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Climate change, climatic disasters, and adaptation techniques: learnings from the lowlands of Nepal

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Nepal is experiencing inevitable consequences of changing climate. Rural communities are badly suffering from these implications. Meanwhile, the rural communities are trying to acclimatize through small–scale adaptation efforts. This study aims to analyze changes in temperature and rainfall trends, identify major climatic disasters, and document current adaptation measures being adopted by rural communities. For this study, we randomly selected 220 households from a total of 4,282 Households, and seven key informants for the questionnaire survey within the study area. Meteorological data from the nearest station were used to analyze changes in temperature and rainfall trends. The study revealed that both mean annual maximum and minimum temperature increased by 0.063 °C/year and 0.072° C/year respectively, between 1991 and 2020. Similarly, mean annual rainfall increased by 12.329 mm/year. Floods, droughts, landslides, hailstorms, and forest fires were major climate disasters experienced by the locals. The adverse impact perceived were loss of crop yield, decrease in water availability, an increase of mosquitoes, and a decline in sightings of the birds and waterfowls in the area. Embankment construction along rivers, changing cropping patterns and cultivation time, forest protection, and maintaining home gardens were major adaptation measures being practiced by the locals. We believe the findings of this study will be helpful for policymakers to develop strategies and programs for communities that will promote resilience against climate–induced disasters at a local level in the lowlands of Nepal.

Keywords: Adaptation strategies, impact, landuse change, livelihood, Terai

Climate means the weather averaged over a long period of time (Ihara *et a*l., 2009). Climate change is defined as the significant change in rainfall, temperature, and other climatic parameters observed over time in a specific area (PAN, 2010). It is obvious that climate change has already adversely affected socio–economic sectors, including water resources, agriculture, forestry, human settlements, and ecological system (IPCC, 2001). Despite their negligible contribution to global warming, least developed countries like Nepal are amongst the countries most susceptible to the impacts of climate change due to their limited capacity to deal with them (Manandhar *et al*., 2011). Nepal is recognized as the fourth most climate–vulnerable nation globally and has good reasons to be concerned about climate change (Adhikari *et al.,* 2018; Khanal *et al.,* 2019). Climate change has added additional stress on poor communities in Nepal (Pant, 2012), where the poorest communities are struggling to fulfill their basic needs (Joshi *et al.,* 2010). More than two million Nepalese depend on climate–sensitive sectors like agriculture

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and forestry for their livelihoods, and they have limited capacity to cope with climate change–induced disasters (Garg *et al.,* 2007). Nepal is particularly prone to natural disasters because of its unique geographical location and topography (Gauli & Upadhaya, 2019; WFP, 2009).

Erratic rainfall, flash floods, landslides, and glacial lake outburst floods (GLOFs) impacting the country's food supply are some of the examples of the disasters that have occurred due to changing climatic patterns in Nepal (Karki & Gurung, 2012). Climate change is linked to an increasing prevalence of natural disasters in Nepal, such as droughts, floods, landslides, and hailstorms with large stones (MoAC, 2009). Buildings and infrastructures can be damaged during extreme climatic events such as flooding, while rising temperatures and water scarcity may affect property value by increasing operation costs (Aboulnaga *et al*., 2019). Habitat degradation and loss of native biodiversity are becoming inevitable with the increasing invasion of invasive species (such as *Mikania micrantha*, *Lantana camara*, *Chromolaena odorata*, and *Ageratina adenophora*) and are bound to increase with the future warming climate in Nepal (Lamsal *et al.,* 2017). Another serious threat associated with climate change is the increase in infectious diseases such as Malaria (Dhimal *et al.,* 2014). Climate change impacts are expected to exacerbate poverty in most of the developing countries and create new poverty pockets in countries with increasing inequality in both developed and developing countries (Joshi *et al.,* 2017). IPCC (2007) highlighted that by the year 2050, the number of people suffering from water stress could double (Bates *et al.,* 2008). The vulnerable groups, mainly poor people, would be in a dilemma of economic hardship because of insufficient knowledge of disaster management, low literacy rates, inadequate physical infrastructure, poor forecasting facilities, and unplanned settlement (Dhungana *et al.,* 2018; Dhungana *et al.,* 2020).

