, ginger production trend was slightly increasing. This indicated the impact of metrological conditions on crop productions, particularly draught, irregular and heavy rainfall and pests.

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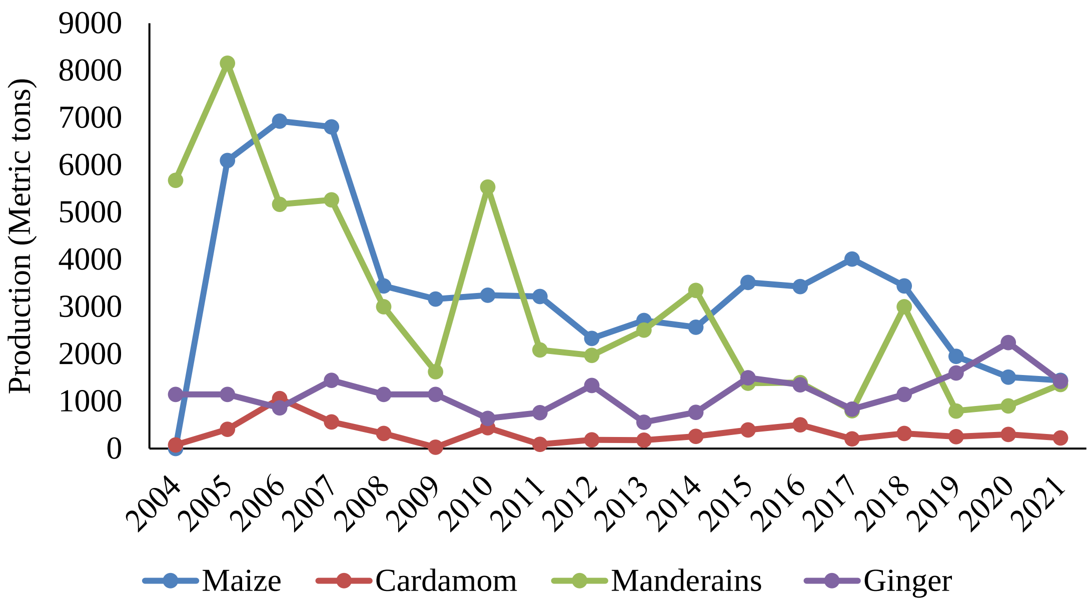
Fig 6: The trend of crop production in metric tons (MTs)



4.5.4 Climate change impact on live stock

Another impact of climate change, in addition to the emergence and spread of new diseases, has been the spread of vector-bone diseases and macro-parasites in animals. Participant's responses also indicated an increase in the populations of some common harmful livestock insects, that include lice, fleas and ticks, which cause cattle to become weak and unhealthy, thereby reducing the production of dairy products. For instance, P5 elucidated: "This irregular rain and rising temperature during summer invites more fleas and ticks that not only affect the health of the animals, it also affects human's health". Similarly, heavy rainfall also reported having caused high mortality in goats and sheep. These findings indicate that impact of climate change is affecting the overall livelihood of farmers at Deling village in different ways.

4.5.5 Correlation between crop production and temperature

Table 1 below shows the Pearson correlation between crop production and the climate variables (temperature and rainfall).

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Table 1: Correlation between crop production and climate variables

	Annual Temperature (1996-2021)		Annual Rainfall (1996-2021)	
Crops	R	p-value	R	p-value
Maize Production (MT)	.245	.328	.503	.033
Cardamom Production (MT)	.243	.330	.384	.115
Mandarins Production (MT)	.232	.354	.399	.101
Ginger Production (MT)	.407	.094	-.140	.580

The Pearson correlation between climate variables and crop productivity displayed a weak positive correlation which is not statistically significant. Overall, the correlation coefficient with annual temperature was 0.282 with p-value greater than 0.05. Correspondingly, the correlation coefficient with annual rainfall was also 0.287 with p-values greater than 0.05.

