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Perception and Understanding of Climate Change and Its Impact in Gandaki River Basin, Central Himalaya, Nepal

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Abstract: Climate change is a global issue. Its impacts are recognized at different scales ranging from global to regional to local. Climate change particularly changes in temperature and precipitation has been observed differently in different ecological regions in Nepal Himalaya. The study area comprises five villages of three ecological regions in the Gandaki River Basin (GRB) of Nepal. Based on the observed climate data of a 30-year period from 1990 to 2020, the changes in temperature and precipitation of each ecological region are analyzed using the Mann–Kendall trend test and Sen's slope. The temperature trend was found to be increasing at the rate of 0.0254 °C per year (°C/a) between 1990 and 2020 in the Mountain region, by 0.0921 °C/a in the Hill region and 0.0042 °C/a in the Tarai region. The precipitation trend in the Mountain region is decreasing by −13.126 mm per year (mm/a), by −9.3998 mm/a in the Hill region and by −5.0247 mm/a in the Tarai region. Household questionnaire surveys, key informant interviews and focus group discussions were carried out to assess the perception of climate change and its impact. The farmers of the three ecological regions have perceived increasing temperature trends, but perceived variability in precipitation trends. Both snowfall and rainfall have varied. Snowfall has drastically decreased. Drought has increased. Extreme disaster events and impacts from such climate-induced events are experienced by 67.9% of respondents. A major impact of climate change is reported on cultivated crops with damage caused by increased insect and rodent pests. The impact of climate change is varied by ecological region. The comparative study of observed data and household data shows the need for a micro-level study so that a real situation can be captured and would be very much useful for policy formulation to combat climate change at a local scale.

Keywords: climate change; impact; rural livelihood; farmer's perception; Gandaki River Basin

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1. Introduction

Variability in the temperature and precipitation trends has been recognized globally [1,2]. The analysis of the long-term trends of temperature, precipitation and increasing drought events indicates that the climate is changing [3–5]. As a result, it has impacted the livelihoods and the economy in many countries around the world [6]. The studies have ascertained the adverse impacts of climate change on agricultural and agro-pastoral-based livelihood [7–9] as farming activities and crop yields are adversely affected at different scales in different parts of the words [10–12]. Studies also show that the Central Himalayan region has faced a severe impact of climate change on the agriculture sector [13,14] of which two-thirds of the population eke out their livelihood.

Global warming has directly impacted precipitation patterns which have adversely affected agriculture production in Nepal [15,16]. Farmers have been experiencing a decline in winter crop production due to a change in climate [17]. The increasing temperature and change in precipitation patterns in the mountains of Nepal have impacts on agricultural production in different ecological zones [16]. The study noted that the South Asian agriculture system is mainly dependent on precipitation, meltwater, and groundwater [18], and the high mountain hydropower system threatened by climate change in the recent decade [19]. The studies in the Nepal and Himalaya regions found an increasing temperature and variability but a slightly decreasing precipitation trend [8,20,21]. A report published by the Department of Hydrology and Meteorology noted that the average annual maximum temperature of Nepal has risen by 0.056 °C/a between 1971 and 2014, and the precipitation trend was found to be variable with a decrease in the post-monsoon period [22]. Similarly, the temperature trend in all the ecological regions (Tarai, Hill and Mountain) of the Koshi River Basin was found to be increasing, whereas, the precipitation pattern was found to have a decreasing trend in the period between 1980 and 2018 [11]. Such climatic variability has adversely impacted people's livelihood and agricultural system where the majority of the farmers depend on rain-fed farming [11,23].

Local people in different regions of the world have been observing and experiencing climatic change and its impacts at a micro-level [24]. Such knowledge and experiences are very important to assess the climate change scenario and its impact at the village scale, which helps to formulate suitable plans and policies in the specific region [25]. The Nepal Himalayan region has a complex and diverse topography that ranges from about 60 m to the top of the world (8848.86 m). The elevation range and presence of valleys and basins in-between produce their own characteristic microclimates [26]. Furthermore, there are 126 different socio-cultural groups in Nepal; for instance, the Indo-Aryan groups in southern Tarai, Tibeto-Burman in the High Mountain and the mixed caste and ethnic groups of these two groups in the Middle Hills with their own way of interaction with nature [27]. Differences in climate and socio-economic and cultural practices, however, not only give rise to the possibilities of diverse agriculture practices and production across the country [28], but farmers are also facing the differential effect of climate change at a local scale [11]. They are using their indigenous knowledge, practices and experiences, to minimize the impact such as shifting plantation time, rotation of the crops, and changing the variety and combination of crops [8,10]. Farmers' perception-based assessment at a household level is, hence, one of the suitable approaches to screening climate change issues, challenges and way forwards to mitigate climate change impact at a local level. It is also important to synthesize the problems and challenges, faced at a micro-scale especially to formulate plans and policies to combat the effect of climate change on a local scale [13,29].

