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Climate Change, Impacts and Adaptation in Chisankhugadhi Rural Municipality, Okhaldhunga - An Application of Perception-based Approach and Climate Data Analysis

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Abstract

Due to Nepal's extensive geographical, climatic, biological, and cultural diversity, perception and place-based studies provide useful information on climate change in the country. As no previous studies in the Chisankhugadhi rural municipality, Okhaldhunga had been done, this study used a household survey, focus groups, and key informant interviews to record local people's perceptions of climate change, its impact, and adapted adaptation practices, along with climate data analysis.Using the web-based version of ClimPACT, trends in the observed data for the nearby meteorological station Okhladhunga (1206) were determined for the period 1980-2020 to support people's perception. In the study area, the majority of respondents perceive that summer day and night temperatures, dry days, hot days, summer days, rainfall intensity, landslides, and droughts are increasing, while monsoon and winter rain, winter night and day temperatures, flood frequency and magnitude, and total precipitation amount are decreasing. Chi-squared (χ^2) test was used to examine the relationship between people's perception of climatic variables and climate change.The majority of people's perceptions are supported by trends in climate extremes, with the exception of total annual precipitation which shows increasing trends.

Impacts of these changes on agriculture, water resources, and biodiversity have been noted.Fundamentally, they have perceived a decline in agricultural production and productivity, improved fertilizer use, fruit and vegetable storage stability, drying up of water sources, deterioration of water quality, an increase in crop failure, populations of insects and pests, a change in the number and species of plants and animals, fish, and shifting vegetation.As an adaptation strategy, people have changed agricultural zones, crop varieties, and cropping patterns; switched to off-farm employment; planted tap roots and quickly growing plants like bamboo in steep barren slopes; avoided building new homes on steep slopes or in already flooded areas; and raised home foundations.

Keywords

Adaptation, Chisankhugadhi, Climate Change, Impacts Perception, Prioritization, Trends

1. Introduction

Currently, an estimated 3.6 billion people (roughly half the world's population) reside in areas that may lack water for at least one month of the year, and by 2050, that number is expected to rise to between 4.8 - 5.7 billion [1]. Flood risk is expected to increase from 1.2 billion people today to roughly 1.6 billion in 2050 (nearly 20% of the world's population) [2]. There is a 0.06 °C annual trend across the entire nation. For locations at high elevations, the warming rates get progressively higher [3]. As a result of the declining summer precipitation anomalies brought on by weakening wind anomalies with anti-cyclonic circulation and moisture divergence, the Indo-Gangetic plain and Nepal experienced increased drought after 2004. The summer drought index (SPEI4-Sep) showed inter-annual variation at a seasonal timescale in the Western region but decadal variation in the Central and Eastern regions [4].

Hydro-climatic data must be thoroughly analyzed to determine whether those extreme events are the result of climate change/variability (CCV), and then adaptation strategies must be developed in response. In order to address this need and understand its effects on various sectors and human responses, research in the social and physical sciences has already begun and expanded, providing useful qualitative and quantitative data, respectively. Statistical tools can be used in physical science to analyze observed hydro-climatic data in order to compute a variety of climatic indices and quantify historical trends [5, 6]. Developing CCV adaptation strategies will undoubtedly benefit from such analyses.

People's perceptions, however, which have been defined as the process by which they organize and interpret sensation to produce a meaningful experience of the world [7]. The perceptions are based on interactions with environmental elements, both natural and man-made, to varying degrees, depending on how well they enable certain perceptions. Local knowledge and experience regarding climate change and variability are included in the study's perceptions, which ultimately help people prioritize the various adaptation strategies [8]. The majority of perception-based studies demonstrate that locals' perceptions coincide with these temperature and precipitation trends [9, 10, 11]. However, research on climate change, its impacts, and perception in various regions is still lacking [12], which is crucial for identifying local and global contexts and creating generalized theories about how people respond to changing environments and associated risks [13]. Though rural residents are still unaware of how climate change is impacting various aspects, rural residents do notice unexpected occurrences in their surroundings [14]. People are skilled environmental observers who can recognize and interpret changes in their surroundings, which can be crucial in determining how society will react collectively to climate change [15].

