ACADEMIC AURORA, 2026, Vol. 1, 41-60
A double-blind, Peer-reviewed, Open-Access Research Journal Indexed in NepJOL

Tri-Chandra Multiple Campus, Tribhuvan University, Nepal

ISSN: 3149-7527 (Print)
ISSN: 3149-7535 (Online)

Impact of Climate Change and Integrated Approach to Adaptation Strategies – A Case Study of Nuwakot District, Nepal

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Received: 25 November 2025; Accepted: 23 May 2026; Published: 15 July 2026

Abstract

Climate change is an inevitable challenge to agriculture. In this paper we intend to gain insights into perceptions of climate change, its impacts, and the adaptation strategies adopted by the farming community in Nuwakot District. The study integrates (i) annual climate indicators for 1976-2019, (ii) yield for major cereal crops (paddy, maize, wheat, millet, barley) for fiscal years 2004/05–2014/15, and (iii) qualitative information from household surveys, field observations, and group discussions conducted in 2020 to assess perceptions of farmers on climate change, perceived impacts, and adaptation responses in Nuwakot District. The climatic trends were analysed using ordinary least squares regression and the Mann–Kendall test with Sen's slope estimator and additionally, sub-period analyses (1976–1999 and 2000–2019) were used to identify shifts in hydro-climatic behaviour in Nuwakot District. The annual mean maximum, minimum, and derived mean temperatures increased by 1.06, 0.91, and 0.99 °C per decade, respectively (Mann–Kendall $p < 0.001$). Rainfall exhibited no significant monotonic trend over 1976–2019, but sub-period analysis indicated increasing rainfall in 1976–1999 (+16.98 mm/month per decade; $p = 0.03$) and declining rainfall after 2000, alongside decreasing relative humidity in 2000–2019 (−4.19% per decade; $p = 0.001$). The crop yields increased over 2004/05–2014/15, particularly paddy (+179.1 kg/ha/year; $p = 0.0003$) and maize (+126.8 kg/ha/year; $p = 0.0019$). The farmers perceived fewer rainy days, higher rainfall intensity, drying water sources, rising pest pressure, invasive plant spread, and irregular flowering/fruiting, and responded through an integrated set of measures: water harvesting and efficient irrigation (ponds, drip), microclimate protection (tunnels), improved varieties and cropping shifts, and organic soil enhancements (compost/vermicompost). These findings indicate rapid warming and changing hydro-climatic conditions. In the meantime, the study highlights locally grounded, practical adaptations that aid targeted support, especially for water security to strengthen climate-resilient agriculture in the mid-hills of Nepal.

Keywords: *adaptation, climate trends, farmer perception, Nuwakot*

Introduction

Climate change, a global concern, is rapidly advancing and is a widespread threat to humanity (IPCC, 2022). Consensus among scientists worldwide is that global warming is real and currently occurring, with evidence supporting the trend (Chaudhary and Aryal, 2009). The global average surface temperature is in increasing trend. It has increased by about 0.6°C during the twentieth century (Houghton et al., 2001). The trendline for air temperature near the Earth's surface has increased by 0.74°C from 1906 to 2009. This is further estimated to increase by as much as 6.4°C on average by the end of 21st century (Solomon, et al., 2007). The temperature increase in the 20th century was greater than in any other century over the past 1000s years (IPCC, 2001). The 1990s was the warmest decade of the millennium, and 1998 was the warmest year on record (Houghton et al., 2001). Temperature is a reliable indicator of climate change (Shrestha et al., 2000) however, precipitation is equally important for monitoring global change, particularly in low and mid-latitude regions, due to their vulnerability to both water scarcity and quality (Milani and Kidd, 2023).

The hydrological system involves the circulation of water from the ocean to the air and back to the ocean. It is an integral part of the global climate system (Critchfield, 1983; Xiong and Yang, 2025). Therefore, any changes in the climate system not only cause changes in the hydrological system but also further alter the climate itself due to these new changes in the hydrological system (IPCC, 2021).

Studies suggest that developing countries are more vulnerable to climate change. These are expected to suffer more from adverse climatic impacts than developed countries (Adom, 2024; Mirza, 2003). In a humid climate like Nepal, changes in the spatial and temporal distribution of temperature and precipitation due to climate change will likely increase both the intensity and frequency of extreme events like droughts and floods (Sharma et al., 2020).

The impacts of climate change on agriculture are multifaceted. These are both direct and indirect, positive and negative (Bhattacharyya et al., 2020). A rise in temperature and spatial changes in rainfall patterns have direct impacts, while disturbances in water resources for irrigation and incidences of pests and diseases are indirect impacts of climate change on agriculture (Neelin et al., 2022; Younger, 2024). Nepal has been suffering from uncertain climatic patterns such as heat stress, longer dry seasons, and erratic rainfall with hailstorms (Chaudhary and Aryal, 2009), since 64% of the land area is fully dependent on monsoon rainfall (CBS, 2006). Agriculture requires much water for irrigation, and worldwide, 70% of the water is used by the agriculture sector (Konar et al., 2011).