In this context, the integrated approaches of farmers′ perception and experience and observed climatic data for the assessment of climate change scenarios and its impact on a farmer's livelihood in different ecological regions of the study area is advantageous. Although there are studies on climate change and its impact at different geographical scales in Nepal [8,13,16,26], a comparative study of the Mountain, Hill and Tarai regions at the basin scale in Nepal is still absent. Notably, the current climate change and impact research and practices have overlooked the wider socio-cultural context in which climate impacts are interconnected [30]. Therefore, this study aims to assess climate change including the farmer's perception and experience and its impact on rural livelihood in three different ecological regions of the Gandaki River Basin (GRB), Nepal.

2. Materials and Methods

2.1. Study Area

Nepal is divided into 3 distinct ecological regions based on elevation, vegetation and topographic characteristics, namely Mountain, Hill and Tarai. The study area comprises a total of 5 sample village sites from three ecological regions of Nepal (Figure 1), which includes one each, from the Mountain and Tarai regions, and 3 from the Hill region based on topographic characteristics, population distribution and socio-cultural diversity (Table 1). The elevation of study villages ranges from 170 m above sea level (masl) of Madi village in Tarai to 2100 masl of Thuman village in the Mountain region. The details of sample villages are provided in Table 1.

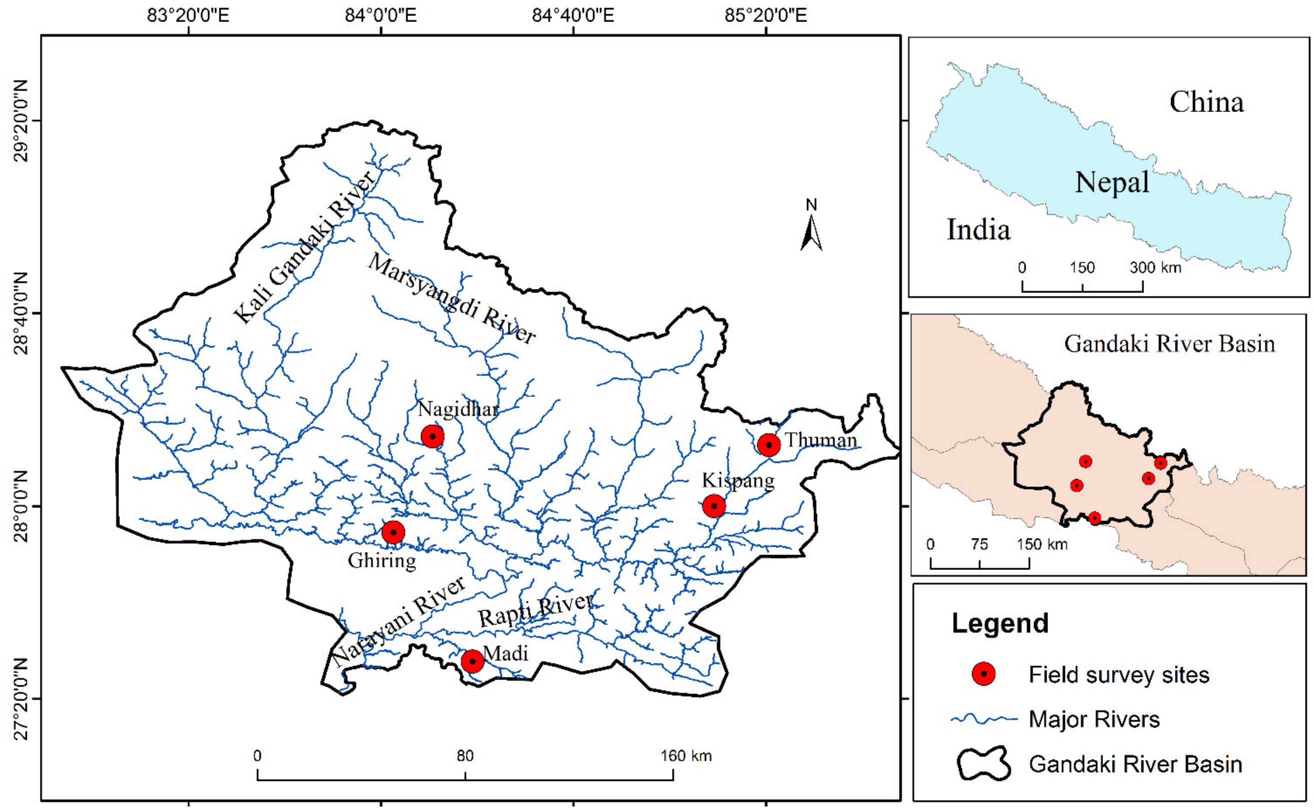

Figure 1. Distribution of sampled villages in the GRB, Nepal.

Table 1. Details of the study sites in the Gandaki River Basin.