4.6 Adaptation strategies on agricultural practices

Farmers have employed various strategies to protect their crops from pest, disease, draught and heavy rainfall. For instance, to withstand climate shocks in farming community, some farmers had started using greenhouses to protect vegetables (tomatoes, onion leaves, coriander and lettuce) from frost and heavy rain during summer. Mulches has also been practiced to improve the soil moisture retention, reduce weed intensity, and improve soil fertility mainly for vegetables. They were also adopting hybrid seeds of cereals and vegetables to heighten production." …hybrid seeds are pest and disease resistant, and also gives more yield compared to local variety" P1. Some farmers used pipes as a means of transporting irrigation water, instead of the traditional direct open drainage irrigation sources that are vulnerable to evaporation and damaged from landslides. Cultivation sites or locations have been changed from year to year to reduce disease and pests' incidences and adjust cropping calendar. As there was no treatment for gingers infection reported by farmers, "…even the gewog RNR (Renewable Natural Resources) official informed us to change crop production sites or switch crops so that infection may disappear" P1.

Only limited farmers were trained and their capacities built on various aspects of climate smart agriculture technologies such as Sustainable Land Management (SLM) technology. "…in 2006 or 2007, we have received a week-long training on SLM". They said that project aided them in

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terracing and water source management. They were supplied with fodder trees and grasses to plant at water sources and other sloppy areas to minimize soil erosion during the project tenure. This trend of fodder tree plantation was still observed in the village using shade trees in cardamom growing areas. Similarly, farmers also reported that they were using organic treatment for pest and diseases in the field such as cow urine and wood-ash. "Cow urine has dual benefits. I am using cow urine in ratio, 1:10 (urine: water) for manuring purpose and more concentrated as bio pesticide" P 4. "I neither learned nor trained, instead I heard from other villagers about cow urine as bio-pesticide" further added by P1. Likewise, wood ash was popularly used in the village as nutrient supplement to soil for crops. "Wood ash is also very good for chili…" P7. These indicated that some farmers were using their indigenous knowledge and experiences as an adaptation measures of climate change.

5. DISCUSSION

5.1 The trend of Climate Variability-Rainfall and temperature Data

The findings of this study revealed decreasing trend of annual mean temperature during 1996-2021 On contrary, the climate records showed that **the average annual temperature has significantly increased in South Asia in recent decades (**Intergovernmental Panel on Climate Change [**IPCC], 2021).** The major increases were in western Afghanistan and southwest Pakistan, south-eastern India, western Sri Lanka, northern Pakistan, and eastern Nepal during the same time period (Mani *et al.*, 2018). In Bhutan, the historical records of climate data indicate an increase in annual temperatures (National Center for Hydrology and Meteorology [NCHM], 2019). However, the analysis of data on individual stations showed a decrease in the trend of the average temperature (NCHM, 2019). According to Dobrowski *et al.* (2009), temperature pattern in mountainous regions is complex because of the influence of geographical position, elevation, slope direction, and slope angle. The highly mountainous and broken terrain in the Himalayas causes an extreme variation in climate, making it difficult to adequately measure and analyze the various climate parameters (Lambert & Chitrakar 1989). Similarly, Dorji *et al.* (2022) also supported temperature variability in Bhutan. Therefore, the finding of this study also supports (Dorji *et al.*, 2021; Dobrowski *et al.*, 2009; Lambert & Chitrakar 1989) that the temperature variability may be influenced by geographical factors as stated above.

The trend of annual rainfall was increasing during the period from 1996-2021 with a weak rainfall variability of 0.52%. However, the climate record exhibited both increasing and decreasing trends of rainfall in different parts of Asia with strong variability (Aryal *et al.*, 2020; Suman &Maitay, 2020; IPCC, 2013;). Suman and Maitay (2020) also found that the South Asian region receives more rainfall due to monsoon wind. The increased precipitation in the region often causes floods over many parts of Asia (IPCC, 2021). Similarly, the southern part of

Bhutan often receives high rainfall due to the summer wind blowing from southwest to northeast (De *et al.*, 2005), and as the elevation ascends the precipitation decreases (Dorji *et al.*, 2022).

5.2 The Perception of Farmers on Climate Change Impacts

The perception of climate change to the farmers of Deling village meant unseasonal and heavy rainfall, prolonged drought, and violent wind storm. The farmers' description of climate change is also interpreted as unreliable precipitation pattern, which are prone to the emergence of pests and diseases, and their experiences of drought and increasing temperature. Farmers also identified shifting geographical locations toward the most favorable zones, reduction in agricultural water availability, and flash floods as indicators of climate change.