Thus, changes in climatic patterns can have significant impacts on agriculture and food security. It's merely because of plant diseases and pests (FAO, 2007). Climate change has affected the agricultural sector in developing countries, leading to serious consequences related to food production and food security, with larger impacts on small-holder farmers and the poor (FAO, 2007; Mendelsohn, 2008; Onyeaka et al., 2024). However, Indigenous and traditional knowledge (ITK) has been proven as a powerful tool and a social capital in many countries of Asia and the Pacific to adapt climate change (Dorji et al., 2024). ITK is dynamic as people continue to generate new local knowledge with various coping strategies. Indigenous and traditional coping strategies resemble scientific methods in their reliance on systematic observation of natural phenomena. Indeed, many Indigenous and traditional coping strategies, which were once considered primitive and misguided, are now seen as appropriate and sophisticated. In this study, we documented traditionl knowledge as a practical knowledge system expressed through on-farm decisions and community actions. Nepal, being agricultural country with most of the arable land depends on rainwater, is vulnerable to climate change (Kattel and Nepal, 2022). Changing climatic conditions cause reductions in soil moisture, as well as thermal and water stress (Oishy et al., 2025).

Thus, this study has quantified the trend of climatic data and simultaneously explore crop production and adaptation strategies adopted by the farming community in the Nuwakot District.

Materials and methods

Study area

This study was conducted in two municipalities (Bidur – 4, Belkothgadhi – 1) and one rural municipality (Tarkeshwor – 2) of Nuwakot District, Nepal **(Figure 1)**. Nuwakot borders Dhading, Kathmandu, Rasuwa, and Sindhupalchok districts, covering an area of 1,121 km^2. The study area is predominantly mid-hill (83.3%), with an elevation ranging from 415-2057 m above sea level. With this vast range of altitudinal difference, the climate is subtropical to temperate, with summer temperatures exceeding 32°C and winter temperatures dropping below freezing point. This region receives an average annual rainfall of approximately 184.54 cm, primarily during the monsoon season. The two major rivers, Trishuli and Tadi with lakes Suryakunda and Sagarkunda serves as main sources of drinking water and irrigation the in area.

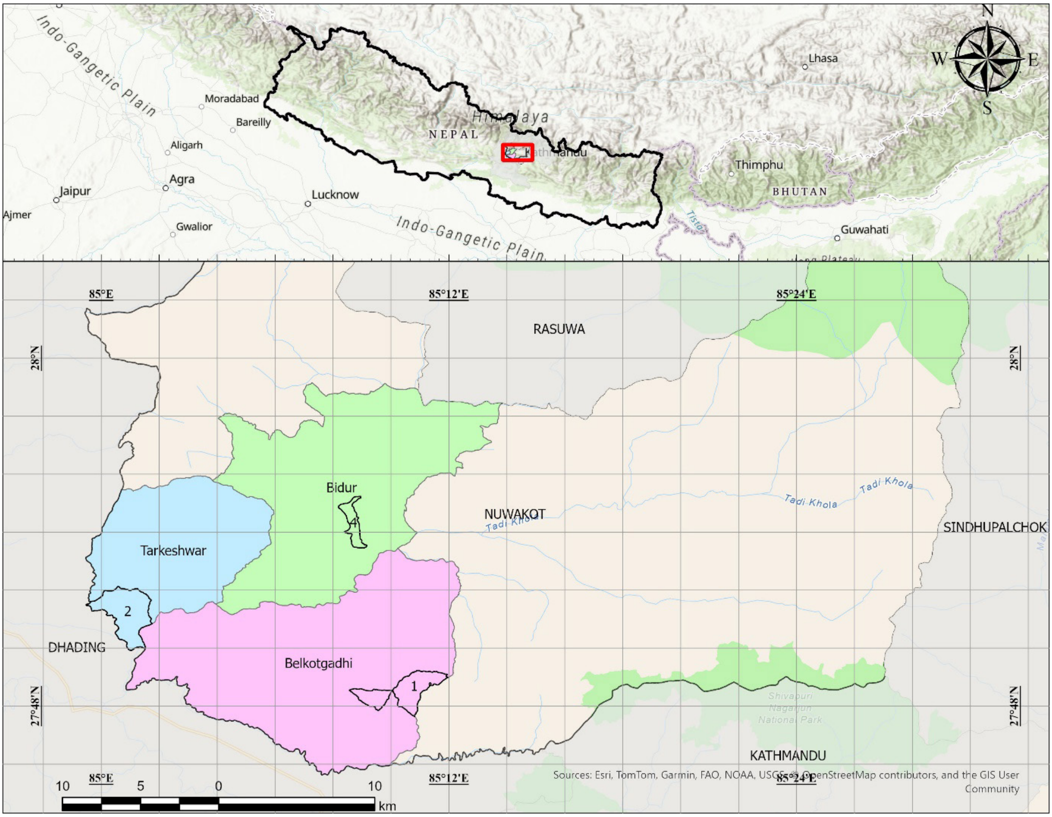

Figure 1. *Map of Nuwakot District showing three local levels and their respective wards where the study was conducted.*