Site of Sampling	District	Ecological Region	Elevation	Number of HSs
Thuman	Rasuwa	Mountain	2100	71
Kispang	Nuwakot	Hill	1400	25
Nagidhar	Kaski	Hill	1200	16
Ghiring	Tanahu	Hill	950	29
Madi	Chitwan	Tarai	170	71

2.2. Climatic Data and Household Questionnaire Survey

This study is based on observed climate data of the past 30-year period between 1990 to 2020, which is obtained from the Department of Hydrology and Meteorology of the Government of Nepal. It is based on the World Meteorological Organization standard and norms [31]. The observed data are collected from the nearest meteorological stations from the sample study sites. Temperature data are collected from 2 stations (Dhunche and Timure) and rainfall data from 3 stations (Dhunche, Timure and Thamchit) were collected in the Mountain region. For the Hill region, temperature data from 6 stations (Damauli, Khairinitar, Begnas, Malepatan, Nuwakot and Pansayakhola) and rainfall data from 5 stations (Damauli, Khairinitar, Ramjokot, Malepatan and Siklesh) were collected and analyzed. Similarly, for the Tarai region temperature data from 2 stations (Bharatpur and Rampur) and rainfall data from 3 stations (Bharatpur, Rampur and Madi-Kalayanpur) were collected. The assessment of temperature and precipitation trends was carried out based on obtained climatic station data. The perception and understanding of climate change by local people were assessed through household questionnaire surveys, key informant interviews (KII) and focus group discussions (FGD). A structured questionnaire was developed to screen the farmer's perceptions and impacts of climate change. The questionnaire was pre-tested in the Hill community village of the mixed socio-cultural groups and finalized afterwards. The study applied a simple random sampling method for the household questionnaire survey in five different villages within the three ecological regions. A total of 212 household questionnaire surveys were carried out representing an equal number from each ecological region between the period from 25 May to 23 June 2022.

2.3. Key Informant Interview and Focus Group Discussion

A total of 2 key informant interviews (KII) in each ecological region, totaling 6 KII, were carried out involving elderly farmers, local leaders and ward chairpersons. Moreover, to identify the overall climate change scenario and its impact in the selected villages, one focus group discussion (FGD) in each ecological region was also carried out. Local farmers, social workers, school teachers and local leaders of both gender were involved in the discussion. The group size ranged from 9 in Mountain village to 20 people in Tarai as the snowfall and drought data were not available from the meteorological stations, data and information on these were collected through KII, FGD and household surveys.

2.4. Climate and Field Survey Data Analysis and Tools

The observed climate data for the 30-year period between 1990–2020 was used for the Mann–Kendall trend test [32,33] and Sen's slope [34] was applied to analyze the climatic scenario over the past 30 years. The significance level was tested at the 95% confidence interval (*p*-value of 0.05). Socio-demographic and household characteristics of farmers, perception on temperature, rainfall, snowfall and drought trends and climate change impact were collected through household questionnaire surveys, KII and FGD. Data collected through these tools were triangulated based on selected indicators (knowledge and experience of weather and climate, means and access to climate information, education level, climate-related discussion forums, agencies and institutions) and analyzed descriptively using simple descriptive statistics such as percentage share and ordinal Likert scale ranking. The findings from observed temperature and rainfall data were comparatively analyzed to validate the perceived climate change trends in three ecological regions. Similarly, the climate change impact on livelihood data was also comparatively analyzed for three ecological regions. Ecological region-specific variability, both observed and perceived, in temperature and rainfall trends was identified at the final stage

3. Results

3.1. Climatic Trend

The analysis of the temperature data shows that the temperature in the Mountain region has been increasing at a rate of 0.0254 °C/a between 1990 and 2020, with a *p*-value of 0.159 at a 95% confidence level (Figure 2). The precipitation trend, on the other hand, shows a decreasing rate by −13.126 mm/a with a *p*-value of 0.239 (Figure 2).

The observed temperature trend in the Hill region is also increasing at the rate of 0.0921 °C/a between 1990 and 2020, with a *p*-value of 0.0001 (Figure 3). The temperature-increasing rate in the Hill region is found to be relatively higher compared to the rate in the Mountain and Tarai regions of the study basin. The trend of the annual total precipitation, however, shows a decreasing rate of −9.3998 mm/a with a *p*-value of 0.171 (Figure 3).

