Assessing the Climate Change Vulnerability of the Communities Residing in Doda River Basin, Far Western Nepal

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ABSTRACT

The study evaluates the vulnerability and climate change (CC) impacts on livelihood-related services aiming to identify strategies for enhancing resilience and adaptation. Key aspects of the study include the analysis of hydro-meteorological data, examination of climatic variability evidence, and vulnerability assessments related to CC. Vulnerability to CC varies based on exposure, sensitivity, and adaptation capacity, especially within a small spatial scale. Employing a bottom-up approach, the study applied trend analysis, Mann-Kendall statistical trend, IPCC vulnerability equation, and the Capacity Building and Vulnerability Assessment (CBCA) framework as fundamental methodologies. Meteorological and household data validate climatic trends and vulnerability. Significant changes in climatic parameters are observed, mirroring previous studies. Local communities experience decreased rainfall frequency, frequent floods, extended dry seasons, delayed monsoons, and intense late summer rainfall, verified by data from the nearest meteorological station. The exposure index ranges from 2.35 to 3.87, with wards 1 and 6 of Laljhadi Rural Municipality (RM) having the least exposure while ward 3 the highest, according to respondent perceptions. Sensitivity is highest in wards near the Doda River, with ward 4 having the highest sensitivity index. Adaptive capacity indices range from 2.01 to 3.68, with the least in wards 1 and 6. The highest vulnerability is observed in wards 3, 4, and 2 with vulnerability scores of 16.8, 13.6, and 11.1, respectively. Overall, the vulnerability calibration index indicated low adaptive capacity across all wards, emphasizing the need to enhance adaptive capabilities as a key recommendation for reducing CC vulnerability.

Keywords: Climate change, Trend analysis, Vulnerability, Adaptation strategies

1. Introduction

It's unequivocal that the global climate change is raising threats to the earth's system and human wellbeing. The impacts mainly threaten the countryside communities that are more dependent on natural resources (Maharjan *et al*. 2011). While climate change poses a universal challenge, its repercussions vary across regions, nations, industries, and communities. The scientific and political communities are increasingly prioritizing the examination of climate change and its effects on livelihoods. Projections indicate that the consequences of climate change will exert significant and detrimental impacts on both societies and economies (Panthi *et al*. 2016; Poudel *et al*. 2020; Sujakhu *et al*. 2019). The vulnerability to climate change is contingent upon diverse factors and varies across locations, sectors, and communities. Those residing in developing nations, relying predominantly on subsistence livelihoods linked to agriculture and livestock production, are notably recognized as vulnerable. Nepal, characterized by a predominant mixed agro-livestock system among its population, has been identified as the fourth most vulnerable country to climate change globally (Panthi *et al*. 2016).

People who are socially, economically, culturally, politically, institutionally or otherwise marginalized are vulnerable to CC (IPCC 2014) because adaptive capacity to CC depends on physical resources, access to technology and information, varieties of infrastructure, institutional capability, and the distribution of resources (Yohe & Tole 2002). The degree of a system's sensitivity to climatic hazards also depends on socio-economic factors such as population and infrastructure (Parry *et al*. 2005). Climate vulnerability, the extent of a system or a community being susceptible to or unable to cope with the adverse effects of CC including climate variability and extremes, is an urgent issue among many countries, impoverished and developing ones (Giri *et al*. 2021). It is a function of exposure, sensitivity, and adaptive capacity regarding a specific risk (IPCC 2014) and depends not only on the system's sensitivity but also its ability to adapt to new climatic conditions. (Cutter *et al*. 2000) points out that vulnerability to CC can be decayed into three distinct components; risk of exposure to hazards, capability for social response, and attribute of places such as geographical location.