Nuwakot's economy is largely dependent on agriculture due to its hilly terrain. The district also hosts two operational hydropower stations – Trishuli Hydropower-A (21 MW) and Devighat Hydropower (14.1 MW), which significantly contribute to the local electricity supply.

Research methods

The data collection method combines primary and secondary datasets to ensure comprehensive understanding of the research objectives. The primary data was collected through field observations and household surveys. Field observations were conducted to document and verify the adaptation practices of local people in response to the impacts of climate change on agriculture.

A household survey was carried out using semi-structured questionnaires, which included both open-ended and closed-ended questions to 70 households. The sample size was determined statistically by using the finite-population sample-size formula for a proportion (Arkin and Colton, 1963) at 5% of error limit.

$$Sample\ size\ (n) = \frac{\mathrm{N} \times Z^2 \times \mathrm{P}\,(1-\mathrm{P})}{(\mathrm{N} \times d^2 + Z^2 \times \mathrm{P}\,(1-\mathrm{P}))}$$

Where,

N = Total number of households (1941)

z = value of standard variation at 95% confidence level

P = estimated population proportion (0.05), as we limited questionnaire survey to people above 40-year age

d = error limit of 5% (0.05)

Thus, the computed sample size was approximately 70.

The survey was conducted using stratified random sampling based on spatial distribution of the study area. The sample size for each study site was determined proportionally based on the total number of households in each area. The sample size for each stratum was allocated proportionally to the number of households in that stratum.

$$n_i = n \times \frac{N_i}{N}$$

Where n_i is the sample size for site *i*, N_i is the total number of households in site *i*, N is the total households across all three sites, and n is the total sample size (70). The distribution of sample households was as follows: Bidur Municipality with 40 households (57%), Belkotgadhi Municipality with 12 households (17%), and Tarkeshwor Rural Municipality with 18 households (26%). The survey targeted household owners aged above 45 years, because the study focuses on multi-decadal climate change experience and respondents of this age group are more likely to have long-term experience of local weather pattern and farming conditions. This age group is also more likely to be directly involved in farm management decisions (cropping calendar, irrigation investment, varietal choice), which helps improve the relevance of responses for documenting adaptation strategies.

To complement the primary data, secondary data was accrued from various sources to analyse the impact of climate change and adaptation practices in agriculture in Nuwakot District. The data on temperature, rainfall, and relative humidity (1976-2019) – three stations (Kakani, Nuwakot, and Pansayakhola) was obtained from Department of Hydrology and Meteorology (DHM), Government of Nepal, to visualise and understand the climatic trends and variation in the study area. The information on agricultural productivity was sourced from Ministry of Agriculture and Livestock Development (MoALD), Government of Nepal, and District Agriculture Office (DAO), Nuwakot.

Data Analysis

The qualitative data from the observation and survey were integrated with the secondary data on climate variables and agricultural productivity to analyse the impact of climate change in agriculture, and effectiveness of adaptation practices in the study area.

First, the climatic data was validated with range of the climatic variables, missing values, and outliers to prevent errors in the analysis using R (Posit Team, 2025; R Core Team, 2025). The missing and NA values were imputed with the monthly average value using *dplyr* package (Wickham et al., 2023). The data were annually averaged using *lubridate* package (Grolemund and Wickham, 2011). Thus, annual climate variables (mean monthly rainfall, annual mean maximum temperature, annual mean minimum temperature, and annual averaged relative humidity) were compiled for 1976-2019 and sorted chronologically. The derived annual mean temperature was calculated as the average of annual mean maximum and minimum temperatures.

The long-term trends of climatic variables were quantified using two approaches: first, using ordinary least squares (OLS) linear regression to estimate rate of change (slope) of each variable per year and per decade. Second, using non-parametric Mann-Kendall test with Sen's slope estimator for trend magnitude to correct the analysis from non-normal data, outliers, and monotonic trends. To quantify the direction or magnitude of changes differed between earlier and recent decades, we additionally divided the data into two sub-periods (1976-1999 and 2000-2019) to identify potential shifts that might not be visible in full period of trend analysis.