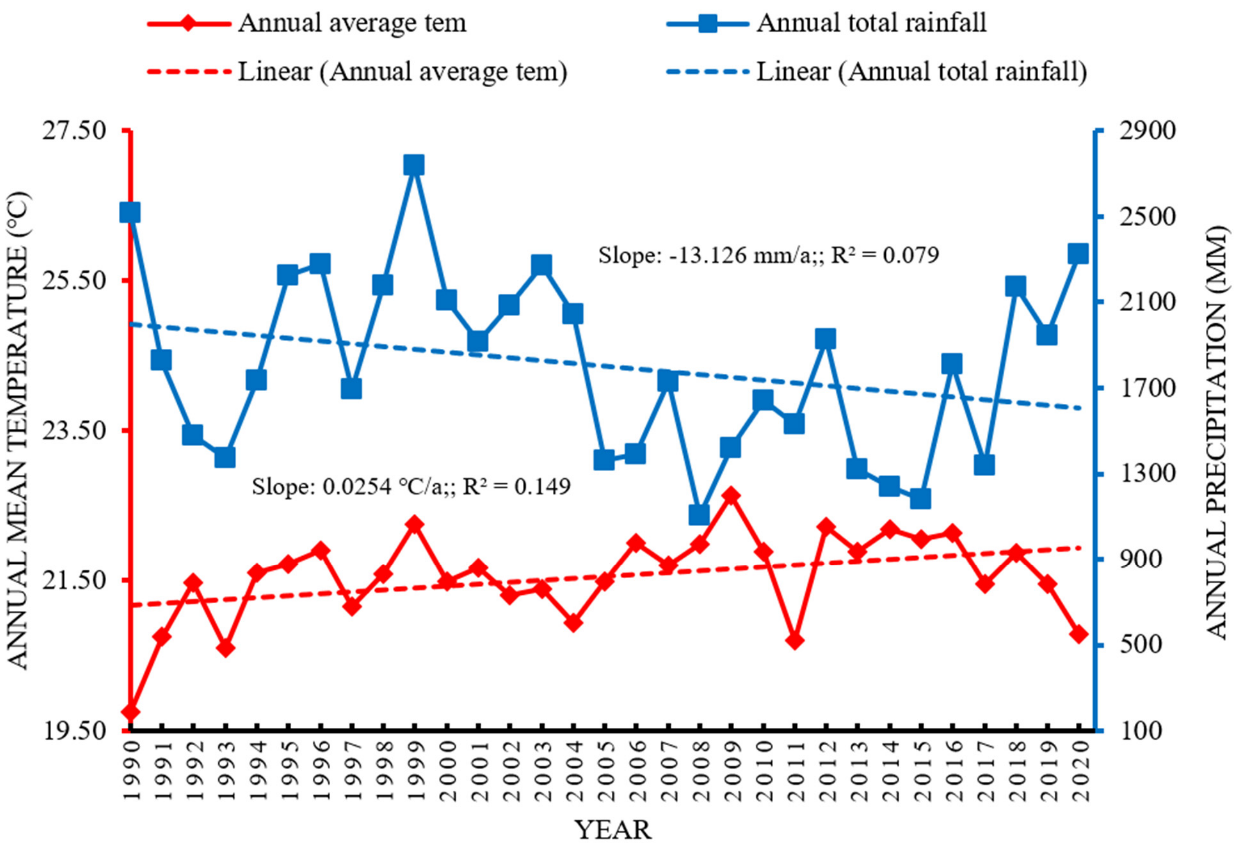

Figure 2. Temperature and precipitation trend in Mountain region of the GRB.

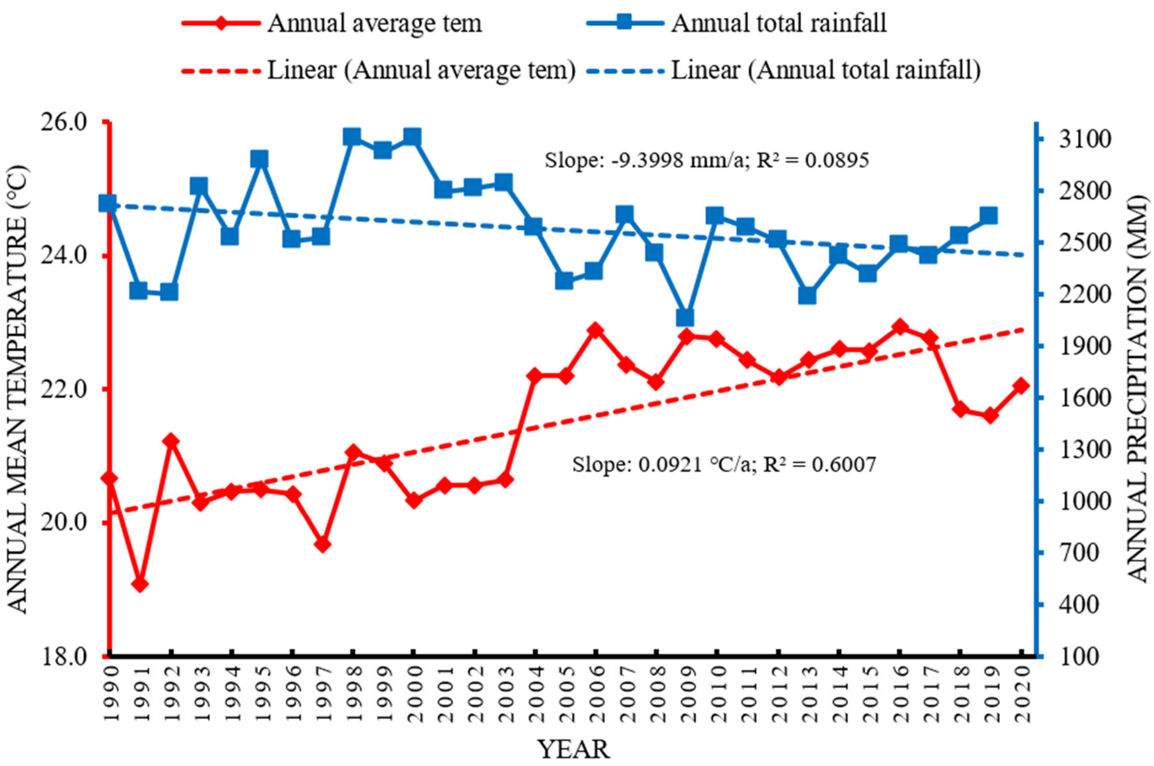

Figure 3. Temperature and precipitation trend in Hill region of the GRB.

