Climatic Trends and Local Perception in Nechasalyan Rural Municipality: A Climate Change Scenario

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ABSTRACT

Climatic policy responses are influenced by how communities and individuals perceive and understand climate variabilities and changes. Integrating community perceptions with observed climate data can provide valuable information to support policies to reduce climate-related risks and enhance climate change adaptation. This study examines climate change in the Nechasalyan Rural Municipality of Solukhumbu district, Nepal, through an integrated analysis of meteorological data and local people's perceptions. Temperature and rainfall data for 31 years i.e. 1991-2021 were collected and analyzed from nearest Meteorological station (Okhaldhunga Station). Local peoples' perceptions were gathered from the household survey (n=70) along with key informant interview (n= 10) and focus group discussion (n= 5). The analysis revealed that the average maximum, winter and summer temperature trends seemed to be increasing where average minimum trend was decreasing of which only average winter temperature was significant ($p<0.05$). Despite insignificance in the increases in average annual maximum and summer temperatures, they pose potential challenges in the long run. Similarly, the average annual rainfall as well as seasonal rainfall trends seemed to be decreasing, and only average July rainfall trend was statistically significant ($p<0.05$). The results indicate that while local perceptions about the changes in the temperature were consistent, there was disconnection between these perceptions and observed rainfall trends. The consistency between local perceptions and rising temperature trends suggests that people remember temperature changes more vividly than rainfall patterns, warranting future research to investigate the causes of disparities between local perceptions and observed climate trends. Additionally, exploring effective communication strategies to bridge the gap between scientific findings and local understanding could enhance community climate resilience.

Keywords : *Climate change, local people, perception, rainfall, temperature*

INTRODUCTION

In recent years, global climate change has attracted public and scientific attention, with human economic activities anticipated to be the primary driver of an uncontrolled increase in Greenhouse Gases (GHGs) emissions within the Earth's climate, resulting in a global rise in temperature (IPCC, 2007). In recent years, research has focused on exploring public perceptions on global warming and climate change, particularly how people perceive, comprehend, and react to associated dangers (Brody *et al.*, 2008). Documenting and comprehending public opinions are critical in defining both local and global socio-political environments, influencing policymakers' and scientists' decisions and activities. Public perceptions are important drivers or restrictions for political, economic, and social responses to climate change, emphasizing the need of studying and understanding this part of the problem (O'Connor *et al.*, 1999; Agho *et al.*, 2010). Assessing local concerns regarding the phenomena and creating locally appropriate solutions for climate change adaptation depends on determining the knowledge, perceptions, and awareness of climate change in the local community (Nkuba, 2020).

In 1990, Nepal produced 0.72 million tons of CO_2, but by 2020, emissions had increased to 16.97 million tons, a 24 times increase. Abdul Jabbar *et al.*, (2022) conducted study in Bangladesh, Pakistan, Sri Lanka, and Nepal for air quality data trends and sustainability indicators using a population-based study design, and analyzed using a step-wise approach. Data were obtained from government websites and publicly available repositories for region dynamics and key variables. Results showed that between 1990 and 2020, air quality data indicated the highest rise in CO_2 emissions in India (578.5 to 2441.8 million tons. The emissions would lead to the hazardous impacts. Numerous investigations on Nepal's historical climate have revealed significant warming patterns, especially in recent decades (Shrestha & Nepal, 2016). Furthermore, by the 2060s, the mean annual temperature is predicted to rise by 1.3°C to 3.8°C, according to data from the Coupled Model Intercomparison Project, Phase 5 (CMIP5) models (World Bank, 2019). Nepal's National Climate Change Policy by Ministry of Forests and Environment (2011) acknowledges increasing temperature trends and irregular rainfall patterns, as well as related natural disasters such as landslides, floods and drought, including Glacial Lake Outburst Flood (GLOF), as Nepal's risks to climate change. According to the Department of Hydrology and Meteorology (DHM) (2017), maximum temperatures are rising more significantly than minimum temperatures, particularly in higher altitude regions where maximum temperatures are increasing while minimum temperatures are decreasing; conversely, in lower altitude regions, minimum temperatures are rising but maximum temperatures are decreasing, indicating a warming trend in higher altitudes. The study also shows that all Nepal average temperature is increasing by at 0.056°C/year. Mountain regions are expected to see a greater temperature increase than other places (Shrestha, 1999). Several studies have demonstrated that without awareness, implementing mitigation or adaptation measures to climate variability and change will remain difficult, which will generally be harmful to the environment as a whole, especially the agricultural sector and these studies also demonstrated that only through knowledge and awareness can reduce the vulnerability of the entire environment (Adeoti & Ajibola, 2008; Gworgwor, 2008; Rosenzweig & Parry, 1994). Communities' and individuals' perceptions and knowledge of climate variability affect how they react to mitigation, adaptation, and climate policy (Egbe *et al.*, 2014). Integrating community perceptions with observed climate data can provide valuable information to support policies to reduce climate-related risk and enhance climate change adaptation (Shrestha *et al.*, 2019).