The Chisankhugadhi rural municipality lacks research on people's perceptions of climate change and climate data analysis. The study's goals are to: i) assess perceived climate change variability, impacts of CCV, and identifying priority sectors and adapted adaptation strategies; and ii) assess the climate extreme trends of the nearby meteorological stations in the rural municipality area.

2. Materials and Methods

2.1 Study Area

Chishankhugadhi is a Rural Municipality in Nepal's Province No.1's Okhaldhunga district. Chishankhugadhi is divided into 8 wards and covers an area of 126.91 square kilometers. The elevation of the rural municipality ranges from 425 to 3200 meters above sea level. The rural municipality stretches from the Dudh Koshi bank to the high hill, with a diverse climate. The rural municipality has a tropical climate in the lowlands and a temperate climate in the higher hills. The rural municipality receives approximately 2940 mm of annual rainfall and temperature ranges from -1 °C to a maximum of 27 °C to 31 °C. The rural municipality has approximately 9561 thousand hectares of agricultural land and 2135 hectares of forest land. With an average family size of 5.92 and a population density of 154 people per square kilometer, the municipality has 19580population living in 3305 households. Animal husbandry is also practiced as a supplement to agriculture, which is the primary occupation of the residents. The area of the rural municipality used in the study is shown in figure 1.

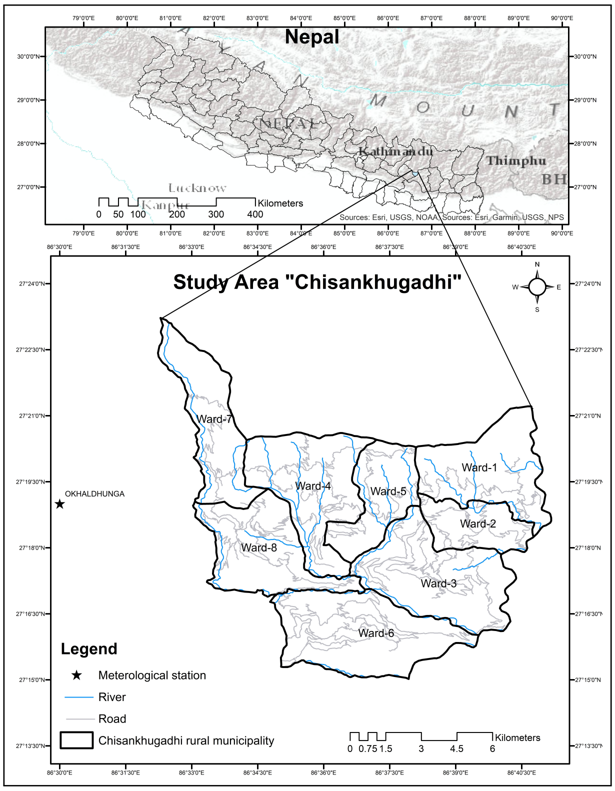

Figure 1: Chisankhugadhi Rural Municipality's location and relevant information

2.2 Methods

The perceptions of locals in the study area regarding climate variability are investigated using the Kobo Toolbox. These perceptions were further assessed using trends in historical data that had been observed,

Table 1: Coordination schema that shows a linkage among objectives, method/activities and data source

Objectives	Methods/Activities	Data and Sources
• To assess perceived climate change/ variability, impacts of CCV and identifying prioritization sectors, and adapted adaptation strategies	• Questionnaire design and pre-testing • Survey site selection; sampling size estimation • Survey implementation (using KoBo Toolbox) • Survey data analysis & interpretation using statistical software,SPSS	• Survey data; stakeholder consultations
• To assess the climate extreme trends	• Climate extreme determination using web -based version of Climpact	• Observed DHM data for station Okhaldhunga (1980-2020)

specifically in the temperature and precipitation from the nearby meteorological station Okhaldhunga (1206). Using the web-based version of ClimPACT, the trends in the historical data of the Okhaldhunga meteorological station were determined. Through Key Informant Interviewers (KIIs) and Focus Group Discussions (FGDs), as well as additional information from Households (HHs), surveys based on a questionnaire, adaptation strategies that are currently being used or that have the potential to fit in that area are identified. The participants for FGDs and KIIs were chosen after preliminary discussions with people familiar with the study area and after conducting a recce of the study area. The co-ordination schema used in our study showing a linkage between the study objectives, methods/activities used, and data and their source is shown in Table 1, which is explained in the following sub-sections.