The temperature of the Tarai region has been increasing by 0.0042 °C/a with a p-value of 0.382 (Figure 4). As compared to the Mountain and Hill regions, the temperature-increase rate was found to be quite lower in the Tarai region. Unlike the temperature, the precipitation trend of the past 30 years is found to be decreased by −5.0247 mm/a with a *p*-value of 0.488 (Figure 4) in Tarai. The variable temperature and precipitation trend, in all three ecological regions, indicate a changing climate trend scenario of the study basin.

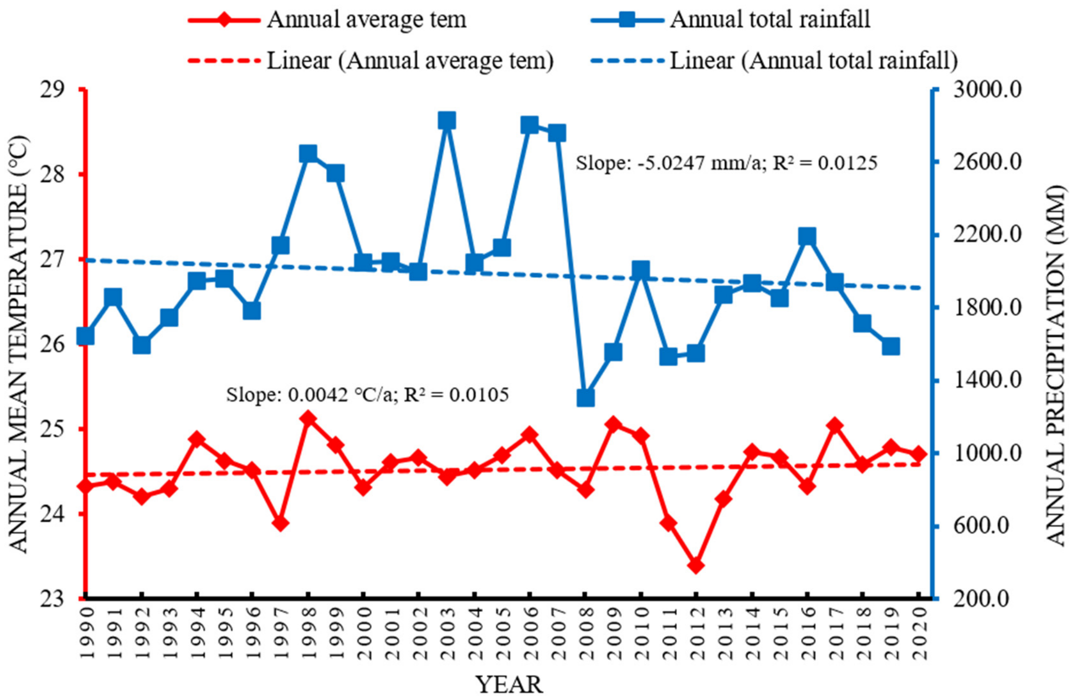

Figure 4. Temperature and precipitation trend in Tarai region of the GRB.

3.2. Household Demography and Characteristics of the Farmers

The ethnic majority of Tamang followed by Sherpa social groups are found in Mountain; whereas, a mixed social group of Gurung, Chhetri, Brahmin, Dalit and Magar are found in the Hill region. Tharu, an aboriginal group of Tarai, and Chhetri, Brahmin and Dalit are the social groups found in the Tarai region. Out of the total respondents, 57.55% were male and the rest, 42.45%, were female. In terms of education level, 34.43% were illiterate, and the rest, 65.57%, were the literate with different level of education status (Table 2). The average age of the surveyed farmers was 50.3 years, which is varied across the ecological region with a higher average age of 52.3 years in the Hill region. Regarding health condition, 91.04% of respondents are in good health, which was evidenced through active involvement in agricultural activities. The average family size was found to be 5.7 persons but the family size was found to be larger in the Hill region with 6.6 persons/household. The average annual income of the household, including remittance, was NRS 178093.07 (ca. 1463.38 USD; based on the exchange rate of 121.7 NRS = 1 USD in 2022), which was varied by ecological region. The highest average annual income was noted in the Hill region (Table 2) with NRS 259,957.1 (2136.05 USD), as the majority of the young people were involved in foreign labor migration and remittance contributing to higher annual income.

Regarding farmland ownership and the irrigation facility, the average farm size owned by farmers ranges from 0.33 hectare (Ha) in Mountain to 0.55 Ha in the Hill region (Table 3). Likewise, farmland abandonment is highest in Mountain and lowest in Tarai. Out of the total farmland, 24.24% is abandoned in the Mountain region, followed by 21.81% in Hill and 3.9% in the Tarai region. As far as irrigation is concerned, rivers and springs are major water sources for irrigation in Mountain and Hill; whereas, river canals and groundwater are major irrigation sources in Tarai. However, rain-fed farming practice is the most common in the Mountain and Hill regions.

Table 2. Household demography and characteristics of the farmers surveyed in GRB.