According to NCVST (2009), local observations and perceptions substantially impact livelihood systems, infrastructure, and economic activities, making them critical in increasing local community resilience to climate change effects. To address these implications, there is a pressing need for local climate change research that uses a bottom-up approach (Piya *et al.*, 2012). Most studies on climate change perceptions have been undertaken in specific local contexts (Battaglini *et al.*, 2009; Bunce *et al.*, 2010). As a result, implementing a place-based research agenda is critical. Comparative studies are critical in bridging perceives across local and global scales, which is especially significant given the widespread impact of climate change and the growing need for mitigation actions at both levels (Lorenzoni & Hulme, 2009). While several studies have been undertaken in the Khumbu section of the Solukhumbu district, there has been limited research in the Nechasalyan Rural Municipality. As a result, this study was motivated by the desire to assess the local community's impression of climate change in the Nechasalyan Rural Municipality of Solukhumbu district and compare it to meteorological data findings. With large altitudinal fluctuations ranging from 640 m to 3000 m, the rural municipality is particularly vulnerable to the magnified effects of climate change, necessitating more local adaptation efforts. Acting as a foundational study, this research serves as a basis for future investigations and initiatives focused on adaptation and resilience building.

MATERIALS AND METHODS

Study area

The study was carried out in Nechasalyan Rural Municipality (NRMP), located in the far southern belt of the Solukhumbu district. Nepal (Figure 1). It is bounded on the east by Thulung Dudhkoshi rural municipality and Khotang districts, on the west by Okhaldhunga district, on the north by Solu Dudhkunda municipality and on the south by Okhaldhunga