2.2.1 Questionnaire design and pre-testing

The initial step involved developing a questionnaire using the best knowledge of perception-based studies inferred from a review of the literature. The following requirements were taken into account when developing the questionnaire: it needed to be brief and straightforward, free of words with multiple meanings, move from the general to the specific, be easy to understand, and be relevant to our study. Before it was introduced to the study area, the questionnaire was tested by participants at various levels to determine how it would address socioeconomic status, CC knowledge and perceptions, impacts, and capacity on adaptation processes. After that, the questionnaire was modified before the HHs survey questionnaire was finalized in response to their recommendations, comments, and feedback. The key questionnaire designed for HHs survey after necessary amendment is shown in Table 2 below.

2.2.2 HHs survey

Potential respondents were made aware that participating in the HH survey was entirely optional. People were asked to consent to taking part in the survey in full before each interview. Participants' rights were emphasized and upheld throughout the entire survey period. The study's participants were made aware that there would be no financial compensation or advantages for taking part. The community might benefit from the study's findings, though. Because of the HHs' high degree of dispersion, the sample was taken using a simple random sampling method. A total of 35 out of 3305 HHs (Rural Municipal Profile) from eight wards (Figure 1) were chosen. The study's location was chosen based on hazard-prone areas, settlement types and sizes, accessibility, and affordability through consultations with key personnel who reside in the rural municipality. Due to numerous constraints such as budget, time, and accessibility, we focused our HH survey on specific areas of the municipality.

2.2.3 Focus group discussions (FGDs)

First, by taking note of the worries and hopes of the residents in the study area, we created a conducive setting for brainstorming during the FGDs. After carefully focusing the discussion on their experiences with and opinions about CCV, we gradually started to draw their ideas and knowledge from them. We then further developed related ideas based on their experience.

2.3 Survey Data Analysis and Interpretation

Data from the HH survey were collected using the android application KoBo Toolbox, extracted from KoBo Toolbox, and processed using SPSS's statistical tools. In a similar manner to [6, 8] contingency tables and chi-squared (χ^2) tests were also carried out in addition to straightforward descriptive statistics like

Table 2: Key questionnaire designed for HHs survey

Change in climatic parameters	Impacts of climate change/variability	Adaptation measures
• Knowledge/understanding of climate change • Summer day & night temperature • Winter day & night temperature • Rainfall (monsoon and winter) • Intensity of rainfall Dry days • Dry days (shifting, occurrence)	• Agriculture (production, productivity, food security, etc.) • Water resources (changes in water amount, water quality, floods frequency and magnitude, etc.) • Bio-diversity (trees, birds,insects, wildlife, etc.)	• Prioritization sectors • Adaptation to droughts, floods, landslides,multi-hazard

summation and frequency to examine the relationship between people's perception of climatic variables and climate change. The Department of Hydrology and Meteorology (DHM) data for the nearby station Okhaldhunga from the municipality was also analyzed, along with people's perceptions of the situation. In order to correlate with data on people's perceptions, the various climate extreme indices were calculated using ClimPACT.