Meanwhile, the rural communities are trying to cope with the changing climate. Individual households are adopting various climate change risk combating measures such as rainwater harvesting, mulching, planting date adjustments, farming drought–tolerant crops, and off–farm employment (Paudel *et al.,* 2019). In order to maintain crop yields, farmers are considering changes in traditional practices such as cropping patterns, timing, crop varieties, and using more fertilizers and pesticides (Shrestha & Nepal, 2016). Adaptation to climate change is a bigger priority in many low–income countries like Nepal than climate change mitigation (Baniya *et al.,* 2021). Nevertheless, in disaster–prone areas, early warning systems for extreme climatic events (such as floods and landslides) are crucial for saving lives and properties (Bajracharya *et al.,* 2021; Thapa & Adhikari, 2019).

Especially, the people of the lowlands i.e., the Terai region of Nepal, are highly susceptible to climate change–induced risks, such as floods, droughts, forest fires, and drying of ponds, rivers, and wetlands (MoSTE, 2010). The changes in climate parameters are evident in the Shuklaphanta Municipality area. To date, limited researches related to climate change and climate–induced disasters have been conducted in the area (Maharjan *et al.,* 2011). In this background, this study aims to analyze changes in temperature and rainfall trends, identify major climatic disasters in the study area, and explore adaptation measures practiced by the rural communities. In doing so, this study anticipates establishing a piece of baseline information on changing climate, climatic disasters, and their impact on the local livelihoods. Further, it also anticipates documenting adaptation measures that can be replicated in other similar areas in the country.

Materials and methods

Study area

The study was conducted in the Shuklaphanta Municipality (28° 32' – 29° 28' N and 80° 30' – 80 °33' E) of Kanchanpur district located in Sudurpashchim province of Nepal (Figure 1). We chose Shuklaphanta Municipality for several reasons: i) the municipality is vulnerable to climate change; ii) climate–induced natural disasters are increasing in the municipality (Climate Change, 2019; Nepali Times, 2019); and the municipality is located close to

Shuklaphanta National Park, one of the most prominent biodiversity hotspots. Thus, to reduce the impact of climate change on biodiversity and human lives, it is very important to carry out this study in the area.

Shuklaphanta Municipality covers an area of 162.57 km^2 and comprises a total population of 24,347 living in 4,282 households (CBS, 2011). Topographically, this municipality embraces three regions: Churia hills, Bhabar range, and Terai plain, with an elevation ranging between 160 m–1,528 m. The average annual rainfall of the district is 1,575 mm. The average maximum and minimum temperatures are 43°C and 24°C during summer and 19°C and 2°C during winter (Joshi & Singh, 2010; Pant & Yadav, 2013). The district has hot and humid tropical to sub–tropical climates. Major ethnic groups in the district include Brahmin, Chhetri, Tharu, Dalits, and others.

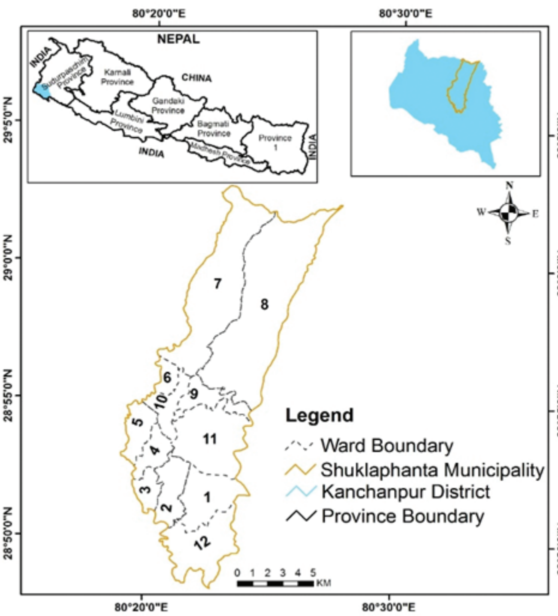

Figure 1: Map showing the study area. Top–left inset shows the location of Kanchanpur district within Nepal. Top–right inset shows the location of Shuklaphanta municipality within the Kanchanpur district