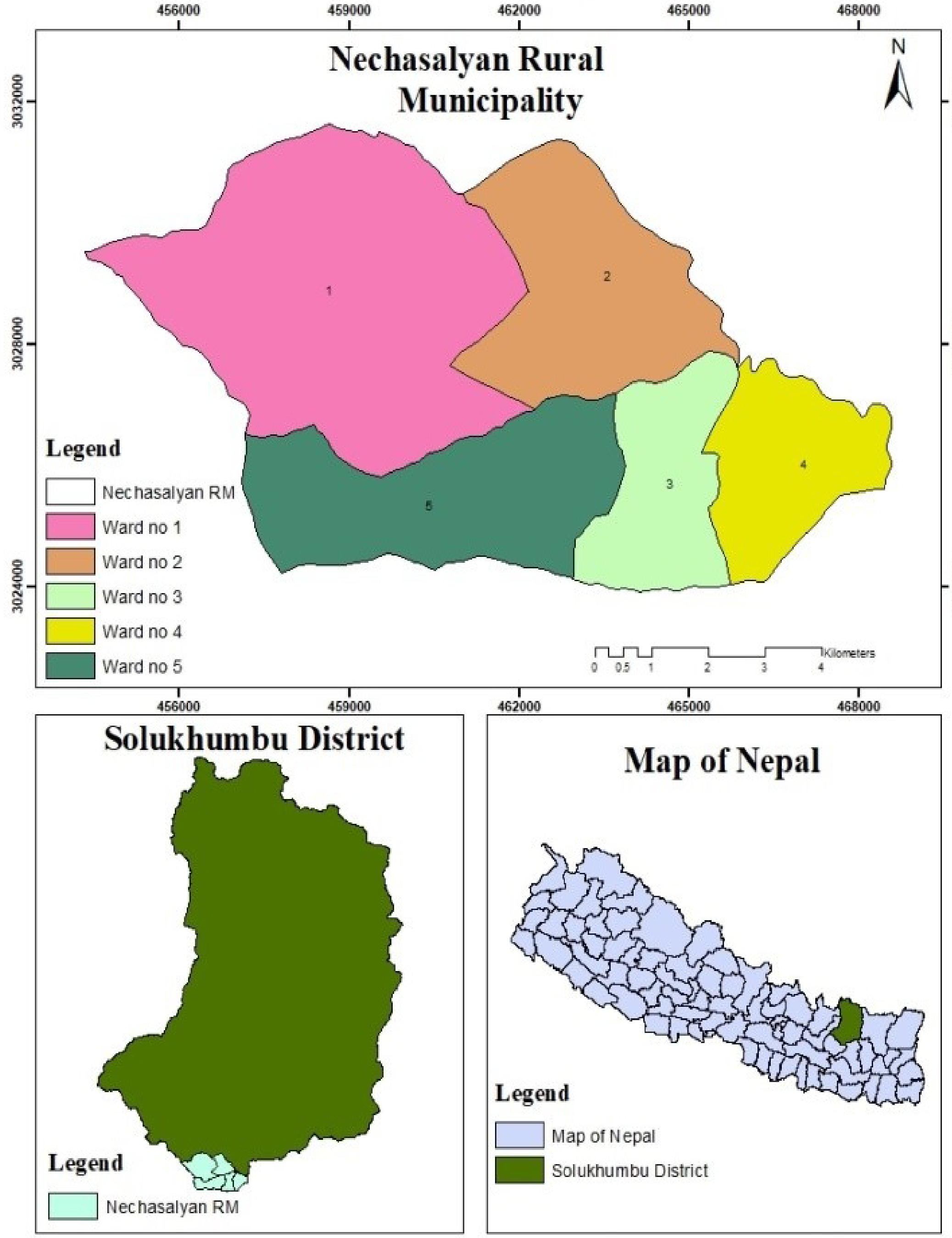

Figure 1 : *Study area*

Table 1: Sample size of different ward numbers

Ward Number	Number of Households	Sample size
1	643	~16
2	429	~11
3	768	~20
4	493	~12
5	416	~11
Total	**2749**	**~70**

district. The elevation range of the study site is 600 m to 3500 m above sea level. Nechasalyan Rural Municipality is divided into five wards with the headquarter Necha Bihibare Bazar which lies in ward no 3. The total area of NRM is 67.54 km^2 and population is 12,207 (Central Bureau of Statistics, 2021). According to the village profile of NRMP, largest proportion of the population was inhabited by Rai caste (24 % of the total population), followed by the Brahmin, Chettri, Sherpa, Kami. Those five castes form about 80 percent of the total population of the rural municipality.

(Nechasalyan Rural Municipality, 2024).

Data collection

For this study both primary data and secondary data were collected and analyzed. Sample size for household questionnaire survey was determined using the formula given by Cochran (1977) (Eq 1). Stratified sampling was used for household selection for the surveys, with wards taken as the strata.

$$n = \frac{Nz^2P(1-P)}{[Nd^2 + z^2P(1-P)]} \text{ ------------------ Eq 1}$$

Where,

n= Sample Size

N= Total number of Household in Rural municipality

z= confidence level

P= proportion of sample on population estimate

d= level of precision

The total number of households in NRM was 2749. Taking confidence interval of 95% gives the value of z = 1.96, proportion of sample on population estimate 25% i.e. 0.25 and 10% level of precision gives the number of sample size which is ~ 70 households. The sample size for each stratum i.e. ward was determined by their household proportion. The sample size for each ward is given in Table 1.

For household survey, wherever possible respondents over the age of 30 years were preferred and has been living in the study area for the past 30 years. A total of ten key informant interviews (KII) were conducted in all five wards including chairperson, rural municipality officials and individuals who were living in the area for long time. They were interviewed about the changes in climate in the area. Five focus group discussions were conducted with community forest user groups (CFUGs), and women groups to triangulate the data obtained from household surveys and key informant interviews. Secondary data were also collected from different articles and reports. Temperature and rainfall data of 31 years i.e. 1991-2021 were collected from the nearest meteorological station to the study site which is Okhaldhunga station.

Data analysis

The socio-demographic data and the perception data from the household questionnaire survey were presented in the tabulated format. The climatic data was analyzed using Mann-Kendall trend test (Kendall, 1948; Mann, 1945) and Sen's slope (Sen, 1968). Mann-Kendall trend test, a non-parametric test, is one of the best ways to determine whether a monotonic positive or negative trend is present and significant in a time series meteorological data (Karpouzos, 2010; Partal & Kahya, 2006). The Kendall rank The Kendall rank correlation coefficient, often known as Kendall's tau coefficient (after the Greek letter), is a statistic used in statistics to assess the ordinal relationship between two measured variables (Basnet *et al.*, 2020). The Mann-Kendall Statistic S can be computed as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\left(T_j - T_i\right) \text{----- Eq 2}$$

Where, T_j & T_i are the annual values and n is the length of the dataset

$$\text{Sign }(T_j\text{-}T_i) = \begin{Bmatrix} 1, & for\ T > 0 \\ 0, & for\ T = 0 \\ -1, & for\ T < 0 \end{Bmatrix} \text{------- Eq 3}$$

The value of S reveals the trend's direction. A declining trend is indicated by a negative and an increasing trend is indicated by a positive score. When $n \geq 8$, Mann-Kendall has shown that the test statistic S has the following mean and variance, with a roughly normal distribution:

$$\sigma^2 = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} T_i \left(T_i - 1\right)\left(2T_i + 5\right)}{18} \text{--------Eq 4}$$