				HH by Ecological Region		
Household Head Characteristics	**Attribute**	**Total Number**	**%**	**Mountain**	**Hill**	**Tarai**
Gender	Male	122	57.55	36	41	45
	Female	90	42.45	35	29	26
Level of education	Illiterate	73	34.43	37	21	15
	Primary level (1–5)	61	28.77	17	21	23
	Secondary level (6–12)	77	36.33	17	27	33
	Higher education (>12)	1	0.47	0	1	0
Age (years)	Average age	50.27		47.8	52.3	50.7
Health condition	Good	193	91.04	64	63	66
	Poor	19	8.96			5
Family size	Average family size	5.7		5.5	6.6	5.1
Major occupation	Agriculture	202	95.28	67	65	70
	Business	7	3.31	3	3	1
	Service	2	0.94	0	2	0
	Livestock	1	0.47	1	0	0
Average non-farm annual income (NRS)	Family income including remittances	178,093.07		116,690.2	259,957.1	157,631.9

Total values were calculated based on 212 sample HH. Values by ecological region were calculated based on 71 HH in Mountain, 70 HH in Hill and 71 HH in Tarai region, where NRS is Nepalese rupees. Sources: Field Survey, 2022.

Table 3. Farmland ownership and irrigation facility.

Farmland Ownership			
	Mountain	**Hill**	**Tarai**
Average farm-land holding (Ha)	0.33	0.55	0.52
Abandoned farmland %	24.24	21.8	3.9
Irrigation Facility in the Farmland by %			
	Mountain	**Hill**	**Tarai**
Permanently irrigated	2.75%	6.56%	19.42%
Seasonally irrigated	27.56	48.77%	53.55%
Rain-fed	69.69%	44.67%	27.03%

Sources: Field Survey 2022.

3.3. Farmer's Perception and Understanding on Climate Change and Impact

The study screened through the farmers' knowhow and means of understanding climate change. The majority of the farmers (50.5%) responded that they know climate change and its impact through their own observation. It was followed by multiple means (18.87%), such as own observation, through public media, other people and social media (Table 4).

Farmers' observation of the temperature and precipitation trends is found to be variable in different ecological regions, though a general increase in temperature is observed by the majority. Out of the total respondents, 78.3% perceived that temperature has an increasing trend (Table 5). Similarly, 67.5% of the farmers perceived precipitation has an increasing trend. About 37% of the respondents perceived that drought event is also increasing, whereas 32.1% indicated no change. The perception of the farmers is varied by different ecological regions and summarized in Table 4. The participants of the KII and FGD also clearly mentioned the increasing trend of the temperature and the mixed opinion regarding the precipitation trend. However, there is a clear mention of the increasing winter precipitation and decreasing summer precipitation. Importantly, all key informants agreed on variability in precipitation amount and pattern.

Table 4. Farmer's sources of information on climate change.

CC Knowhow Means	Total HH	%	HH Mountain	HH Hill	HH Tarai
Self-observation	107	50.47	43	32	32
Other people	19	8.96	4	9	6
Public media (Radio, TV, Newspaper)	23	10.85	0	9	14
Social media	23	10.85	8	7	8
Combination of Self-observation, Other people, Public media and Social media	40	18.87	16	14	10
Total	212	100	71	71	70

Total values were calculated based on 212 sample HH. Values by ecological region were calculated based on 71 HH in Mountain, 70 HH in Hill and 71 HH in Tarai region, where NRS is Nepalese rupees. Sources: Field Survey, 2022.

Table 5. Farmer's perception and understanding of climate change.

Farmer's Perception	Attribute Details	Total Number	%	HH by Ecological Region		
				Mountain	Hill	Tarai
Temperature	Increased	166	78.3	40	59	67
	Decreased	8	3.8	7	1	0
	Not change	32	15.1	20	8	4
	Do not know	6	2.8	4	2	0
Precipitation	Increased	143	67.5	52	55	36
	Decreased	42	19.8	6	8	28
	Not change	19	8.9	7	6	6
	Do not know	8	3.8	6	1	1
Drought event	Increased	78	36.8	8	27	43
	Decreased	34	16.0	19	8	7
	Not change	68	32.1	27	22	19
	Do not know	32	15.1	17	13	2
Experience of extreme disaster events	Yes	144	67.9	43	44	57
	No	68	32.1	28	26	14
Impact on livestock	Yes	34	16.0	5	11	18
	No	178	84.0	66	59	53
Impact on crops	Yes	128	60.4	39	48	41
	No	84	39.6	32	22	30

Total values were calculated based on 212 sample HH. Values by ecological region were calculated based on 71 HH in Mountain, 70 HH in Hill and 71 HH in Tarai region., where NRS is Nepalese rupees. Sources: Field Survey, 2022.