3. Results and Discussion

3.1 People Perception's on Knowledge/Understanding of Climate Change

80% of the 35 responders were men and 20% were women; 31% were illiterate, whereas 69% were literate; 17% were over 60 years old, while 83% were between the ages of 19 and 59; 60% of the respondents were Janajati, followed by 17% Brahmin, 14% Chettri, and 4% Dalits; 43% of households utilized both firewood and LPG for cooking,37% used bio-mass, 17% used LPG, and 3% used both firewood and bio-gas; 83% of respondents used electricity for lighting, 11% used both electricity and solar power, and 3% used solar power and 3%used both solar power and bio-gas, 80% of respondents homes used galvanized sheet, 11% used concrete roofed,6% used straw or hatched, and 3% used tile or slate. 54% of respondents say they have heard about climate change, 40% haven't, and 2% say they are unsure. Of the 54% who are aware, 32% learned about it through television, 32% from radio, 16% from awareness campaigns, 16% from newspapers or publications, and 5% from some other source but almost all respondents (89%) are aware of CC issues based on their own observations, such as thermal discomfort due to high summer temperatures and erratic rainfall. The vast majority of respondents perceived an increase in both summer day (94%) and summer night (91%) temperature, but 54% perceived a decrease in both winter day and night temperature, and some did not experience any change in both summer day and night as shown in Figure 2a. The amount and timing of rainfall has also been perceived to vary over the course of the seasons which is shown in Figure 2b. 37% of respondents perceived a shift in the start of dry days, 49% believed there was no change, and 14% had no idea; among the 37%, 85% noted an early start of dry days and 15% a late start of dry days. Figure 2c depicts the change in the length of dry days observed in response to people's perceptions over the past and present decades. The computed temperature and

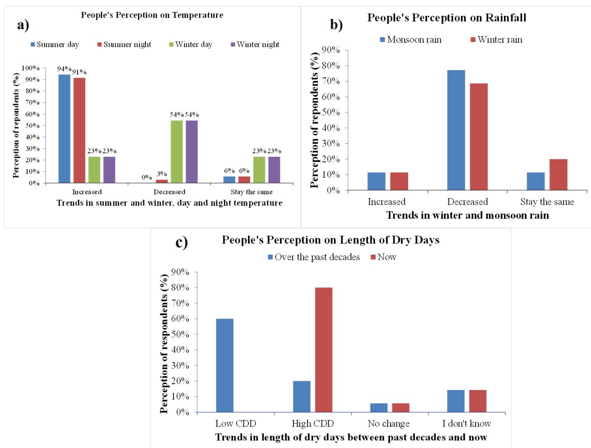

Figure 2: People's perception on CC in Chisankhugadhi Rural Municipality: a) Temperature; b) Rainfall; c) Dry days

precipitation trends corresponded well with people's perceptions of CC in the study area. Most of the tests conducted between people's perceptions of climatic variables yielded statistically significant results at the 5% level of significance using Chi-squared (χ^2) tests.But the p-value for forest fires is 0.412 and is higher than 0.05, it can be inferred that the sample does not accurately represent the views of all residents of rural municipalities regarding the increase in forest fires. It confirmed that the majority of the interviewed locals had experienced climate change in some form

Table 3: Chi-squared (χ^2) test for perceived climate change and climatic variables in study area

Perceived change / variability in	% of responses	p-value	Perceived change / variability in	% of responses	p-value
Summer day temperature (+)	94.3	0.000	Change in the amount of water in river, stream, lakes - Dry Season (-)	82.9	0.000
Summer night temperature (+)	91.4	0.000	Change in the amount of of water in river, stream, lakes -Monsoon season (-)	85.7	0.000
Winter day temperature (-)	54.3	0.032	Change in water levels of ponds/kuwa/well (-)	80.0	0.000
Winter night temperature (-)	54.3	0.032	Community fire (=)	60.0	0.003
Monsoon rain (-)	77.1	0.000	Coldwave (=)	48.6	0.003
Winter rain (-)	68.6	0.000	Diseases/insects (+)	88.6	0.000
Rainfall intensity (+)	71.4	0.000	Windstorm (=)	45.7	0.036
Shifting in beginning of dry days (×)	48.6	0.041	Droughts (+)	93.3	0.000
Lightening (=)	54.3	0.000	Forest fire (+)	40.0	0.412
Landslides (+)	62.9	0.001	Flood (-)	37.1	0.036
Heatwave (=)	77.1	0.000	Flood frequency (-)	42.9	0.074

(Note: "+" means increase; "-" means decrease; "=" means no change; "×" means no)

or another. Additionally, more than 88% of respondents believed that disease/insects and droughts have increased in the study area over the past few years as shown in Table 3.