Similar observations have been reported in various studies about climate change from Bhutan, and Asian countries. For example, in the studies of Chhogyel *et al.* (2020), Suberi *et al.* (2017), Katwal *et al.* (2015), and Lhendup (2012) described the perception of Bhutanese farmers on the impact of climate change as the fluctuation of weather events, and their experiences of draught, unreliable monsoon, the outbreak of pest and disease, rising temperature, and changing precipitation pattern. Similarly, Wangchuk and Wangdi (2018, p. 47), also reported that the annual temperature and climatic pattern has been changing in the country.

In Nepal, more than 80% of households have asserted that climate change has occurred. For instance, Hussain *et al.* (2018) reported that in Nepal, the most common hazards attributed to climate change include droughts and dry spells, followed by increasing livestock diseases, flood events, insect attacks, and crop pests. These phenomena were also Bangladesh and China, where the heat waves during summers were felt to have increased and rainfall to have decreased during the past 5 or 10 years (Shi-Yan *et al.*, 2018; Toan *et al.*, 2014).

The above claims indicate that the farmers have been affected to a large extent due to climate change in recent years. However, it was quite interesting to note that the farmers' perception of climate change was related to its impacts manifested in different ways. Therefore, the farmers are considered as a rich source of information in climate studies (Senbeta, 2009).

5.3 Impacts of climate change on crop production and livestock

In this study, it was observed that climatic change often poses challenges on farmers' livelihood and consequently affects the society's socio-economic activity. The main impacts highlighted by local farmers were growth of new crops and plants, change in crops phenology, the emergence of pests and diseases, and rural-urban migration. In the household interview, farmers also expressed that increasing temperatures and unseasonal rainfall pattern have both positive and negative consequences in farming. Consistent with these results, Wangchuk and Siebert (2012) reported the growth of new plants due to rising temperature in recent years. Similarly, Wangchuk and

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Wangdi (2018) reported that alpine vegetation is growing faster than the normal pace because of warming. Consequently, barren lands are gradually being colonized by plants. This showed that geographical vegetation of lower altitudes is gradually shifting towards higher altitude so that the crops growing in low altitudes are thriving in higher altitudes (International Center for Tropical Agriculture [CIAT], 2017; Lhendup, 2012;). In South Korea, cultivation regions for pears, peaches, grapes, and sweet persimmons have also shifted north, and some areas in the southern region have become unsuitable for cultivating those fruits due to high temperatures (Kim *et al.*, 2013). Some crops such as watermelons, peppers, and tomatoes, grow faster and have better quality, including higher sugar content, as temperatures rise until they reach the growth inhibition limit (35°C) (Cheng, 2002). This indicates that as temperature increases, not only the possibility of growing new crops by the farmers with climate change but they are also challenged by the invasion of unwanted weeds. Suberi *et al.* (2017) and Lhendup (2012) reported the emergence of invasive weeds in the field because of increasing temperatures in the paddy field.

In the last 5 to 10 years, farmers have been reporting high incidence of pests such as aphids, army wombs, cutworms, grasshoppers, leaf miners, pod bugs, whitefly, and many other unidentified pests. In the researcher's observation, these pests were the main causes of crop failures in the village. Alongside, bacterial and fungal diseases on crops and vegetables were reported by the farmers from the study area. Previous studies also found similar levels of pests and diseases in crops, vegetables, and livestock. For example, in 1996, farmers at high-altitudes lost between 80 and 90% of their rice production due to a rice blast epidemic in Bhutan (CIAT, 2017). Likewise, the northern corn blight disease outbreak from 2007 caused maize harvest losses of more than 50% at altitudes above 1800 meters (RNR-statistics, 2015). The citrus industry has been devastated by citrus greening, or the Huanglongbing (HLB) disease since 2003 (Donovan *et al.*, 2011). In the apple orchard in northern Bhutan: woolly aphids, brown rot, collar rots, and apple scab diseases have been reported by Dorji (1999). Lhendup (2012) also reported the incidences of pests such as ants in potatoes, cutworms in cabbage and turnip, trunk borers in rice and wheat, and fruit flies. According to Teshome *et al.* (2021), an increase in temperature and rainfall or climate variability leads to a higher prevalence of pests and diseases on the farm. Consistent with above literature, Richard *et al.* (2013) also noted that incidences of insect pests (stem borer and armyworm) increased as a result of climate change and variability. This may be the change in rainfall and temperature ascribed to favorable conditions created for the proliferation of diseases and pests. Thus, in recent years, the incidences of insect pests and diseases appeared to be on the increase.