The survey results show that around 67.9% of farmers experienced extreme disaster events such as floods, landslides, short-term heavy precipitation, drought and storm-hailstorm. The climate change impact observed by the farmers is mostly on the agriculture sector, particularly on cultivated crops. More than 60% of respondents noted the impact of climate change on their crops, and the highest percentage is shared by the Hill region (Table 5). KII and FGDs analysis, also confirm that climate change impact is largely on cultivated crops. A commonly noticed adverse impact of climate change is a decrease in agriculture production, as per the 46.5% who responded from the Tarai region (Table 6). Farmers perceived that climate change has not impacted human health much, new diseases with flu-like symptoms have been reported mostly through vector carriers such as mosquitos and white butterflies. Around 26% of farmers in the Hill region, 9.9% in the Mountain and 7.0% in the Tarai region reported such type of symptoms. Likewise, increased insects and rodent pest in crops in Tarai is found to be the dominant impact of climate change, whereas it is reported as the second dominant climate change impact experienced in Hill and Mountain (Table 6).

Table 6. Noticed adverse impacts of climate change.

Mountain Region	%	Hill Region	%	Tarai Region	%
Decrease in agricultural production	39.4	Decrease in agricultural production	41.4	Increased insect and rodent pests in crops	46.5
Increased insect and rodent pests in crops	21.1	Increased insect and rodent pests in crops	32.9	Decrease in agricultural production	22.5
Landslide and soil erosion	5.6	Damaged crops and vegetables	8.6	Increase in flood events	9.9
Others	11.2	Others	8.6	Others	15.4
None	22.5	None	8.6	None	5.6

Total values were calculated based on 212 sample HH. Values by ecological region were calculated based on 71 HH in Mountain, 70 HH in Hill and 71 HH in Tarai region, where NRS is Nepalese rupees. Sources: Field Survey, 2022.

The variable climate change impact is found on staple crop production in different ecological regions. Increasing rodents and pests, reduced yield, the collapse of terracing land and reliance on irrigation are major impacts, noticed regarding staple crop farming. From FGD and KII it is came to know that the monsoon onset has delayed or become unpredictable. In the past, heavy rain comes in July instead of June, delaying the recharging of the natural springs, which are major sources of irrigation to paddy fields in the Hill region. Snowfall in Mountain occurred in the third week of December and it was 3 to 4 feet deep, remaining unmelted for a week. However, in the last 10 years, snowfall occurs only in January and it is only half a foot deep and melts within two days. It has been three years without snowfall. Crop harvest is better during the year of snowfall because snow slowly melts and the soil remains moist for a longer period. Importantly, the impact of draughts has increased due to the decreasing amount of cow-dung manure to farmland. Draught usually occurs in March–April and crop plants dried before yielding grains. According to farmers, cow-dung manure keeps the soil moist. Nowadays, farmers use more chemical fertilizer and less cow dung, and plants are dried before yielding grain. In order to minimize the impact of climate change, farmers are practicing coping strategies such as changing crop varieties, improving irrigation systems, increasing agricultural input and using new technology. As the overall impact of climate change varied in different ecological regions, the coping strategies too varied.

4. Discussion

4.1. Climate Change Scenario: Observed and Perception Data

The majority of the past studies conducted in different parts of Nepal show the increasing rate of temperature and decreasing rate of precipitation [11,35]. The climate change scenario in different ecological regions of the GRB was found to be varied at different rates. The observed climate data clearly indicated that the annual temperature trend has risen in all ecological regions. However, the increased rate is found to be significant only in the Hill region, with a p-value of 0.0001. The region-wise perception of the farmers, on the other hand, shows that 94.4% of the respondents noted an increased annual temperature trend in the Tarai region, 84.3% in the Hill region and 56.3% in the Mountain region. The perceived temperature trend in all ecological regions coincides with the observed temperature trend. Further, the observed precipitation record shows a slightly decreasing rate of precipitation in all three ecological regions, but the value is not significant. The majority of the respondents perceived a variable precipitation trend more than the observed data. The observed data shows a slightly decreasing trend of precipitation; whereas, farmers perceived the increasing trend of precipitation with seasonal variability.

The discrepancy in observed and perceived/experienced precipitation trends can be attributed to the farmers' perception based on instantaneous experience. The observed record shows that the amount of precipitation for the last three years is increasing as opposed to the previous 27 years. Nonetheless, long-term scenarios (30 years or above) show that there was no such positive trend of precipitation. A similar finding was noted in the climate change study conducted among residents in a small community in Eastern Siberia [36] though most of the perception-based studies in the Himalayan region noted the observed climate data and people's perception within the same line/trend [8,23]. Hence, the finding of this study deviates from the previous studies regarding the perception of precipitation trends. This indicates that the recollection of the recent trend is a dominant perceived climatic phenomenon from farmers' perspective in contrast to long-term climatic trends. Notably, the deviation can also be attributed to the selection and inclusion of climate data stations at a local level, nearest to study sites and excluding regional/national climatic stations data, on which most of the previous studies have relied [8,13]. FGDs and KII discussion at a local level also acknowledged the increased precipitation trend in the last few years with seasonal variability and intense rainfall in a short duration compared to the past decade.