Because district-average yields (kg/ha) for paddy, maize, wheat, millet, and barley were available for fiscal years 2004/5 to 2014/15 only, we used the annual climate series data for 2004-2014 (using the fiscal year start as the year of production). However, we did not run any statistical model to explore relationship between climate variables and crop yield.

Results and discussion

Average temperature and rainfall data for the period 1976-2019

The long-term trend analysis of climate data indicates a consistent warming signal in Nuwakot. The annual mean maximum temperature increased by 1.06 °C per decade, annual mean minimum temperature increased by 0.91 °C per decade and derived mean temperature is increased by 0.99 °C per decade **(Figure 2c, 2d, 2e)**. The non-parametric Mann-Kendall test with Sen's slope gives similar results (T_{max} 1.03 °C/decade; T_{min} 0.85 °C/decade; T_{mean} 0.93 °C/decade; all $p < 0.001$) which supports the direction and strength of trends.

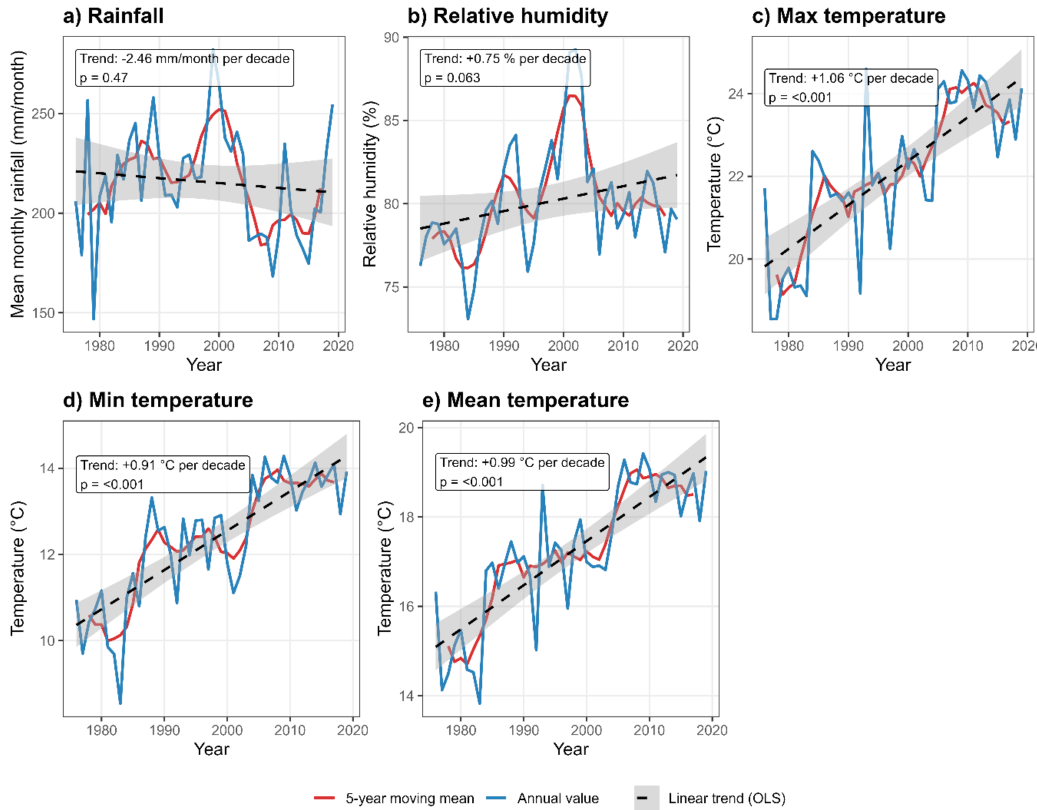

Figure 2. *Annual climate series for Nuwakot (1976–2019): mean monthly rainfall, T_{max}, T_{min}, mean temperature, and relative humidity.*

Over the four decades (1976-2019), the mean monthly rainfall shows no significant monotonic changes **(Figure 2a)**, however the relative humidity shows a slight increase in overall (0.75% per decade) **(Figure 2b)**.

These findings are consistent with the wider evidence in the Himalayan region, warming-related extremes are increasing across Asia (Shrestha et al., 1999). The respondents also reported that they have been experiencing hotter and colder days in summer and winter months, intense rainfall of shorter duration with hailstorm and decrease in rainy days, water deficit, spread of invasive plant species, increase of pest and crop diseases have caused difficulty in major food crop production.

Sub-period pattern analysis

We also did a pattern analysis in hydro-climatic behaviour for two durations: 1976-

1999 and 2000-2019. The mean monthly rainfall increased during 1976-1999 (16.98 mm/month per decade, $p = 0.03$), while this declined during 2000-2019. The temperature in both sub-periods increased with continued warming after 2000 (mean temperature = 0.86 °C per decade, $p = 0.007$). The relative humidity increased from 1976-1999 (2.18% per decade, $p = 0.006$) but decreased from 2000-2019 (-4.19% per decade, $p = 0.001$).