Interestingly, bird pests had been a rigorous threat to farmers in the last 5 years in the study area. Particularly Bulbul species and other unidentified granivorous birds had been common pests besides others. Responses from farmers and accompanying field observations also indicated that the population of these bird pests is increasing every year and damaging the crops of farmers to a larger extent than any other animal and insect pests suggesting that birds are becoming an invasive pest throughout the study area and the adaptation measures are crucial to shield against the loss of crop yields. In this context, Thibault *et al.* (2018) mentioned that Bulbul has become an invasive pest that damages crops.

Another finding derived from this study was the change in plant phenology in recent years. For example, farmers of Deling village have reported owing to increasing temperatures and unseasonal precipitation, the flowering season of some crops and vegetables has changed. A similar result was also reported by Suberi *et al.* (2017) that the flowering of some plants has changed due to rising temperatures and erratic rainfall. Similarly, in the study of Chaudhary and Bawa (2011) have reported the emergence of early budburst, early flowering, and early ripening of fruits in plants. This indicates that some plants flower early and mature faster due to climate and weather variability. Such unseasonal rainfall and unexpected surging temperature attribute to plants phenology changes.

It was noted that majority of the respondents claimed the loss of crops yield due to climate change and variability. Congruently, the analysis of Agriculture Statistics report (2004-2021) also indicated declining trend of crop production. The most perceptible climatic factors that affected crop production in the study area were increasing temperatures, pest and disease, insufficient and erratic rainfall as well as variability in the date of onset and cessation of rainfall. The vegetative and reproduction growth of plants is affected when temperature increases, thereby yield of crops decreases (Teshome *et al.*, 2021). Similarly, erratic rainfall, late-onset as well as an early cessation of rainfall resulted in moisture stress and wilting in crops, thereby reducing its yield. Consistent with this result, (Chhogyel *et al.*, 2020; Chhogyel& Kumar, 2018; Suberi *et al.*, 2017) also reported the yield loss due to pest and diseases, and climate variability in Bhutan. India reported yield decrease by 5%, 6–8% and 10–30% in wheat, rice, and maize, respectively (Mathauda *et al.*, 2000; Kalra *et al.*, 2007; Gupta *et al.*, 2017). In Bangladesh, the yield of wheat, and rice were reduced by 60%, and 2.6-13.5% respectively (Basak *et al.*, 2009; Karim *et al.*, 1996). Prasai (2010) and Malla (2008) also reported decreasing trend of rice and maize production with increasing temperature however, positive impacts on wheat yields was recorded. A similar level of yield reduction was also reported in, Pakistan, and Sri Lanka (Agarwal & Sivakumar, 2010; Vidanage&Abeygunawardane, 1994). This showed that farmers in all countries are affected by climate change and climate variability. As a result of low crop production recently due to emerging challenges in the village, finding depicted many youth entrepreneurs are also migrating to urban areas for better opportunities. A similar finding was also reported by Chhogyal *et al.* (2020) that many youths are leaving farming for better

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opportunities. These results collectively deduced that farmers are largely affected by the impact of climate change.

The Pearson correlation between crop yields and climatic factors showed that both rainfall and temperature had correlated with a weak association. From the result, the annual rainfall and temperature were found to be not significantly explaining yield of the crops. Similar findings were also reported from Nepal that annual rainfall and maximum temperature was not significantly explaining the yield of cereals crops (Aryl *et al.*, 2020). There is a strong relationship between the intensity of rainfall and temperature and crop production. In this connection, the past studies observed significant changes in crop production owing to climate variabilities. For example, In Bangladesh, rice production was found decreasing due to the increasing trend of the highest maximum temperature. The decreasing trend of rice production was also ascribed to the flash flood related to heavy rainfall, nor 'wester, Tornados, and early onset of monsoon (Aryl *et al.*, 2020). Similar findings were also evident in India, China, and other neighboring countries where increasing temperature and erratic rainfall damages crop production (Aryal *et al.*, 2020; Rahman *et al.*, 2017).