4.2. Climate Change Impact on Agriculture and Livelihood

Climate change and induced disaster events have impacted farming practices and farmers' livelihoods in different regions in different ways. Shifting planning and harvesting time, investing more time in maintaining production and even switching to secondary livelihood options where possible, to minimize climate change are some of the strategies adopted by farmers. Studies on climate change and drought indicated that the trend of the drought event is happening more frequently in recent decades, and such events adversely impacted the cultivated crops and people′s livelihoods [37,38]. The short-term intense precipitation has caused flood events, especially in the lowland, Tarai region, and landslides in the Hill and Mountain regions. Such flood and landslide events have caused losses to the lives of the people and damaged the agricultural crops affecting farmers' lives and livelihoods. The decline in production makes people's primary livelihood option more vulnerable. It is obvious that a decline in production, leads to a decline in agricultural income, putting additional economic burdens on the farmers to survive and sustain their livelihoods.

The present study found that variable temperature and precipitation trends in the study area have impacted farmers' livelihood and farming practices (Table 6). The detrimental impacts included a decrease in agriculture production, an increase in insect and rodent pests and crop damage and loss due to climate-induced hazards such as landslides in Hill and Mountain and flood and soil erosion in the Tarai region. Farmers indicated that a major impact is seen in crop production, i.e., a decrease in crop yield is noted by 39.4% of farmers in the Mountain, 41.4% in the Hill and 46.5% by the Tarai region and increased insect and rodent pests in crops (Table 6) leading to vulnerable subsistence farming and food insecurity. As a result of such climate change impact, people are abandoning their primary occupation of farming and shifting to the non-agricultural sector, such as construction labor, labor migration service, business and the tourism sector. The major consequence is the abandonment of farmland on a larger scale [39,40], which has further increased food insecurity in the region. The farmers reported through questionnaire surveys that almost 24.24% of the area of total farmland in the Mountain ecological region was abandoned, and it was 21.8% in the Hill region and 3.9% in the lowland Tarai region of the basin. Such abandoned farmland is distinctly visible in recent times, particularly in the Mountain and Hill regions compared to the Tarai region.

Agricultural water-related issues are also associated with climate change. Due to an increasing trend of temperature, irrigation sources are largely impacted. The declining volume of spring water is noted in the Mountain and Hill regions, which has directly impacted the cropping activities affecting livelihoods [41]. Rain-fed farming practice is the most common in Mountain (69%) and Hill (44%), though permanent irrigation facilities are limitedly available (2.7% in Mountain and 6.5% in Hill). Due to declining water quantity, farmers are forced to compromise on farming activities and look for alternative livelihood options. Farmers have claimed in the KII and FGD that about 40% of crop production has decreased due to decreasing rainfall and snowfall, seasonal variability and winter drought.

The occurrence of climate-induced extreme events has major impacts on cultivated crops, resulting in the decreasing production of major crops.

4.3. Policy Implication and Future Perspective

The majority of the farmers (94%) are unaware of climate change and agriculture-related policies, legislations and their implementation at a local level through agriculture subsidy, crop insurance, livestock insurance, adaptation programs and awareness activities, and agriculture-related interventions are implemented and are in practice (26% in Mountain, 57% in Hill and 40% in Tarai) in the study area.

Suitable plans, policies and strategies are needed to minimize climate change impact in different regions within GRB. The topographical and climatic variation, together with the socio-cultural diversity, necessitates region-specific strategies, plans and policies in order to mitigate climate change impacts and facilitate primary livelihood means of the farmers. The National Adaptation Programme of Action (NAPA) to Climate Change [42], and the National Framework on Local Adaptation Plans for Action (LAPA) [43] have made some strategies to mitigate the climate change impact on people's livelihoods. However, the strategies need to be timely updated and focus on region-specific issues based on the local climatic scenario, agricultural practice and indigenous knowledge of the peoples, which facilitate the mitigation of the climate change impact in the specific regions. Further, the plans are required to solve the impact of climate change on local residents in each ecological region. The local knowledge and experiences of farmers can contribute to updating existing adaptation strategies to mitigate climate change impact to favor climate resilience communities.

5. Conclusions

The observed climatic data and farmers' perceptions and experiences were used to screen the climate change scenario and its impact in three ecological regions of the Gandaki River Basin in Nepal. The study found an increasing temperature trend and decreasing precipitation rate between thirty-year period of 1990 to 2020. Local people have very rich knowledge and experience of climate change and its impacts. The majority of the farmers perceived that the temperature trend is increasing as compared to the past decade. The perception regarding drought events is, however, varied in different ecological regions. Major climate change impacts noticed are on staple crops, such as increasing pests and diseases in maize, paddy, wheat and millet in all three regions but with variable impact and decreases in crop production. The Hill region, followed by Mountain, is affected the most while livelihood options are very limited in the case of Mountain. Increased climate-induced events such as floods, landslides and hailstorms are also noted which have primarily impacted Tarai and Hill compared to the Mountain region. Climate change has, therefore, differential impacts on the different ecological regions of the GRB.

The comparative study of the observed data from the study villages and the household survey data shows that there are different trends of temperature and precipitation change and also differential impacts on crops and farmers' livelihoods. The national-level analysis often overlooked or present generalized pictures and can hardly capture the micro-scale realities in the complex geographical and socio-cultural context of the study area. Thus, this study clearly shows the need for climate change policies and strategies at a local scale so that climate change impacts can be addressed.

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