Data collection

The fieldwork was conducted in the months of December 2019 to January 2020. In total, 220 households (HH) were selected randomly for HH survey. HH heads were interviewed wherever applicable, if not available then adult HH members were interviewed. A structured questionnaire was used for the interview, which took 15–20 min per respondent. The three–page questionnaire was divided into five parts. Part A included open–ended questions related to respondents' details and socio–demographic characteristics such as age, name, sex, education, and occupation. Part B included close–ended questions (Yes, No, Don't know and Increasing, Decreasing and Don't know) related to respondents' experience of changes in temperature and precipitation. Part C included close (Increasing, Decreasing and Don't know) and open–ended questions related to respondents' experience of climate–induced impact on agriculture yield, water resources, mosquito prevalence, and birds/waterfowls. Parts D included close (Increasing, Decreasing and Don't know) and open–ended questions related to climate–induced disasters, namely flood, drought, forest fire, hailstorm and landslide, and adaptation measures practiced to adapt to flood, drought, forest fire, and hailstorm.

Farmers, community leaders, local teachers, Community Forest Users Group (CFUG) committee members, ward chairperson, the mayor, and representatives of local non–government organizations were selected through snowball sampling for key informant interviews (KII). Key informants were interviewed to get information about major climatic events and their impacts. Field observation was carried out to validate the information gathered from KII and HH surveys. Climatic data (1991–2020), such as maximum and minimum annual temperature (°C) and rainfall (mm) were obtained from the Department of Hydrology and Meteorology (DHM), Nepal, for the Mahendranagar meteorological station (Index no. 0105). Additionally, published literature relevant to this study was downloaded from Google scholar, and reports from government and non–government organizations were also collected and reviewed. The questionnaire used for the HH surveys, and the Checklists used for KII are provided in Supplemantary material.

Data analysis

Datasheets were reviewed and checked daily for completeness, consistency, and accuracy. After finalizing the data collection, all the data were rechecked, edited, coded, categorized, entered, and analyzed. The linear least–squares curve fitting technique, shown in Equation 1, was used for analyzing changes in mean annual maximum and minimum temperature and mean annual rainfall trends (PAN, 2009). It is the simplest and the most used technique in regression analysis that provides the best–fitting straight line through a set of points (Chakrabarty, 2014). MS Excel version 2013 and SPSS version 23 were used for data analysis.

$y=mx + c$ ………….. Equation 1

where, y is temperature in degrees Celsius (^{o}C) or rainfall in millimeters (mm),

"m" and "c" are the constants estimated by the principle of least squares

As a major part of this study, we explored the valued perceptions of sampled individuals and analyzed their opinions with bar diagrams and tabular forms, in a simplistic way to make them easier to understand. The Chi–square test was used to analyze the association between the socio–demographic characteristics of the respondents and their knowledge of climate change. While using a chi–square test, we have considered only "Yes" and "No" and excluded "Don't Know" response from the analysis.

Results

Socio–demographic characteristics of the respondents

In total, 220 respondents participated in the HH survey. The average age of the respondents was 41 years old, with a median age of 39 years. Majority of the respondents were females (56%). About 77% of the respondents were Brahmin/Chhetri. Similarly, agriculture was the primary occupation of 74% of the respondents. The majority of the respondents (75%) were literate (Table 1).

Table 1. Socio–demographic characteristics of the respondents

Socio–demographic characteristics	Count (%)
Age (years)	
Less than 35	84(38.2)
35–55	98(44.55)
More than 55	38(17.25)
Gender	
Female	124 (56.36)
Male	96 (43.64)
Ethnicity	
Bhramin/Chhetri	169(76.82)
Tharu	22(10.00)
Dalits	19(8.64)
Others	10(4.54)
Occupation	
Agriculture	162(73.63)
Service	16(7.27)
Business	42(19.10)
Education	
Illiterate	55(25.00)
Literate	165 (75.00)
Primary level	78 (35.45)
Secondary level	37(16.82)
Higher Secondary level	28(12.73)
Bachelor's level	17(7.73)
Masters level	5(2.27)

Respondents' knowledge and experience of climate change

Except for gender, every other five variables, ethnicity, age, years of residence, occupation, and education level, were found to have a significant effect on respondents' knowledge and experience of climate change, and hazards (things which cause harm to the people) (Table 2–4).