Agriculture Productivity

The data on the crop yield of major crop types in the study area were collected from the annual report of the MoALD, Government of Nepal. Unfortunately, the data were available only from 2004 to 2015. Paddy, maize, wheat, millet, and barley are the major crop types found in the study area. The yields of all crops have shown an increasing trend over the period of 11 years as shown in **Figure 3**. The paddy yield increased sharply over the period with an average rise of 179.1 kg/ha per year ($p = 0.0003$). Such a rapid rise in the yield within a short period is likely because of combined effect of climate (paddy flourishes on warming climate) and improved varieties of crops, irrigation, and fertilizers. The overall maize yield also has significantly increased by 126.8 kg/ha per year ($p = 0.0019$), however there is sharp decline of yield in the year 2012. This was because of pest infestation and maize disease such that there was problem in germination which reduced the maize yield in the study area. The millet yield increased by 93.4 kg/ha per year ($p = 0.0002$) and barley yield increased by 65.2 kg/ha per year ($p = 0.0054$), however these were largely aided with better management of crops and fertilizers.

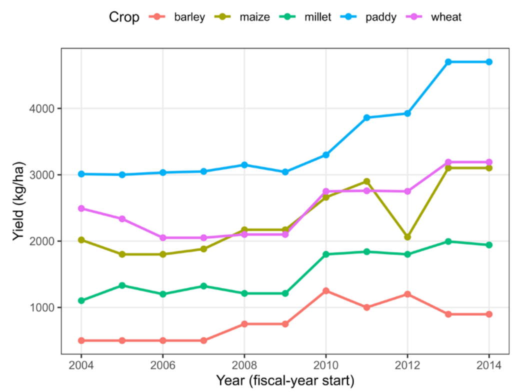

Figure 3. *Average crop yields in Nuwakot District (fiscal years 2004/2005–2014/2015; fiscal-year start used as year)*

The yield of major food crops variation in Nuwakot district was also found similar to the study done in Dhading district, where the study suggested change of weather pattern could be responsible for the variation of food crops as it could not be predicted and the yielding of crops and its productivity became unpredictable (Paudyal, Bhuju, & Aryal, 2015). A statistical report of a national climate change impact survey reported that changes in rainfall pattern, insufficient water for crops especially for paddy, extreme weather incidents such as droughts, spread of pests and crop diseases could affect agricultural production which has been seen in the present study (CBS, 2017). The primary concerns of climatic effects in agricultural production are not only early seasonal monsoons, which result in rain deficits that generally reduce the production of crops, but also intense heavy rainfall that destroys planted crops and reduces crop production (Panday, 2012).

However, the key factors in increased agricultural productivity and yields in the study sites in general are due to technological advances such as improved crop varieties, irrigation systems, and availability of snow-fed Trishuli River. The practice of integrated pest management system, mulching practices, crop rotation, and change of farming system have played vital roles in Nuwakot district for better yield of crops.

The low input technological advancements like drip irrigation, tunnel farming, pond construction, compost, jholmol and oilcakes are the climate resilient agricultural practices which the respondents of the study sites in Nuwakot have adopted too in agricultural sector (Pandey et al., 2017).

People's perception on water source

Of the three selected local levels, the household survey of the study sites revealed that 54% of the respondents had water sources for drinking water mainly from the piped line in the form of tap water distributed by District Drinking Water Supply. The water from tube wells and wells was used by 15% and 4% of the respondents, respectively, followed by river and stream water, which was the source for 27% of the respondents. River water and tubewell are the sources of irrigation in the area. The respondents claimed that decrease of spring water, tube well, and well water could be the result of decrease in rainy days and an increased in hotter days. It can be depicted that drying up of spring water in the mid hills of the study sites may be a signal of climate change (Gurung & Bhandari, 2009).

The question on the changing trend of water sources in the study sites reflected that 48% of the respondents believed the decrease in the source, 38% believed the sources have been increasing, 12% believed it to have no changes and remain constant in the water sources and 2% of the respondents showed anonymity regarding the source of water change trend due to climate change impact as shown in **Figure 4**. These perceptions are consistent with broader evidence from Nepal's hills that water availability and reliability are sensitive to changing rainfall patterns and dry-season water stress. (Shrestha et al., 2022; Kattel & Nepal, 2022).