Then the standardized test statistics Z can be computed as:

$$Z = \begin{Bmatrix} \frac{S-1}{\sigma}, & for\ S > 0 \\ 0, & for\ S = 0 \\ \frac{S+1}{\sigma}, & for\ S < 0 \end{Bmatrix} \text{----------- Eq 5}$$

Where, m is the number of tied groups and Ti is the size of the i_{th} tie group

This test statistic is used to examine the null hypothesis, Ho. The null hypothesis is invalid if $|Zs| > Z_{\alpha/2}$, where α is the specified significance level (for example, 5% with $Z_{0.025} = 1.96$) and the trend is significant (Motiee & McBean, 2009).

After Mann-Kendal trend test Sen's slope method is used to quantify the trend using a non-parametric procedure which was developed by Sen (Poudel & Shaw, 2016). It is computed as:

$$Qi = \frac{X_j - X_k}{j-k}\ for\ i = 1,2,3,4 \ldots\ldots N \text{-------- Eq 6}$$

Where, Xj and Xk denotes the data values at time j and k (j > k) respectively.

For determining climatic trends, Addinsoft's XLSTAT 2020 was used to perform Mann-Kendall test. At a 95% confidence level, the null hypothesis was tested for both temperature and rainfall data.

RESULT

Socio-demographic characteristics of the respondents

The majority of the respondents in the study area were male, which is 64.3% compared to female, i.e., 35.7% (Table 2). Rai (35.7%) and Brahmin/Chhetri (30.0%) were the major ethnicity of the respondents. The majority of the respondents were of the age group 40-55 years, followed by age group 55-70 years. Since the respondents were of the higher age group, majority (54.3%) were illiterate. Significant proportion of the respondent's (61.4%) livelihood was based on agriculture, while 74.3% of the respondents have small land holding (5-10 ropani).

Climatic analysis

Temperature

The analysis of the monthly temperature shows that the temperature reaches maximum in June and minimum in January (Figure 2). The value of mean monthly temperature shows that it is highest in July and lowest in January. Both maximum and minimum annual temperature showed an increasing trend. The maximum temperature of the year 1991 and 2021 was recorded to be 28.4°C and 29.4°C respectively. The difference in the maximum temperature between the initial year and the recent year was seen to be 1°C. Similarly, the minimum temperature of the year 1991 was 1.9°C and the minimum temperature of the year 2021 was 3.8°C. The difference in the minimum temperature between the initial year and the recent year was seen to be 1.9°C. Similarly, the average summer temperature and winter temperature exhibited an upward trend. The trends of average maximum, minimum summer and winter temperature are shown in Figures 2 and 3.

Rainfall

One of the most important aspects of analyzing the meteorological state of the research region was the rainfall distribution. Over a span of 31 years, the average monthly rainfall data highlights June, July, and August as the months characterized by substantial precipitation. Among these, July stands out with the highest average rainfall of 423.16 mm, followed closely by August with 416.23 mm, and June with 288.10 mm. Moreover, September also experiences notable rainfall with 262.91 mm. Conversely, November and December exhibit the lowest rainfall levels, with November being the driest month at 7.79 mm of average rainfall, followed by December at 8.69 mm.

Table 2: Socio-demographic characteristics of the respondents

Socio-demographic variable	Frequency	Percentage
Sex		
Male	45	64.3
Female	25	35.7
Ethnicity		
Rai	25	35.7
Brahmin/Chhetri	21	30.0
Newar	3	4.3
Sherpa	11	15.7
Others	10	14.3
Age Group (years)		
25-40	8	11.4
40-55	41	58.6
55-70	16	22.9
Above 70	5	7.1
Education		
Illiterate	38	54.3
Primary	7	10.0
Secondary	16	22.9
Higher Secondary	5	7.1
Bachelor's and above	4	5.7
Occupation		
Agriculture	43	61.4
Job/Service	8	11.4
Business	10	14.3
others	9	12.9
Land Holding (ropani)		
Marginal (1-4)	7	10.0
Small (5-10)	52	74.3
Medium (11-15)	6	8.6
Large (More than 16)	5	7.1