The results showed that half of the respondents (50%) have knowledge of climate change. A chi–square test of independence was performed to examine the relationship between several socio–demographic characteristics and the respondents' knowledge on climate change (Table 2). Among five variables, ethnicity (p=0.001), age (p=0.001), occupation (p=0.001), and education (p=0.001) were statistically significant to the knowledge of climate change.

Table 2: Contingency table showing the interrelation between different socio–demographic variables and respondents' knowledge of climate change

Socio–demographic Characteristics	Categories	Yes (count)	No (count)	Don't Know (count)	Chi–squared test (p–value)
Ethnicity	Bhramin/Chhetri	95	74	0	0.001
	Tharu	3	19	0	
	Dalit	5	14	0	
	Others	7	3	0	
Gender	Female	58	66	0	0.276
	Male	52	44	0	
Age	Less than 35	63	21	0	0.001
	35–55	39	59	0	
	More than 55	30	8	0	
Occupation	Agriculture	55	107	0	0.001
	Services	39	3	0	
	Business	16	0	0	
Education	Illiterate	3	52	0	0.001
	Primary	35	43	0	
	Secondary	24	13	0	
	Higher Secondary	26	2	0	
	Bachelor	17	0	0	
	Master	5	0	0	

One–fourth (26%) of the respondents have feelings about any climate pattern change. The contingency table indicates that except for gender, all other variables such as ethnicity (p=0.001), age (p=0.001), occupation (p=0.001), and education (p=0.001) were statistically significant to the experience with climate change (Table 3).

Table 3: Contingency table showing the interrelation between different socio–demographic variables and respondents' experience with climate change

Socio–demographic Characteristics	Categories	Yes (count)	No (count)	Don't Know (count)	Chi–squared test (p–value)
Ethnicity	Bhramin/Chhetri	49	79	41	0.003
	Dalit	2	16	1	
	Tharu	2	19	1	
	Others	5	3	2	
Gender	Female	29	71	24	0.178
	Male	29	46	21	
Age	Less than 35	32	30	22	0.001
	35–55	20	57	21	
	More than 55	6	30	2	
Occupation	Agriculture	21	114	27	0.001
	Services	26	3	13	
	Business	11	0	5	
Education	Illiterate	2	52	1	0.001
	Primary	21	44	13	
	Secondary	6	17	14	
	Higher Secondary	11	4	13	
	Bachelor	13	0	4	
	Master	5	0	0	

More than one–third (36%) of the respondents understand that increasing climatic hazards have been the last 30 years. A chi–square test shows that except gender, other variables such as ethnicity, age, occupation, and education were statistically significant to the understanding of increase of climatic hazards over 30 years (Table 4).

Table 4: Contingency table showing the interrelation between different socio–demographic variables and respondents' understanding of natural hazards increase due to climate change

Socio–demographic Characteristics	Categories	Yes (count)	No (count)	Don't Know (count)	Chi–squared test (p–value)
Ethnicity	Bhramin/Chhetri	64	65	40	0.076
	Dalit	6	12	1	
	Tharu	5	16	1	
	Others	5	3	2	
Gender	Female	42	59	23	
	Male	38	37	21	0.2314
Age	Less than 35	43	19	22	0.001
	35–55	27	51	20	
	More than 55	10	26	2	
Occupation	Agriculture	41	94	27	0.001
	Services	28	2	12	
	Business	11	0	5	
Education	Illiterate	11	43	1	0.001
	Primary	27	38	13	
	Secondary	10	13	14	
	Higher Secondary	13	2	13	
	Bachelor	14	0	3	
	Master	5	0	0	

Temperature trend

The study showed that the mean annual maximum temperature increased at the rate of 0.063°C/year between 1990 and 2020 (Figure 2). The average annual maximum temperature for the past 30 years was found to be 30.88 °C. The year 2008 was recorded to be the hottest year, with a mean annual maximum temperature of 34 °C (Figure 2). Also, there is an increasing trend in the mean annual minimum temperature (0.072 °C/year; Figure 3). The average annual minimum temperature for the past 30 years was found to be 17.28 °C. The lowest mean annual minimum temperature (14.5 °C) was recorded in 1997 (Figure 3).