5.4 The correlation with climate variables (rainfall and temperature)

The Pearson correlation between climate variables and crop productivity displayed a weak positive correlation which is not statistically significant. Overall, the correlation coefficient with annual temperature was 0.282 with p-value greater than 0.05. Correspondingly, the correlation coefficient with annual rainfall was also 0.287 with p-values greater than 0.05. The correlation coefficient between crop yields and climatic factors showed that both rainfall and temperature had correlated with a weak association. From the result, the annual rainfall and temperature were found to be not significantly explaining yield of the crops. Similar findings were also reported from Nepal that annual rainfall and maximum temperature was not significantly explaining the yield of cereals crops (Khanal, 2015). There is a strong relationship between the intensity of rainfall and temperature and crop production. In this connection, the past studies observed significant changes in crop production owing to climate variabilities. For example, In Bangladesh, rice production was found decreasing due to the increasing trend of the highest maximum temperature. The decreasing trend of rice production was also ascribed to the flash flood related to heavy rainfall, nor 'wester, Tornados, and early onset of monsoon (Rimi *et al.*, 2007). Similar findings were also evident in India, China, and other neighboring countries where increasing temperature and erratic rainfall damages crop production (Aryal *et al.*, 2020; Rahman *et al.*, 2017).

The climate data of past 26 years (1996-2021) was projected using the Simple Exponential Smoothing (SES) method. The projection of climate data (temperature and rainfall) was made for

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one scenario from 2022 to 2100. Intriguingly, the climate projection of this study area till the end of this century was constant indicating weak variability. This indicated that, in the absence of extreme climate projection, the likelihood of climate change impact on farmers' livelihood may be minimum, except the erratic rainfall may fetch pest and disease infestation, flash floods, and other phenomenological changes on crops. This information at the lowest level of the farming community is very crucial to develop effective adaptation practices (Senbeta, 2009).

5.5 Adaptation

The study identified seven major climate change adaptation strategies implemented by farmers at village. That includes; (i) greenhouses to protect vegetables (tomatoes, onion leaves, coriander and lettuce) from frost and heavy rain during summer, (ii) Mulches has also been practiced to improve the soil moisture retention, reduce weed intensity, and improve soil fertility mainly for vegetables, (iii) Adopting hybrid seeds of cereals and vegetables to heighten production, (iv) Land management by planting fruit trees and fodder plants, (v) Cow urine as bio-pesticides, (vi) water pipeline for irrigation, and (vii) Wood ash as manure. Interestingly, to sidestep the prevalence of infection in ginger, farmers use to change the sites for cultivation or replace ginger cultivation with other crops to eliminate causative agents from the soil based on their years of experiences.

Consistent with this observation Lhendup (2012), Chhogyel *et al.* (2020) and Suberi *et al.* (2017) also reported similar adaptation practices in Bhutan. According to Suberi *et al.*, (2017), farmers in Wangdue irrigate crops and spray insecticides to overcome the adverse impacts they experienced. Similarly, in Haa, farmers were using their indigenous knowledge to overcome climate change impacts namely cow urine, wood ash, hand weeding, bio-pesticides, and use of farm yard manure. Remarkably, the majority of farmers were also identified as superstitious that astrological significances are considered important while sowing and exchanging seeds in the farm and within the farming communities (Eden, 2021). This shows that farmers are aware of some of the adaptation practices in the study area in the response to climate change impacts.

6. CONCLUSION AND RECOMMENDATION

This study shows that farmers have been impacted to a large extent by climate change in recent years. In recent decades, crop production has also declined in the region. The correlation coefficient between crop yields and climatic factors, however, revealed that temperature and rainfall had only a weak correlation, not significantly affecting crop yield. This may be attributed to the declining trend of crop production. Climate variability, according to farmers interviewed, brought pests and diseases, changes in plant and animal species, the drying up of water sources, and erratic heavy rainfall, resulting in flash floods in communities. Thus, crop production was assumed to have declined over the years. Consequently, many youths also migrated to urban areas for better opportunities due to poor crop yields.

Therefore, the underlying recommendation was made based on this research;

- More exploratory studies on how climate changes will manifest themselves at the lowest level of society are important to identify specific community needs to address climate change impacts.
- Due to ever-changing weather patterns, the growing season of crops has been changing and farmers are often afflicted with their yield loss. Therefore, it is crucial for farmers to be provided with cropping calendars of their respective agroclimatic zones to avoid yield loss due to unseasonal cropping practices.
- Joint awareness campaigns regarding the adoption of different strategies for climate change should be launched in rural areas to increase the awareness level of communities so that small farmers can easily secure their livelihoods.
- High-yielding crop varieties across ecologies are one of the short-term measures to adapt to the impacts of climate change. Varieties that could tolerate both biotic and abiotic stresses, such as drought, heat, diseases, and pests, must be made available and promoted.

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