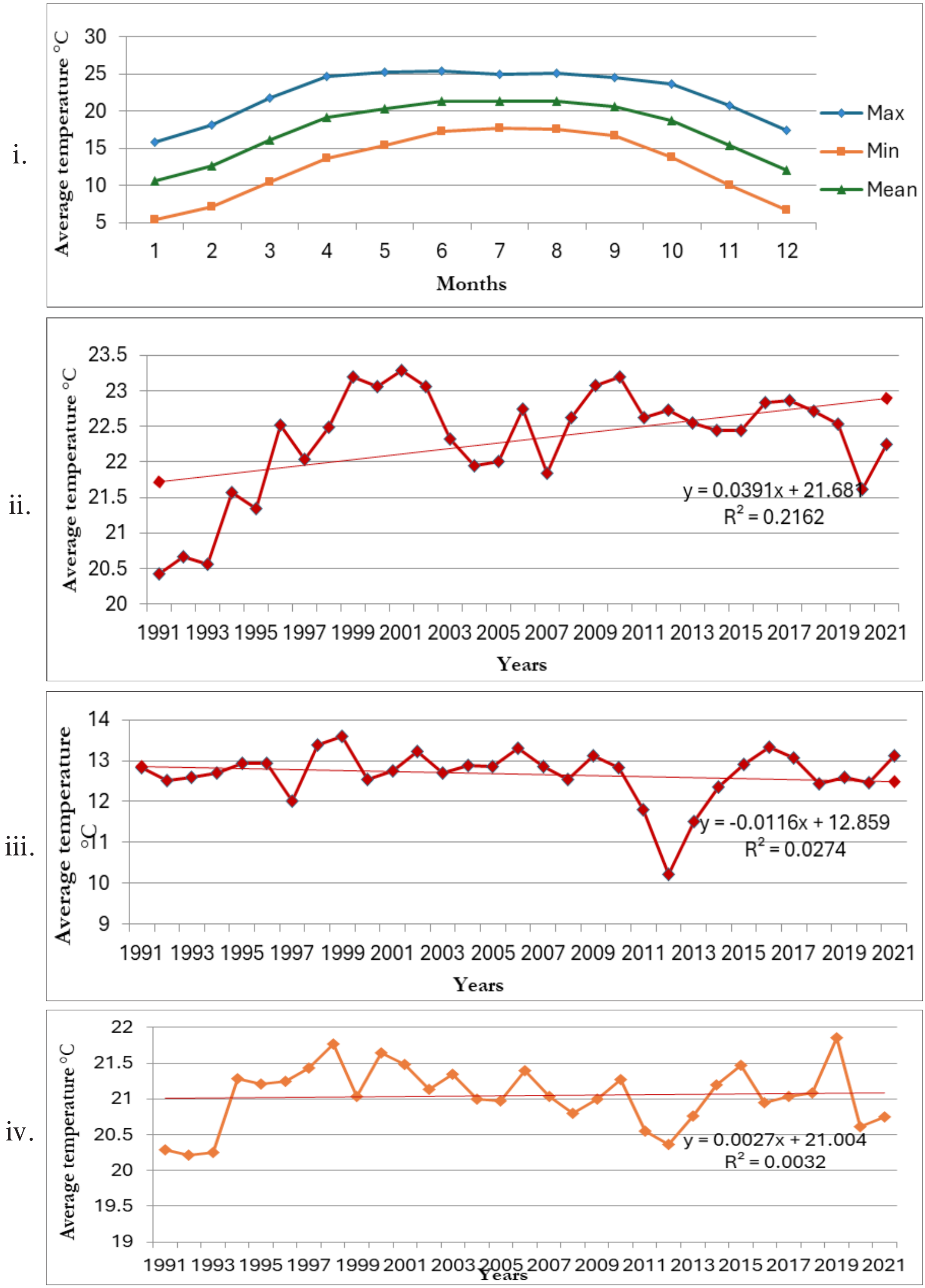

Figure 2: *i) Average monthly temperature; ii) Average maximum temperature; iii) Average minimum temperature; and iv) Average summer temperature*

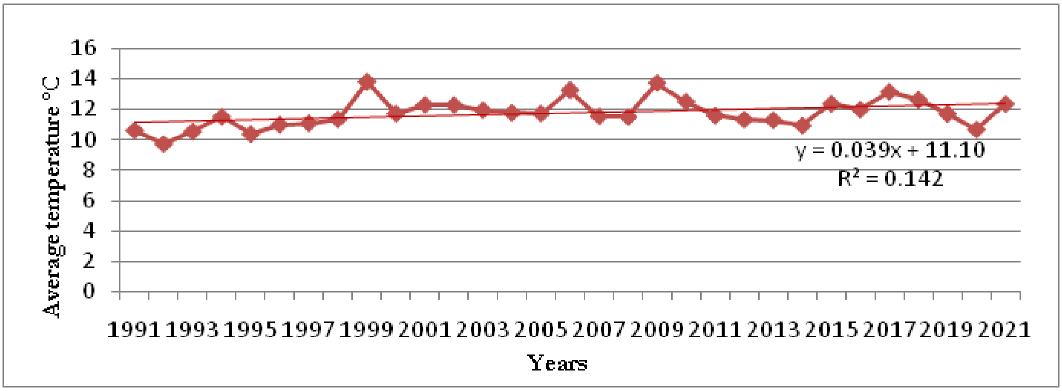

Figure 3: *Average winter temperature*

Table 3: *Maximum, minimum and seasonal temperature trends*

Variables	Kendall Tau(τ)	p-value	Sen's slope	Trend
Average maximum temp	0.204	0.110***	0.028	Increasing
Average minimum temp	-0.049	0.708***	-0.006	Decreasing
Average summer temp	0.037	0.786***	0.003	Increasing
Average winter temp	0.265	0.038*	0.044	Increasing