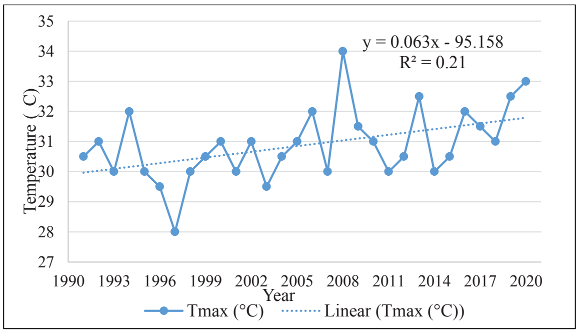

Figure 2: Mean annual maximum temperature trend

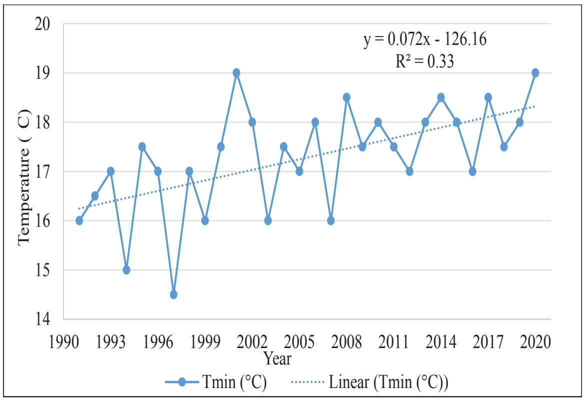

Figure 3: Mean annual minimum temperature trend

Rainfall trend

The study revealed that annual rainfall increased at the rate of 12.329 mm/year between 1990 and 2020 (Figure 4). The average annual rainfall for the past 30 years was found to be 1863 mm/year. The annual rainfall was the highest (2540 mm) in the year 2007 and the lowest (1150 mm) in the year 2006 (Figure 4).

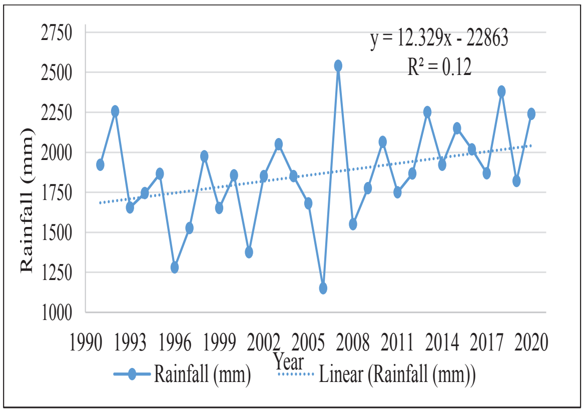

Figure 4: Annual rainfall trend

Respondents' perception of climate change

Seventy percent of the respondents reported that the temperature is increasing, 20% reported that it is decreasing, and the remaining 10% had no clue about the change in temperature. Likewise, 28% of the respondents reported that rainfall is increasing, 60% reported that it is decreasing, and the remaining 12% had no clue about the change in rainfall (Figure 5).

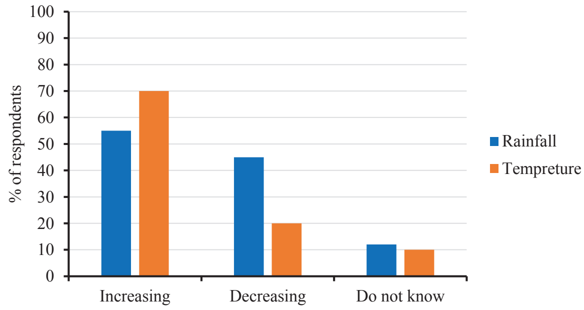

Figure 5: Perception towards changing rainfall and temperature in the area

Climate–induced disasters and their impacts

The chronology of the climate–induced disasters together with their impacts in and around the study area, is presented in Table 5. There was no measurement system or systematic documentation of disasters and their impacts in the study area. The key informants were asked to recall climate–induced disasters and the impacts that they had experienced. Flood, droughts, and hailstorms were the major climate–induced disasters experienced by the people of the study area.