The concept of CC vulnerability helps to understand the cause/effect relationship behind CC, its impact on people, the economy, and socio-ecological systems (Fritzsche *et al*. 2014). On the other hand, Vulnerability Assessments (VAs) and Climate Risk Assessments (CRAs) help identify the nature and extent to which CC and its impacts may harm a country, region, sector, or community. The assessments of vulnerability and/or climate risks are therefore a central component of adaptation action. Vulnerability varies across temporal and spatial scales (Kayastha *et al*. 2023) and depends on economic, public, geographic, cultural, institutional, and environmental factors (Giri *et al*. 2021; Kayastha *et al*. 2023; Pandey & Jha 2012). In many developing countries, including Nepal, high vulnerability and direct exposure are also the outcomes of shortsighted development processes made more inadequate by environmental mismanagement (Dixit *et al*. 2015). Nepal, with predominantly natural resource-based livelihoods, and a low level of adaptive capacity due to higher incidence of poverty, is placed among the most vulnerable country to CC (Oxfam 2009).

The latest study shows that the maximum temperature of Nepal increased by 0.45 °C per decade from 1976–2015 (Thakuri *et al*. 2019). It is predicted that intense precipitation of quick duration will intensify problems like flooding, landslides, and sedimentation (NCVST 2009; NAPA 2010). Vulnerability science operates on the premise that human populations play a mediating role in environmental change, thereby influencing its impacts. Consequently, the bottom-up approach can be applied in crucial policy and practical contexts, emphasizing the interconnectedness of society and nature (Pandey & Jha 2012). There is a scarcity of knowledge and information regarding the specific ways in which climate hazards are affecting livelihood resources, the diverse impacts of climate change on various well-being groups, and the responses of impoverished individuals in the mountainous regions of Nepal to climate changes. Examining the varied impacts of climate change is crucial in Nepal's historically hierarchical society, characterized by widespread poverty linked to rural-urban disparities, geographical variations, gender distinctions, and caste/ethnic divisions (Aryal *et al*. 2014; Bista 2023; Gentle & Maraseni 2012)adaptive capacity is low due to limited information, poor access to services, and inequitable access to productive assets. Few studies have reported on the current status of rural and remote mountain areas in Nepal with little known about adaptation strategies in use. This article is based on a study in the remote mountainous Jumla District of Nepal to explore how climate change is affecting the livelihood of local communities and how different wellbeing groups are differentially impacted. Looking from a wellbeing lens, adaptation practices by households as well as local support mechanisms were explored to predict the severity of effects now and into the future. Using a climate vulnerability and capacity analysis (CVCA.

The present study analyzed the perceptions and evidence of climate variability, adaptive capacity, and vulnerability to CC among rural communities in the Doda River Basin, Laljhadi RM, Kanchanpur district, Sudurpashchim Province, Nepal. Utilizing a bottom-up assessment approach, the research explores local perspectives on climatic and non-climatic drivers of change and their effects on livelihood-related services. The goal is to identify adaptation options for creating a climate-resilient community. The study addresses academic and policy needs by developing a vulnerability index to assess climate change vulnerability at the community level. The methodology aims to connect community priorities with macro-level policies, emphasizing that higher-level planning should be informed by insights gained at the local level. Through a bottom-up approach, the proposed index identifies urgent adaptation needs and local coping strategies, providing recommendations for prioritized action and contributing to a comprehensive, integrated model for enhancing climate resilience at national, regional and local levels.