*Significant at 5% significance level

*** not Significant at at 5% or 10% significance level

The Figure 4 shows that the trend for average annual rainfall is decreasing where the year 2001 received the highest average rainfall of 70.71 mm and the year 2018 received the lowest rainfall of 42.25 mm. Similarly, the average monthly rainfall of the wettest months i.e. June, July and August also showed the decreasing trend as shown in Figure 5.

Perception of local people

This study examined the perceptions of local residents regarding climate variations by comparing their current experiences to those from 10 years ago. Therefore, to minimize potential overestimation, a 10-year timeframe was utilized for data collection. The study shows that more than 50 percent of the respondents were unaware of the word *Jalbayu Paribartan* which is a Nepali translation for climate change, but felt that there was change in the climate over 10 years. Some respondents have heard about it but don't have broad knowledge while others have comprehensive knowledge on climate change. 65.7% of the respondents acknowledged that there were significant changes in the climate. A significant proportion of respondents (78.6%) believed that there is an increase in average temperature as well as summer temperature, while 21.4% of the respondents believe that there is no change. Also, a noteworthy proportion

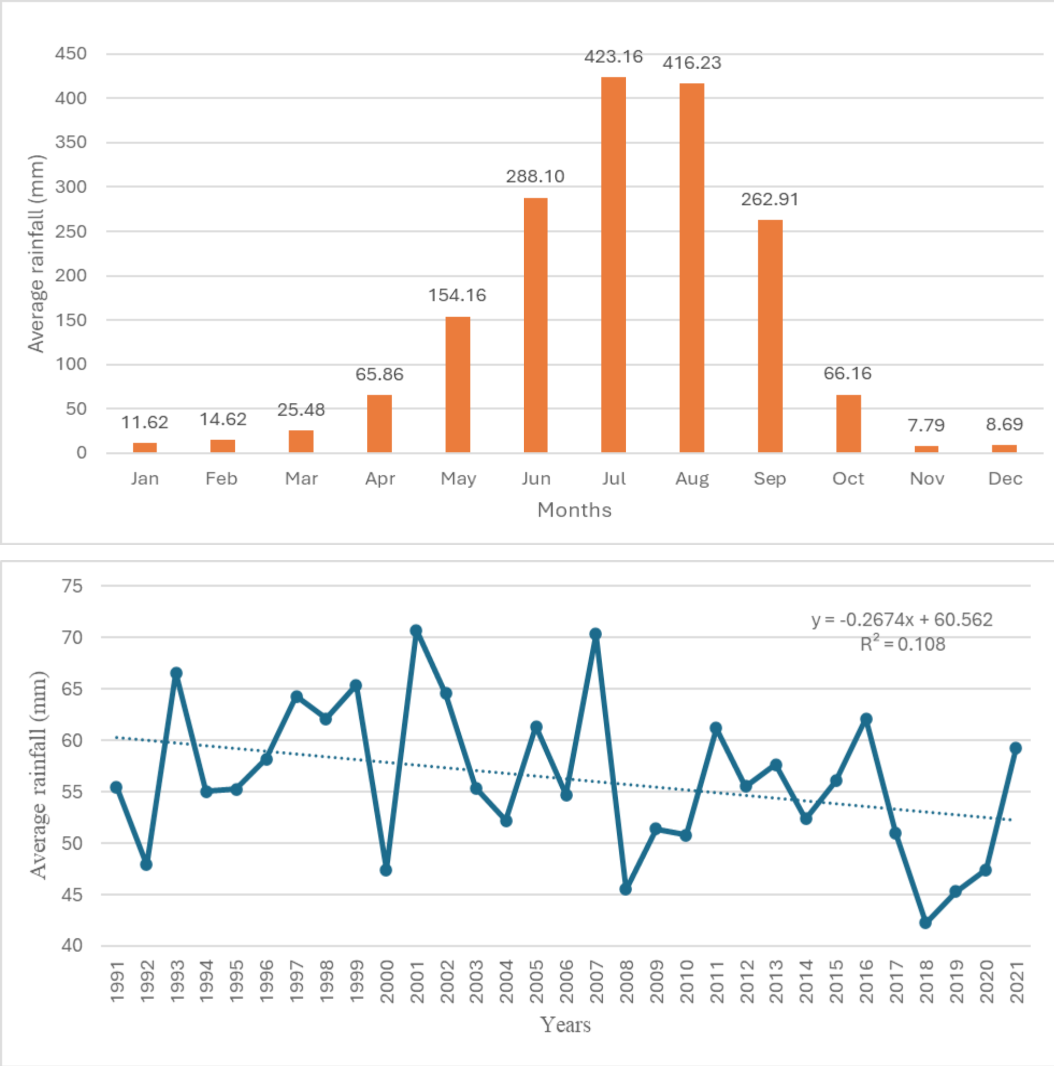

Figure 4: *i) Average monthly rainfall ii) Average annual rainfall*

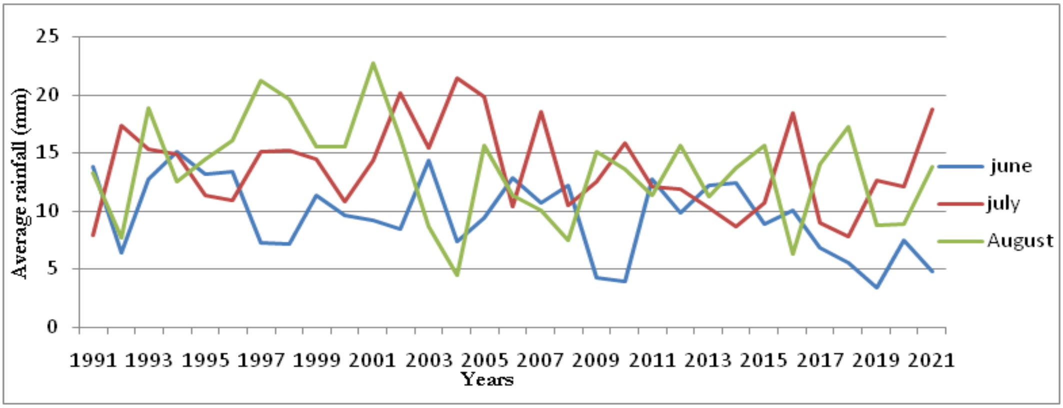

Figure 5: *Average monthly rainfall of June, July and August*

Table 4: *Annual and seasonal rainfall trends*

Variables	Kendall Tau(τ)	p-value	Sen's slope	Trend
Average annual rainfall	-0.213	0.090**	-0.265	Decreasing
Average June rainfall	-0.320	0.012*	-0.182	Decreasing
Average July rainfall	-0.214	0.101	-0.130	Decreasing
Average August rainfall	-0.186	0.153	-0.129	Decreasing

* Significant at 5% significance level