Table 5: Timeline of climate–induced disasters and their impacts

Year	Climate–induced disasters	Effects
1995	Cold wave and winter rain	Caused blight outbreak and damaged tomato and potato crops.
2002	Prolonged drought	Farmers could not plant winter and early crops, which affected subsistence living.
2002	Malaria outbreak	Kanchanpur is a malaria–endemic district (NHRC, 2007), and many died because of the outbreak.
2004	Rain deficit	Crop production decreased by 12.5% on a national basis (NHRC, 2007)
2008	Mahakali River flood	Ten persons died, and damaged 5,500 houses in ward number 2, 11, 12, and 15 of the former Mahendranagar Municipality (MOHA, 2009)
2013	Hailstorm	An intense hailstorm of less than half an hour completely damaged crops in the wards of the study area.
2018	Cold waves and thick fog	Schools in the Kanchanpur district were closed for a few days.

Impacts of climate change

Based on the perceived impacts, local people perceived a decrease in crop production, water availability, forest area, and birds/waterfowl, but they expressed mosquito number has been increased compared to a previous time.

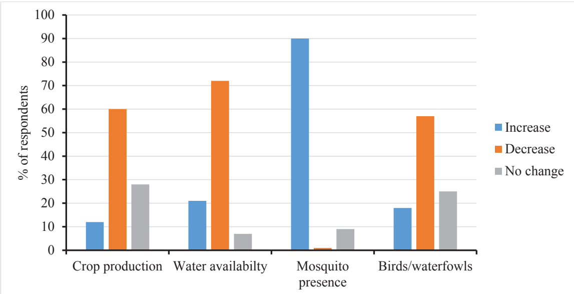

Figure 6: Locals' perception towards the impact of climate change

The impacts of climate change on various sectors are discussed separately in the following paragraphs.

Agriculture yield: Most of the respondents (60%) (Figure 6) claimed that agricultural production (main crops: paddy and wheat) has reduced. Among them, 12% of the respondents reported that production of paddy and wheat has increased slightly whereas the remaining 28% claimed that they did not perceive any change. While interviewing about agricultural productivity during the field study, local people reported that together with main crops such as paddy and wheat, other crops such as sugarcane and mustard production have also dropped in recent years.

Water resources: About 72% of the respondents (Figure 6) reported that water sources were drying up (decrease in the quantity of water quantity in hand pumps and borings) and abandoned their use (Figure 7). In contrast, 21% of the respondents reported that water resources are increasing, and the remaining 7% reported they do not know about changes in water resources.

Mosquito presence: About 91% of the respondents (Figure 6) claimed that the number of mosquitoes had increased considerably in the Suklaphanta Municipality.

Figure 7: Abandoned dried–up spring (left) and dried water boring (right) in Shuklaphanta municipality–8

Birds and waterfowls: Majority (57%) of the respondents (Figure 6) claimed that the bird population has decreased in the study area. According to them, habitats of the birds are shrinking due to decline in forest area and water entities because of increase in climate–induced disasters (such as fires and droughts).

Locals' perception of climate change–related disasters:

The disastrous events such as floods, drought, forest fire and hailstorms are found increasing in the area (Figure 8). According to respondents, the main disasters are floods followed by drought. Most of (70%) of the respondents agreed that flood occurrences are increasing, 20% said decreasing and 10% expressed do not know. For drought, 60% of respondents agreed that drought is increasing. Similarly, 49% said forest fires are increasing and 45% agreed that hail storming events are increasing in the area.