Seasonal and annual trends in temperature and precipitation indices of nearby municipal stations in order to assess people's perceptions is shown in Table 4. The table illustrates how well local residents' perceptions of changes in annual and seasonal precipitation, rainfall frequency, and temperature in the summer and winter seasons match the trends in the measured data. Because people can't generally recall the climatic conditions and specific events from the distant past, it was found to be reasonable to take recent times into account when analyzing hydro-climatic parameter trends. According to the station data, the mean daily mean temperature (TMm) for all seasons and annual shows statistically significant increasing trends, indicating that the temperature in the regions is rising. This is supported by the trends of maximum of maximum temperature (TXx) and minimum of maximum temperature (TXn), which also show statistically significant increasing trends. Cold days (TX10p) and hot days (TX90p) trends show statistically significant decreasing and increasing trends in the region, respectively, whereas cold nights (TN10p) and warm nights (TN90p) trends show statistically significant increasing and decreasing trends in the region, respectively, but cold nights in the monsoon show decreasing trends. Summer days (SU) in the region show statistically increasing annual and seasonal trends, with the exception of the winter season, which shows no trend. Consecutive dry days (CDD) show statistically significant increasing trends in the regions, indicating that dry days are increasing in the region, whereas consecutive wet days (CWD) show no trend. The daily precipitation intensity (SDII) is increasing slightly in the regions. Total wet day precipitation, i.e. (sum of daily precipitation $\geq$ 1.0 mm), increases in the annual, pre-monsoon, and post-monsoon seasons while decreasing in the winter and monsoon seasons.

3.2 Perceptions on Impacts of Climate Change

3.2.1 Agriculture

66% of the respondents said they were involved in agriculture, however the majority did subsistence farming on small plot of land. Production in the area is dropping along with the decline in productivity as a result of the increase in temperature and irregular rainfall. The main effects in the regions include an increase in weeds, blight, and harmful insects, as well as a change in the vegetation. This results in reduced fruit storage stability. Locals believe that plants and agricultural products growing at lower altitudes produce superior results at slightly higher altitudes. Figure 3 shows the severity of CC impacts on agriculture sector from the people's perspective. Even though agriculture employs the vast majority of people, most of them can only survive for six months

Table 4: Trend in annual and seasonal temperature and precipitation indices of Okhaldunga station (1206) for the period of 1980-2020

Extreme Indices	Annual	Winter (DJF)	Pre-monsoon (MAM)	Monsoon (JJAS)	Post-monsoon(ON)
Maximum of maximum temperature (TXx)	**0.047**	**0.122**	**0.042**	**0.072**	**0.114**
Minimum of maximum temperature (TXn)	**0.063**	**0.088**	**0.105**	**0.058**	**0.056**
Maximum of minimum temperature (TNx)	-0.015	0.015	-0.029	-0.013	0.011
Minimum of minimum temperature (TNn)	0.000	0.000	-0.020	0.000	0.000
Cold days (TX10p)	**-0.468**	**-0.501**	**-0.344**	**-0.421**	**-0.413**
Hot days (TX90p)	**0.455**	**0.415**	**0.398**	**0.394**	**0.292**
Cold nights (TN10p)	0.027	0.106	0.060	-0.011	0.000
Warm nights (TN90p)	-0.061	-0.035	**-0.229**	-0.030	-0.040
Summer days (SU)	**2.746**	0.000	**0.711**	**1.82**	**0.286**
Mean daily mean temperature (TMm)	**0.036**	**0.046**	**0.022**	**0.031**	**0.037**
Consecutive dry days (CDD)	**0.617**	-	-	-	-
Consecutive wet days (CWD)	0.617	-	-	-	-
Daily precipitation intensity(SDII)	0.007	-	-	-	-
Annual total wet-day precipitation (PRCPTOT)	0.234	-0.346	1.073	-1.226	0.196

(Bold indicates the statistically significant at 95% confidence interval)

on their own production. The cost of production has risen, and as a result of low productivity, the majority of the population is looking for new jobs, and young people are losing interest in agriculture.