** Significant at 10% significance level

of respondents (51.4%) perceived that there is increase in winter temperature. Local perception on the rainfall was quite variable. 55.7% of the respondents perceived that the rainfall is erratic while 22.9% respondents believed rainfall has increased over period of time and only 21.4% felt that rainfall has decreased. Also, 55.7% of the people responded that they have felt the drying up of fresh water sources due to climate.

Comparison between local perception and observed climatic trends

Local perceptions about the changes in the temperature were seen more consistent than that of rainfall. The majority of the local people perceived that there was an increase in average temperature, summer temperature, and winter temperature. Statistical analyses supported these perceptions, showing increasing trends of average maximum temperature, summer and winter temperature. The trend of winter temperature was significant at 5% significance level, while the others were insignificant at that significance level. Even though the trends were negligible, if this situation persists for a long time, it could be detrimental to people. We observed that there was discrepancy between the annual rainfall trend and the local peoples' perception of annual rainfall trend. The majority of the local people perceived that the rainfall in the study area was erratic followed by an increasing trend. But the rainfall trend shows the decreasing trend although none of them were statistically significant at 5% significance level except June rainfall trend. The correspondence of the local people's perception of the temperature trends being higher shows that people are more likely to recall the hotness or coldness of the particular year than that of how much it rained the years previously. People also perceived that fresh water sources were drying because of the climate change in the study area which is likely due to increasing temperature trends as well as decreasing rainfall trends, while majority of the respondents believed that there was no change in the conditions of hazards compared to 10 years ago