2. Materials and Methods

2.1 Study Area

Doda River Basin, spanning from 28°50’59.69” N to 28°39’54.68” N and 80°20’15.9” E to 80°30’0.54” E, encompasses an area of 154.65 km^2. It includes two primary river channels, the Syaali River and the Banara River, situated within Laljhadi Rural Municipality. It is located in Laljhadi RM, with predominantly flat topography and is positioned 46 km to the east of the district headquarters, Bhimdatta Nagar, in the Kanchanpur district of the Sudurpashchim Province, Nepal (Fig. 1). The population of the Rural Municipality is reported as 25,037 according to the census conducted in 2078 BS. The study zone primarily covers the six wards of Laljhadi RM. Krishnapur and Punarwas Municipality lie to the east of Laljhadi RM, with Shuklaphanta and Belauri Municipality comprising its western boundaries. The northern boundaries are shared with Shuklaphanta and Krishnapur Municipality, while to the south, it is contiguous with Belauri and Punarwas Municipality. Laljhadi RM holds significant religious, social importance, and possesses unique characteristics. The predominant ethnic groups in Laljhadi Rural Municipality are Tharu, Bahun/Chetri, and Dalit, with RanaTharu also considering this area as their home. The RanaTharu community constitutes approximately 80% of the local population. Kanchanpur district is classified as moderately vulnerable concerning temperature, rainfall, and flood vulnerability (MoE 2010).

The study area is characterized by a subtropical climate, typical of the Terai region of Nepal. The wet season typically spans from June to September, coinciding with the South Asian monsoon, during which the area receives the majority of its precipitation. The average annual rainfall over the 34-year span from 1985 to 2019 is about 3459.79 mm, however average annual rainfall in winter 142.68 mm, pre-monsoon 179.61 mm, monsoon 2468.75 mm and post monsoon 99.92 mm. The study area accounts an average maximum temperature of 30.55°C and an average minimum temperature of 17.58°C for the same 34-year period, as documented by weather stations situated in Attariya (station no. 209) and Mahendranagar (station no.105). In terms of land use, agricultural land occupies approximately 6654.85 ha (43.17%), water bodies encompass about 1153.43 ha (7.48%), settlement areas encompass around 1026.13 ha (6.66%), and forest area spans about 6579.82 ha (42.69%).

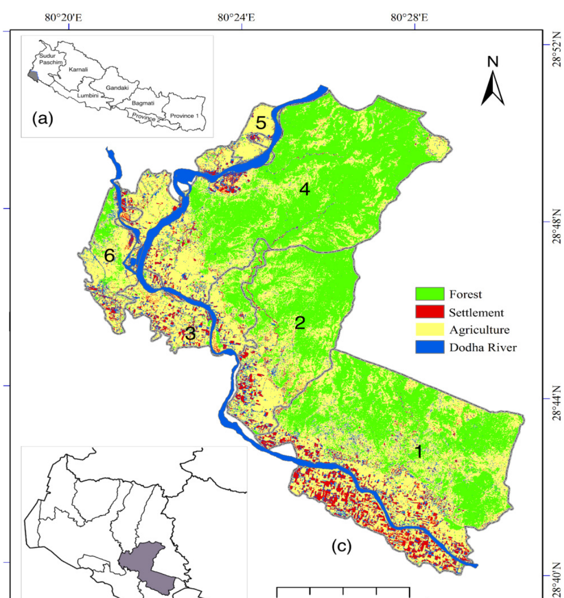

Fig. 1: Map showing the study area with land cover classification in Laljhadi RM, Kanchanpur district, Sudurpachim Province (b). A map of Nepal is shown in the inset (a).

2.2 Analytical Procedures and Methods

An analytical framework was developed for a systematic assessment of the factors contributing to vulnerability. Subsequently, a comprehensive approach to data collection was executed, incorporating both quantitative and qualitative methods. The objective of this methodology was to thoroughly appraise the vulnerability of the specified study site by employing the parameters established in the framework. Table 1 outlines the parameters and indicators used to evaluate the components of vulnerability, categorized into Adaptive Capacity, Exposure, and Sensitivity. For each criterion, specific indicators were identified and rated on a scale of 1 to 5, ranging from very low to very high perception, as per the NAPA (GON), 2010, and household questionnaire sources.