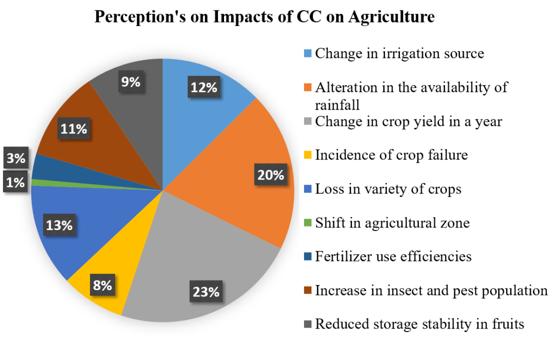

Figure 3: Pie-chart showing impacts of cc on agriculture from people's perspectives

3.2.2 Water resources

The amount of rainfall is decreasing compared to previous decades, while the intensity of rainfall is increasing (i.e. a large amount of rainfall in a short period of time), resulting in an increase in the length of consecutive dry days and a decrease in the length of wet days. However, in terms of rainfall, this year has been exceptional, with people experiencing an increase in rainfall throughout the year. Some respondents have also reported a shift in the seasonal time frame this year. The change in water levels in rivers, rivulets, and spring over the course of season as per people's perception is shown in Figure 4. similarly, 80% of respondents perceived that the water levels in kuwas, wells, and ponds had decreased, while 9% perceived that the levels had increased, 9% perceived that there had been no change, and 3% had no idea; 54% answered 'no' that the quality of water in kuwas, wells, and ponds is not deteriorating, 40% answered 'yes', 3% answered 'no change' and 3% have no idea. Flood frequency was perceived to be increased by 43% respondents, decreased by 26%, unchanged by 17%, and unknown by 14%. Similarly, 63% perceived a decrease in flood magnitude.

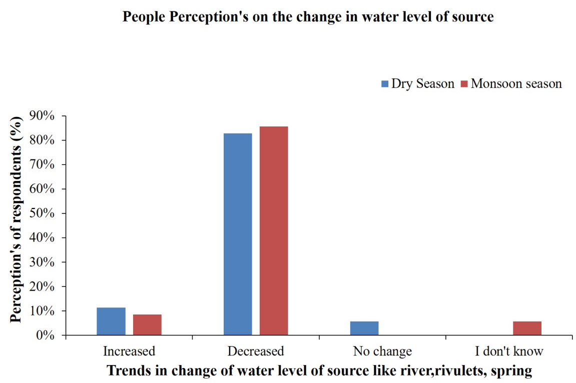

Figure 4: People's perception on the change in water level of river, rivulets, and springs in two different season

3.2.3 Bio-diversity

The impact of CC on bio-diversity in the surveyed region as per people perception is shown in Figure 5. The majority of respondents reported a change in the number and species of grass/fodder, trees, birds, insects, and wildlife in the surveyed areas. Similarly, the majority of those mentioned no change in the number and species of medicinal and non-timber forest products, aquatic plants, and aquatic animals that exist in the regions.

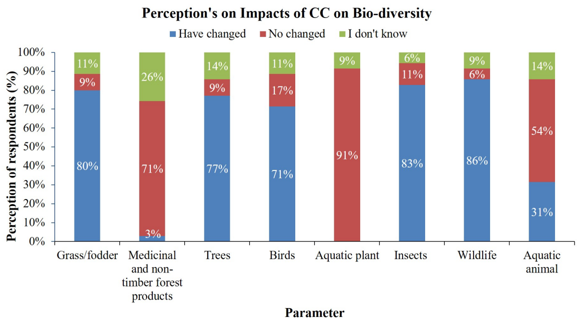

Figure 5: People's perception on the impact of cc on bio-diversity

3.3 Adaptation trategies

3.3.1 Prioritization sectors

Based on the field surveyed; HHs, KII, group discussion and expert consultations the prioritization sectors that need to be addressed are identified. The prioritized sectors are given in priority order according to the field survey: • Protection of water source • Protection of crops from the attack of wild animals like monkeys, deer, etc and from insects • Bio-engineering to prevent from landslides • Afforestation • Practice of earthing • Design of farm pond • Awareness on climate smart agriculture • River training work to prevent from flood • Rural electrification

3.3.2 Droughts adaptation strategies

To address the issue of drinking water scarcity, it was discovered that a community water supply system was implemented in some regions, with a common water tap for 10-15 households. To cope with the impacts of droughts on agricultural systems, the majority of respondents stated that they are mostly practicing; change in cropping pattern (change in crop rotation, inter-cropping), increased use of organic fertilizers, shifted to off-farm employment, change in planting dates (seedlings, etc), land left fallow, non-conventional irrigation system, diversify crop to less water consumption, etc.