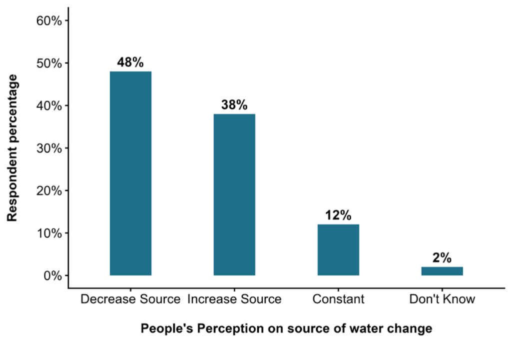

Figure 4. *Perception of water source change trend in the study sites from the respondents*

People's perception of changes in Agricultural production

The respondents of the three study sites were asked to express their opinions about agricultural production within the past 10 -15 years. Majority of the respondents have argued on behalf of the change in agricultural production due to climate change. About 64% said significant increase, 26% said decrease, 9% of the respondents said constant, and 1% of the respondents were uncertain regarding agricultural productivity. The irrigation facilities have been assisted to increase production whereas the people who are dependent on rain and cannot bear irrigation have said reduced agricultural production. One of the causes of reduction in the crop production is the migration of young people abroad in search of better jobs and study purposes that have made the land barren, and labourers are not available to work in the field these days as compared to the past days.

During the field study, the respondents informed that they are aware of climate change and have been experiencing its adverse impacts in the present days as compared to the past years. Therefore, their overall farming system has been affected. Nearly 55 % of the respondents stated that they are using improved varieties of paddy crops instead of local varieties indicating the shifting to the crop types for production results in increased productivity.

The respondents who disagreed about agricultural production said that the crops could not grow these days due to soil pollution and soil nutrients have been lost by using excess pesticides to kill pests and crop diseases and lack of irrigation in the field in the dry season.

Farmers who used to grow maize during the summer and pulses in the winter have shifted to the cultivation of vegetable and hybrid paddy and maize. Some of the farmers with medium and large farms around the road have been found growing vegetables, especially tomatoes and shifted to perennial fruit plantations like bananas in the uplands and low productive land.

Perception of people on the biological system of plants

The flowering and fruiting of plant species have been found irregular, as said by 92% of the respondents. For example, Aaru (*Prunus persica)* ripen in Jestha instead of Ashad, Painyu (*Prunus cerasoides*) flowered in Kartik and early fruiting of Kafal (*Myrica esculenta*) was noticed in the month of Falgun instead it used to be fruiting in Chaitra end in the past years. The early flowering of oranges and infectious diseases in it has reduced the yield of oranges and has been mentioned by 8% of the respondents in the study area as shown in **Figure 5**. This changing flowering and fruiting of plants and invasion of plant disease indicate the onset of the effect of climate change impacts (Dahal, 2006).

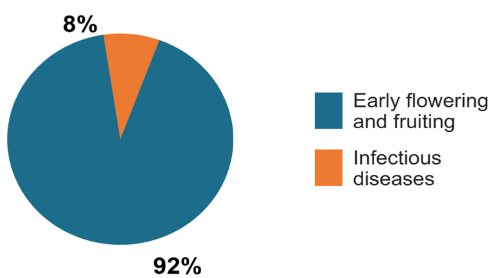

Figure 5. *Perception on climatic effect on flora of Nuwakot District (Source: Field Survey, 2020)*

These plant characteristics are considered as important "human" indicators for observing and experiencing about increase or decrease of temperature, rainfall days, rainfall intensity, invasive plant species, crop diseases and pest infestation as well as condition of agricultural productivity and yields in their agricultural land. They are taken as ground truth as they have intimate relation with the changing environment regarding floral and faunal condition because plants and animals are the most prevailing source of indicators to indicate the impact of climate change (Sujakhu et al., 2016). Therefore, early flowering and fruiting of flora could be due to change in temperature and early onset of seasons **(Table 1** and **Figure 5)** which can affect the timing of reproduction and phenology of vegetation (Julius & West, 2008).

Respondents' perception on changing climate and its effect on the locality

As demonstrated in **Table 1**, the respondents of the study area have indicated an increase in the number of hot days in summer and cold days in winter over the past two years. They have also noted erratic rainfall patterns, the introduction of invasive species, changes in agricultural production, shifts in water sources, forest sources, and landslides and soil erosion. The findings of this study suggest that climate change is beginning to have an impact on the study area. This conclusion is supported by the fact that more than 50% of the respondents' provided information that was used in the synthesis analysis of the climate change impact report (Solomon et al., 2007). All the respondents agreed growth of invasive plant species and landslides has hindered the soil quality as new plant species can absorb soil nutrients that have caused the loss of crop production. The landslide and soil erosion in Nuwakot district was thought of as short rainfall with its high intensity causing landslide and soil erosion as they explained.