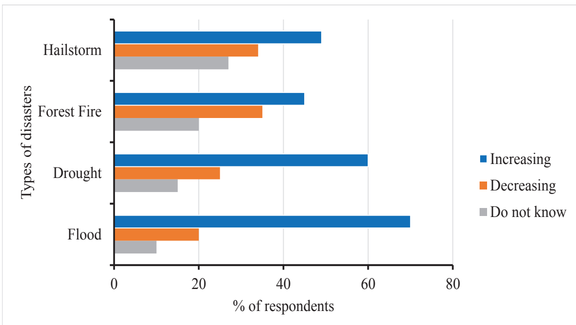

Figure 8: Locals' perception on climate–induced disaster occurrences

Adaptation measures practiced by local communities

Further, the analysis of KII and HH surveys revealed that those local communities are practicing adaptation measures at both community and individual levels. *Shayali* and *Sunbara* rivers are two main streams flowing in the study area gets huge volume of water flow during torrential rains in monsoon season, resulting in flood and waterlogging, so local people have constructed embankment along the river with the governmental support. Locally available stones and bags filled with pebbles and gravels were used to construct such embankment. Respondents shared embankments and plantations along streambanks have been helpful in controlling erosion hazards and agricultural land cutting to some extent. People were found constructing deeper borings for drought management than in the past to extract more water for daily use. Respondents reported that seed sowing, planting, and harvesting time for rice, wheat, and maize had shifted two to three weeks earlier in comparison to 30 years back. The respondents have switched to cash crops like vegetables, fruits, etc., because the productivity of traditional crops has been decreasing in recent years. Community forests in the study area are supporting locals to protect and conserve their forests. In addition, respondents have also started planting trees, including fruit trees and fodder/fuelwood trees, in their home gardens. They expressed that the installation of ICS has been helpful in adaptation as well as mitigation of climate change as ICSs use less fuelwood and produce less smoke compared to traditional stoves.

Major adaptation measures being practiced by local communities are summarized in Table 6.

Table 6: Climate–induced disasters, common effects, and practiced adaptation measures

Disasters	Perceived effects	Adaptation measures
Flooding	Damage to crops especially paddy fields, loss of life and livestock, Destruction of the riverbanks, wooden houses and roads, Soil erosion	Embankment of rivers and streams, plantation of trees, and constructing raised shed houses
Drought	Crop yield reduced, less water for household use and irrigation purpose, Handpump drying	Pipeline from a far distance, Irrigation canal sharing with neighbors, Deep boring, drought–tolerant species
Hailstorms	loss and damage of major crops and vegetables	Plastic tunnel, crop diversification with agroforestry
Forest fires	Reduced fuelwood for cooking, and unavailability for cattle	Forest watcher provision and awareness campaigns, recently the installation of Improved cooking stoves (ICS) which needs less fuelwood

Discussion

Changes in temperature and rainfall trend

This study found that the mean annual maximum temperature is increasing at the rate of 0.063°C/year (Figure 2), which is comparable to the national average of 0.06°C/year between 1977 and 2000 reported by Sharma *et al.* (2009). Similarly, we also found that the mean annual minimum temperature is increasing at the rate of 0.072°C/year (Figure 3). Thapa *et al.* (2015) reported an annual increment of 0.03 °C/year and 0.05 °C/year for mean annual maximum and minimum temperature respectively, between 1982 and 2011 for the Kailali district, the district adjoins the study district, which is slightly lower than what we found. We found that annual rainfall is increasing at the rate of 12.329 mm/year, which is in line with the results of Chhetri (2012). An increase in temperature and decrease in rainfall leads to drought (Gautam *et al*. 2020), but for the study increase in both the temperature and rainfall has been observed. Shrestha *et al.* (2000) found that the monsoon rainfall shows great inter–annual variability. Such variability in the rainfall is likely to have an impact on agriculture, ultimately affecting the peoples' livelihoods. There is an agreement between climate data and local's perceptions of mean annual temperature and rainfall. In cases of temperature, more than 70% of the respondents perceive an increase in temperature and, there is an increasing mean annual maximum temperature and mean annual minimum temperature (Figure 2 & 3). Local perceived irregularities in rainfall pattern with overall increase in rainfall which is similar to the increasing trend of mean annual rainfall shown by the recorded data (Figure 4).

Impacts of climate change

The study found that agriculture, water resources, mosquito numbers, and birds/waterfowls are the sectors being affected by climate change. Short–term droughts, unpredictable rainfall, a decrease in the water table, and an increase in evapotranspiration have mostly affected the agriculture sector in Nepal (Sharma *et al.,* 2018). Chhetri (2012) found that the number of crops per year has been reduced from three to two crops per year. Due to climate change, water resources have been decreased (Ghimire *et al.,* 2019). Diseases like Malaria and allergies, and itching are increasing with the changing climate (Blayneh *et al.,* 2009) and are affecting human health. Increment in mosquito numbers has been identified to be the main reason behind an increase in Malaria spread (WHO, 2009). The respondents reported that because of the rising temperature, mosquito number is increasing in the study area. An increase in the drought period has led to an increase in the incidence of fire, resulting into the decrease in a number of birds not only in the area but also across the country (GoN, 2011; GoN, 2014). Dahal (2009) suggested that some native tree species such as *Shorea robusta, Dalbergia sissoo, Terminalia tomentosa, Acacia catechu, and Bombax ceiba* are decreasing due to climate change. Baral (2009) reported that human properties like houses, sheds, and agricultural lands are mostly being destructed by weather–related disasters like landslides and flooding and the situation is not different in the study area. This suggests that changing climate has serious impacts on the livelihood assets of rural communities (MoFE, 2019).