Table 1: Parameters and indicators used for assessing the vulnerability components

Parameter	Indicator
Adaptive Capacity	
Human	Literacy rate, Per capita income, Awareness on CC, Profession
Social	Households affiliated to a formal and informal institution, Number of CBOs, NGOs, GOs,
Financial	Total number of cooperatives and banks
Physical	Infrastructure for services, schools, metaled road, bridge
Information	Communication source
Exposure	
Temperature	Hot days, hot waves, and cold waves
Precipitation	Monsoon Rainfall, winter rainfall, change in rainfall duration
Indicator	Appearance and disappearance of species, change in sowing period
Climate-induced disaster	Flood and drought events
Sensitivity	
Agriculture and food security	Loss of crop production, livestock products, agricultural land, a decline in cash crop productivity
Forest and biodiversity	Forest coverage, increasing and spreading of invasive species, forest fodder dependency, a decline in forest products
Human settlement and infrastructure	Community settlement and Infrastructure, types of the shed, distance from the river
Water resources	Water bodies and their quality
Energy Demand	Dependency on traditional biomass energy
Gender	Total number of male and female ratio

**Each criteria indicator was ranked as 1 for very low, 2 for low, 3 for medium, 4 for high, and 5 for very high perception (Source: NAPA 2010 & HH Questionnaire)*

2.3 Data Collection

A comprehensive field survey was carried out at the study site, encompassing household surveys, key informant interviews, focus group discussions, and community transect walks to gather primary data. Climatic data, specifically temperature and rainfall information, were acquired from two meteorological stations: Station Index 209 in Attariya and Station Index 105 in Mahendranagar. These data, spanning 35 years from 1985 to 2019, were obtained from the Department of Hydrology and Meteorology, Government of Nepal (GON/DHM 2020), with a monthly temporal resolution.

2.3.1 Household Survey

A systematic approach was employed to survey 145 households out of a total of 3909 households in Laljhadi Rural Municipality, chosen through random sampling, to obtain the representative necessary data. A combination of quantitative and qualitative data from the community was gathered through interviews conducted with the aid of a semi-structured questionnaire, as outlined in (MOEST 2012). The sample size for households was determined using the formula developed by (Arkin & Colton 1963) as:

Sample size, $n = \frac{NZ^2P(1-P)}{Nd^2+Z^2P(1-P)}$

Where,

n=sample size

N=total number of households

Z=confidence level (at 95% level Z=1.96)

p= estimated population proportion (0.5, this maximizes the sample size),

d=error level of 8%

This methodology ensured a representative and statistically sound collection of information from the targeted community.

2.3.2 Data Collection

In order to systematically record the evolving dynamics and adaptive strategies within the community, a Key Informant Survey was undertaken. This involved interviewing individuals who possess in-depth knowledge of the community, its changing circumstances, and act as indicators of the community's vulnerability to CC and disasters. The selected key persons were chosen for their comprehensive understanding of the community's context, providing valuable insights into how the community is adapting to and managing the impacts of climate change and disasters.

2.3.3 Focus Group Discussion

In order to gather specific details about changes in livelihood patterns, socio-economic conditions, climatic hazards, agricultural practices, as well as temperature and precipitation levels, a targeted group discussion was organized. This involved engaging with ward members and representatives of social institutions across five wards within Laljhadi RM.

2.3.4 Community Transect Walk

A community transect walk was conducted, encompassing flood plains, community settlements, and agricultural fields, with the aim of observing and collecting information on the state of natural, social, and physical resources. Additionally, observations were made regarding the impacts of climatic disasters, livelihood practices, and the informal perceptions of the local residents.

2.4 Data Analysis

2.4.1 Mann-Kendall statistical trend test

A significant examination was conducted utilizing the Mann-Kendall test. The Mann-Kendall test, a nonparametric statistical trend analysis tool, is extensively applied in the assessment of trends in climatological (Mavromatis *et al*. 2011) and hydrological time series (Yue & Wang 2004). This test relies on the computation of Kendall's tau, a measure of association between two samples derived from the ranks within the samples. The Mann-Kendall statistical test was executed using Addinsoft's XLSTAT 2014 Software. The null hypothesis was assessed at a 95% confidence level for both temperature and precipitation data, encompassing both annual and seasonal temperature and precipitation data.