The majority of the region's agricultural land is rainfed, which makes it difficult to deal with rising temperatures and a tendency toward more consecutive dry days as shown in Table 4. Less water-intensive crop varieties, mulching techniques, promoting knowledge of climate-smart agricultural systems, crop and livestock insurance, seed banks, cold storage, and soil moisture conservation strategies are recommended adaptation practices in the region.

3.3.3 Floods adaptation strategies

Flash floods are becoming more common in the regions due to an increase in precipitation intensity. Some of the adaptation strategies adopted by local people include avoiding already flooded areas for housing, raising household foundations, and constructing barriers in flood-prone areas. According to the field data, local people have not developed a comprehensive strategy on their own, but with local government assistance, they have installed rock beams, rock rip-raps, sandbags, and vegetation on the slopes.

Local governments are seeking technical and financial assistance from the central government and other institutions in order to identify flood risk areas and build structural measures, as well as develop infrastructure for safe community housing to safeguard flood-affected households.

3.3.4 Landslides adaptation strategies

To prevent landslides, locals are planting tap roots plants and quick growing plants like bamboo in steep slope barren land and avoiding building houses on steep slope areas. Local governments are attempting to identify landslide susceptibility zones and design structural and bio-engineering measures to avoid landslides in partnership with the national government and other organizations that provide technical and financial help.

Landslides have increased in the study region as a result of unplanned and hazardous road construction. As a consequence, professionals and locals agreed that prior to the construction of physical infrastructure such as roads, appropriate study and planning must be performed.

4. Conclusions

With the aid of trend analysis of historical climatic data from the nearby meteorological station, this study has used a perception-based approach to assess CC and its impacts, identify sectors for prioritization, and adaptation strategies to boost community resilience. Locals have noted a decrease in the frequency of flooding, a reduction in the amount of precipitation, an increase in summer daytime temperatures, as well as a decrease in winter daytime temperatures as a result of CCV. When processed in SPSS after proper digitization, the majority of the respondents' data displays statistical significance.

Reduced crop yield, decreased soil productivity, shifting of agricultural zones, increased crop failure owing to pests and insects, are some of impacts of climate change on agriculture. These impacts result in increasing production costs, a shifting to off-farm jobs, and food insecurity. The impacts on water sources include a decline in the amount of water at the surface of springs, rivers, lakes, and other bodies of water, a decline in the quality of rivers and other water sources, the drying up of water sources, and a reduction in the frequency and magnitude of floods. The vegetation in the areas has changed, and that the number of wild animals, particularly monkeys, deer, and porcupines has increased in almost all of the survey regions. Decline in the species and number of birds and fishes found in the study area.

Prioritization sectors include water source protection, crop protection from wild animal and insect and pest attack, afforestation, farm pond design, and climate-smart agriculture awareness. Changing agricultural zones, crop varieties and cropping patterns, shifting to off-farm employment, planting tap roots and quickly growing plants like bamboo in steep barren slopes, avoiding building new homes on steep slopes or in already flooded areas, and raising home foundations are few of the adaptation strategies employed by the residents of the study regions.

In the annual and seasonal (winter, pre-monsoon, monsoon, and post-monsoon) observed meteorological station of the nearby study area, shows increasing trends in TXx, TXn, hot days (TX90p),summer days,cold nights (TN10p), TMm, CDD, CWD, SDII, whereas decreasing trends in TNx, cold days (TX10p),warm nights (TN90p) and no trends in TNn. The trends in precipitation amount shows increasing in annual,pre-monsoon, post-monsoon where as decreasing in monsoon and winter season. It demonstrates that people perceive temperature and precipitation trends in the study area well, except for total annual precipitation trends.

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