Adaptation measures practiced by local communities

This study revealed found that local communities are practicing adaptation measures at both community and individual levels. Major adaptation measures being practiced by local communities are embankment construction along the river, deeper borings, change in crop planting time, change in types of crops, plantation of trees in the home garden, and installation of ICS. Such practices have also been observed in other parts of the country (Tiwari *et al.,* 2010). The study found that locals are using locally available materials like stones and bags filled to construct embankments. They are also planting multipurpose tree species along the embankments to reinforce them. Such tree plantations not only re–strengthen the embankments but also provide additional benefits such as carbon sequestration, greenery promotion, fuelwood production, and ecological balance (Pandey, 2016), which in turn helps local communities in recovering from climate change impacts (Udayashankara *et al.,* 2016). Kattel & Nepal (2022) reported that local people are practicing rainwater harvesting techniques and the establishing conservation ponds to adapt to water scarcity. Nepal disaster report showed that rainfall pattern is changing, and drought periods are increasing throughout the country (GoN/MoHA, 2019). Local communities are using harvested rainwater and water stored in conservation ponds for crop plantation (MoHA, 2009). However, in our case, local communities are using irrigation canals to irrigate their agricultural lands. To address the issue of declining agricultural production, local communities have introduced hybrids (e.g., Gorakhnath, US–312) and improved varieties (e.g., Shanti, Ramdhan, Sarju) of rice crops, which is in line with the finding that the hybrid seeds are replacing the local varieties (Khanal & Kattel, 2017; Khanal *et al.,* 2019). Forests and trees, when sustainably managed, can play an important role in climate change mitigation and adaptation as they help in reducing drought, increasing rainfall, and maintaining rainfall time (FAO, 2007). Indeed, the community forests in the study area are supporting local communities to protect and conserve forests. In addition, respondents have also started planting trees, including fruit trees and fodder/fuelwood trees, in their home gardens. Local communities are switching to improved cooking stoves (ICS), which is helping them to reduce greenhouse gas emissions, avoid adverse health effects of indoor air pollution, and also improve forest conservation (Anenberg *et al.,* 2013).

Conclusion

The findings of the study provide a basis for preparing a community–level adaptation plan for climate change since results from the study cannot be generalized to a larger scale. The impact of climate change at the local level should be understood in order to prepare local communities for the implementation of adaptation and mitigation measures. Furthermore, documenting the perceived impacts of climate change and the countermeasures taken can help in the decision–making process for climate change mitigation. Our study shows that people residing in the study area experienced an increase in both average annual rainfall and mean temperature. However, the perception of climate change may differ based on the socio–demographic characteristics of the local people. Similarly, the recoded data of the study areas have unsurprisingly supported the perception of local people. The data shows that the mean annual minimum and the maximum temperature have increased from 1990 to 2020. The yearly rainfall fluctuates from high to low, with alternative years showing variation in the amount of rainfall. Farmers have experienced climatic disasters, mostly floods and droughts, that had negatively impacted their livelihood options in terms of agricultural production, and water availability.

To reduce the impacts of climate change, the study shows that local people have accommodated several adaptation measures. The adaptation strategies such as rescheduling the cropping time, planting trees in their home gardens, constructing embankments along streams, and installing ICS systems. Though this research examined changes in rainfall, and temperature and gathered local perceptions, the exact quantification of socio–economic losses resulting from changing climate was not possible due to a lack of baseline data. Comprehensive research should be done to determine the impact of climate change on diverse sectors, such as agriculture, biodiversity, disasters, and local livelihoods, to recommend specific solutions accordingly. Communities should be involved in developing plans that take traditional knowledge and combine it with scientific solutions to curb climate change disasters and increase climate resilience.

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