Table 1: *Local people's perception on changing climate effect in their localities*

Parameters	Increased	Decreased	Same	Don't Know
Rainfall Days	26%	63%	10%	1%
Rainfall Intensity	69%	0%	22%	9%
Temperature	74%	0%	17%	9%
Hailstorm	64%	0%	36%	0%
Lightning	89%	1%	0%	10%
Drought	11%	50%	36%	3%
Weather getting hotter	97%	0%	3%	0%
Early Summer	83%	11%	0%	6%
Early Spring	36%	55%	0%	9%
Early Monsoon	97%	0%	3%	0%
Colder Days	97%	0%	3%	0%
Pests	91%	0%	9%	0%
Invasive Plant species	100%	0%	0%	0%
Biodiversity	43%	16%	33%	9%
Water Resource	49%	39%	11%	1%
Agriculture Productivity	64%	26%	9%	1%
Forest Resources	69%	16%	11%	4%
Landslide/Soil Erosion	100%	0%	0%	0%

Source: Field survey, 2020

The majority of the respondents reported being troubled by increased pests such as stem borer (Gabaro), Khumre Kira (white grub), fruit fly, fruit borer, mealybug, tomato leafminer (*Tuta absoluta*), rice hispa, brown planthopper (*Nilaparvata lugens*), and green leafhopper (*Nephotettix* spp.), as well as plant diseases such as maize and rice blast, which could be signs of the impacts of climate change. The study also revealed that the strong cold days along with increasing foggy days had aggravated the occurrence of pests and diseases affecting the winter crops far more than what it used to be in the past. All the respondents reported that they have observed an increase in invasive plant species (*Ageratina adenophora* known as Kalo Banmara, *Chromolaena odorata* known as Seto Banmara, *Ageratum houstonianum* known as Gandhe Jhar, and shrubs: *Lantana camara* known as Banmara/Ban Fanda) in the study area. They perceived that it has contributed to decreased crop production these days as these weeds and pests had not troubled much in the past days as presented in **Table 1**.

The higher intensity of rains but fewer rainy days have been felt by more than 50% of the respondents and such changing rainfall events may be of irregular monsoon pattern in the country. The early onset of monsoon and early onset of summer as well as weather getting warmer together with weather getting colder have been felt over by 50% of the respondents in the locality as shown in **Table 1**.

Likewise, the survey indicates that 50% of the respondents have mentioned that drought has decreased while 11% have said that drought has increased. While 36% of respondents have said it has neither increased nor decreased and 3% of the respondents did not know about the drought.

Regarding biodiversity, 43% of respondents said that species diversity is increasing while 33% said that it is the same, 16% said that it is decreasing, and the rest 9% of the respondent showed indifference about biodiversity.

The forest resources have been improved as of the implementation of the community forestry programme nationwide by the government to protect the forest handing over to the community forest user groups to manage and sustainable use of it could be the reason for better improvement of forest condition in the study area according to the response of local people of more than over 50% as mentioned in **Table 1**. The importance of forests is that it provides a carbon reservoir as they contain about 80% of all carbon stored in terrestrial ecosystems (Six, Conant, Paul, & Paustian, 2002), and they serve as important adaptation buffers. The improved protection of forests could be less use of energy sources such as fuel wood in that electricity has been provided by the Trishuli Hydropower.

The study found, people were distressed by increased landslide and soil erosion because of motorable road construction and maintenance at a slow pace that ends to Rasuwa and intense rainfall of shorter period during monsoon season could be the reason for sliding of land and soil erosion even after monsoon dries up.

Major crops and crop calendar

The major crops and crop calendar have been developed from group discussion with the respondents **(Table 2)**. There is no change in crop cultivation and crop harvest as obtained from group discussion, but they said that their crops especially paddy and maize seed have been affected by pest, crop diseases, and erratic rainfall with hailstone at the time of harvest of crops and they also had to wait for monsoon to plant paddy these years.

The respondents have been planting and harvesting crops like rice, maize, wheat, barley, millet and vegetables according to the seasons **(Table 2)**. The respondents however expressed their concern only over the invasion of plant species, increase of pests and crop diseases, increase of rainfall intensity with decrease in rainy days **(Table 1)**.

The crop pests such as mealybugs, tomato moth (*Tuta absoluta*), white grubs, stem borer (a pest destroys rice at any stage of the plant from seedling to maturity), rice hispa (a serious insect pest responsible for damaging the upper surface of leaf blades by scrapping the leaves leaving only the lower epidermis causing damage to crop plants), brown plant hopper (a pest initially turns the leaves orange to yellow and later to brown that makes the crop plant to kill), blast (a fungal disease that affects all above ground parts of a rice plants), fruit fly (a pest stings fruit and fruiting vegetables), fruit borer (a pest of tomato, brinjal, pumpkin and cucumber).

Low land and perennial water sources nearby agricultural land has caused more production of crops and vegetables. In the dry season vegetables, millet and maize has been planted to Pakho land and in low agricultural land where access to water is difficult.