Table 5: Local peoples' perception of climate variabilities

Statements and responses	Frequencies	Percentage
Knowledge about climate change		
Yes	33	47.1
No	37	52.9
Change in climate over the last 10 years		
Yes	46	65.7
No	24	34.3
Changes in the average temperature now compared to 10 years ago		
Increased	55	78.6
Decreased	0	0.0
No change	15	21.4
Changes in summer temperatures now compared to 10 years ago		
Increased	55	78.6
Decreased	0	0.0
No change	15	21.4
Changes in winter temperatures now compared to 10 years ago		
Increased	36	51.4
Decreased	21	30.0
No change	13	18.6
Changes in average rainfall now compared to 10 years ago		
Increased	16	22.9
Decreased	15	21.4
Erratic	39	55.7
Drying up of fresh water sources due to climate now compared to 10 years ago		
Yes	39	55.7
No	31	44.3
Incidence of hazards since last 10 years		
Increased	32	45.7
Decreased	0	0
No change	38	54.3

DISCUSSION

This study identified patterns of climate variability and compared them with local residents' perspectives. The majority of residents in the study area had never heard of climate change, which is consistent with the findings of (Shrestha *et al.*, 2019). Although local people were unfamiliar with the term "climate change", they perceived changes in temperature and rainfall over the decades in their local surroundings. Our findings show that winter temperature has been increasing significantly. Additionally, there's a slight increase in average maximum temperatures and summer temperatures, though this increase isn't statistically significant. However, over the long term, even these slight increases could pose challenges for the local community. Practical Action Nepal (2009) found that the trend in the maximum annual air temperature in eastern Nepal was rising over Nepal from 1976 to 2005. According to Aryal *et al.* (2014), around 80% of respondents in Solukhmbu district observed rising summer temperatures, while 92% reported decreasing winter precipitation. The respondents concurred with the rapid melting of snow in rangelands, erratic precipitation patterns, and a rise in drought occurrences (Aryal *et al.*, 2014). Our analyses indicate that the trend in average minimum temperatures is decreasing, which contradicts the findings of (Dhakal, 2014). The inconsistency may be because of the different periods of the analysis of the meteorological data of both studies. Conversely, the observed decrease in rainfall aligns with the findings of Salerno *et al.* (2016) and Subba *et al.* (2019). The respondents in study of Dahal *et al.* (2018) who claimed to have monsoon by mid-June also reported it to delay by a month with prolonged, erratic and partial rainfall event. Also, the study by Aryal *et al.* (2014) revealed that the local people perceived the dwindling water supplies, intensifying drought, and emergence of new livestock diseases in Solukhumbu district. In a comparative study carried out by Paudel *et al.* (2022) in Gandaki River Basin, Central Himalaya, Nepal, they revealed that climatic data some how aligned with farmers perceptions. The study found an increasing temperature trend and decreasing precipitation rate ina thirty-year period of 1990 to 2021, which was also perceived by majority of farmers. However, perception regarding drought events varied in different ecological regions.

Similar results are shown in several other studies (Chaudhary & Bawa, 2011; Darjee *et al.*, 2022; Hamal *et al.*, 2022) where the increase in average temperature coincides with the perception of local people. People's perceptions on average rainfall trends varied between communities. Local people perceived that rainfall has increased and become more erratic in the recent years compared with the last 10 years. However, the local perception about the rainfall is not supported by the climatic trend statistics as the rainfall has decreased over time and this result of the study is consistent with the different other studies (Devkota & Lal, 2017; Osbahr *et al.*, 2011; Savo *et al.*, 2016; Shrestha *et al.*, 2019; Uprety *et al.*, 2017). These studies found that people's perceptions are correlated with observed changes in average and seasonal temperature but not with rainfall factors. It is recognized that people often over estimate recent events while forgetting distant historical occurrences over time (Simelton *et al.*, 2013).

CONCLUSION

This study assessed the climate change in Nechasalyan Rural Municipality with the integrated analysis of meteorological data and local people's perception. The study on perception of local people alone did not provide the concrete basis for presence of climate change impacts and adaptation planning. The study employs integrated analysis that combines both meteorological data and local people's perception, which enhances the understanding on evidence-based climate change by incorporating scientific data and community perspectives. Local people of the Nechasalyan Rural Municipality perceived changes in temperature and rainfall. There were significant trends in temperature increase, particularly in winter, in the Nechasalyan Rural Municipality of Solukhumbu district. Despite the insignificance of the increases in average maximum and summer temperatures, these trends could have adverse long-term effects on local communities. The findings showed a disconnect between local perceptions and observed rainfall trends, with local perceptions often diverging from actual decreases in rainfall. People believed that the rainfall pattern is quite erratic, and perceived that water sources were drying. The consistency of the local people's perception with the temperature trends being higher shows that people are more likely to recall about the temperature than that of the rainfall. As the study relies on the recall of past evidence by local residents, there is a possibility of both overestimation and underestimation of the results due to memory biases. Future research could delve deeper into understanding the reasons behind the discrepancies between local perceptions and observed climatic trends.

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