The name of spring rice which is planted in the month of Chaitra (March – April) in the study area include the paddy seed as Chaite – 4, Hardinath-1 and are called as Chaite Dhaan in Nepali and is completely harvested before beginning of the month of June whereas the normal rice or monsoonal rice or even known as Barkhe Dhaan is planted in the middle of the month of June and harvested it at the end of the month of October which includes Jhinuwa, Basmati, Radha -7, Khumal -8 , Khumal -10 and Mansuli rice in the study area.

Table 2. *Crop Calendar in Nuwakot District*

Heading level	Land type = Khet	Land type - Pakho	Harvesting - Khet	Harvesting – Pakho
Paddy (Monsoon)	May - June	May – June	Oct - Dec	Aug – Sep
Paddy (Summer)	-	March – June	-	Aug – Sep
Maize	Feb - March	April – May	June – July	Agu – Sep
Wheat	Oct - Nov	Oct – Nov	May – June	March – April
Millet	April – May	April – May	Oct – Nov	Oct – Nov
Vegetable (Winter)	Aug - Sep	Aug – Sep	Jan – Feb	Jan – Feb
Vegetable (Summer)	Feb - April	Feb – April	April (end) – May	April (end) – May
Potato (Winter)	Jan – Feb	Sep – Oct	March – April	Feb – March
Potato (Monsoon)	March – April	March - April	April - May	April - May

Source: Field survey, 2020

The planting and harvesting of paddy crops are not regular as the paddy plantation and harvesting period has been determined according to the weather pattern. The vegetables grown in the summer season include cucumber, pumpkin, bitter gourd, tomato, lettuce, brinjal, string beans, lady fingers, chilli whereas cabbage, cauliflower, radish, onion, potato, garlic, coriander, broad leaf mustard green and kidney bean are grown in the winter months by the respondents.

Adaptation and Mitigation Measures in Agriculture

In the study area, farmers reported and demonstrated different types of practical measures that we have grouped into water security, microclimate protection, seed/production intensification, soil fertility management, and pest risk management. These measures form an integrated package to cope with warming, rainfall uncertainty, and resisting pest invasion.

Erratic rainfall and dry-season water stress: Pond construction is a major practice in the area to convert the erratic rainfall into usable irrigation water during dry season while drip irrigation reduces the evaporation loss and maintain crop moisture reliably. Similarly mid-hill studies in Nepal repeatedly identify small-scale water harvesting structures (including ponds) and efficient irrigation (including drip) as practical adaptations under drought risk and rainfall variability (Adhikari, 2018; Kattel & Nepal, 2022).

Weather shocks (hail/frost/temperature swings): Tunnel farming was found mainly used for high-value vegetables (tomato, cucumber) to reduce damage from hailstorm, frost, and sudden temperature drops and, and to stabilise production under irregular rainfall conditions.

Shifting seasons and production goals: The uptake of hybrid and improve crop variety was widespread in the area, and a greater emphasis was on cash crops. The use of improved seed varieties and change in cropping patterns are common adaptation practices in Nepal (Ranabhat et al., 2023; Shob & Joshi, 2022).

Soil resilience: The use of organic compost manure, and vermicompost to improve soil condition and reduce dependence on chemical fertilizer was found in the study area. These practices are a supportive measure for soil resilience under drought conditions and rainfall variability (Adhikari, 2018; Kattel & Nepal, 2022).

Conclusion

This study shows that farming households in Nuwakot are responding to climate stress with a practical, integrated bundle of measures rather than a single intervention. The long-term trend analysis of climatic variables indicates a clear warning signal. In response, the farmers in Nuwakot are combining ponds + drip irrigation (to manage dry-season water stress), tunnels (to reduce hail/frost/weather damage), and soil amendments (to maintain soil condition). The crop yield gains at district scale suggest improving resilience in the study area, but inference is limited because rainfall was analysed as mean monthly rainfall (not rainfall days/intensity). The rising crop yield of the major corps grown in the area shows the locally adopted measures are helping to buffer the production against climate change stressors. Since, climate and crop yield series data only partially overlap, and yields are district averages that the study was not able to capture the relationship between the climate change and crop yield. Thus, the future work should use monthly/daily rainfall and extreme indices and collect farm/plot-level yields plus management data to test which adaptation bundles work best and why across hill districts.

Acknowledgements

We would like to acknowledge Ministry of Agriculture and Livestock Development, Government of Nepal for supporting us with crop yield data, Department of Hydrology and Metereology (Ministry of Energy, Water Resources and Irrigation, Government of Nepal) to for supporting with meteorological data, Agriculture Development Office, Nuwakot for supplementing required support on data and status of agriculture, and Dr Mahadeb Prasad Poudel for guiding us to work with agriculture data.

Authors contribution

Dipesh Raj Pant: Conceptualisation, supervision, methodology, data curation, writing- review and editing

Subash Duwadi: Field investigation, project administration, writing- review and editing

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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