2.4.2 Vulnerability Assessment

The primary determinants of vulnerability encompass exposure, sensitivity, and adaptive capacity (NAPA 2010, GoN/MOE). In line with the definition provided by the Intergovernmental Panel on Climate Change (IPCC 2014), this study measures vulnerability as follows:

$$\text{Vulnerability (V)} = \text{f}\,(S * E * \tfrac{1}{A})$$

Where, S = Sensitivity, which is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli; E= Exposure of system; A= Adaptive capacity of a system

In this study, exposure refers to the nature, extent, and pace of climate variations at the local level. The assessment of CC exposure considered various factors, including temperature, rainfall, hazards, proxy indicators (plants and animals), and physical changes observed over the past 30 years. Exposure was examined at two levels: the community level, through focus group discussions, and the household level, through household surveys. Sensitivity, as explored in this study, relates to the impact of local CC and associated hazards on both local biophysical and socioeconomic systems. The adaptive capacity of a system plays a crucial role in its ability to adapt to CC and mitigate its impacts. A community's effectiveness in adjusting to and moderating the impacts of CC is directly related to its resource endowment, access, and control over resources.

2.4.3 Computation of Index

The evaluation involved the creation of indices for key contributing factors, namely Exposure, Sensitivity, and Adaptive Capacity. Indicators for each factor were assessed on a scale of 1-5, with 1 indicating very low, 2 for low, 3 for medium, 4 for high, and 5 for very high perception based on the IPCC-AR5 report (IPCC 2014). The individual indicator rankings were averaged to derive sub-indices for the components of the major variable. Subsequently, these sub-indices were averaged to obtain the major variable indices (E, S, and A) as per the IPCC-prescribed function. The resulting vulnerability value (V) was categorized into five groups: 0.2-5.04 for very low, 5.04-10.08 for low, 10.08-15.12 for medium, 15.12-20.16 for high, and 20.16-25 for very high vulnerability. Following the determination of vulnerability (comprising Adaptive Capacity, Sensitivity, and Exposure indices), an overall vulnerability index map for the study sites was generated using ArcGIS 10.2.1 software. Additionally, a graph illustrating the results was plotted using OriginPro2023b software.

3. RESULTS AND DISCUSSION

3.1 Social and Economic Status

Out of the 145 respondents, 72.4% were male, with the remaining 27.6% being female. The RanaTharu community emerged as the predominant group, followed by Brahmin/Chhetri and Dalit, constituting 79.5%, 14.6%, and the remainder, respectively. The majority of respondents resided in single-family households, with an average family size of 6.3 members. Regarding literacy, 64.8% of the respondents were literate, with a breakdown of 67.1% for males and 32.9% for females. Conversely, the study revealed that 35.2% of the respondents were classified as illiterate. Agriculture played a pivotal role in the subsistence livelihoods of most respondents, aligning with the national context where over 80% of the population is engaged in agriculture, contributing 33% to the GDP (ADB 2009). In the study area, the primary sources of income for respondents were agriculture (88.17%) and government service (5.6%), while a smaller percentage engaged in business (4.7%) and other activities (1.53%). A few respondents relied on foreign employment in India. Notably, a majority of households demonstrated food sufficiency for an average of eight months per year.

The respondents land holdings were divided into three categories as small (<0.338 hectares), medium (0.338-1.69 hectares), and large (>1.69 hectares). The analysis revealed that the majority of respondents fell into the medium landowner category (0.338-1.69 hectares), with an average landholding size of 0.846 hectares per household. Approximately 76% of respondents engaged in cropland production, and all cultivated lands were located along the banks of the Doda River.

The primary crops cultivated included paddy, wheat, maize, potato, millet, and various cereals. Paddy and maize production emerged as the principal sources of income. Firewood constituted the primary energy source for the community at 81.4%, supplemented by Liquefied Petroleum Gas (LPG) at 13.6% and biogas at 5.0%. Interestingly, 62.9% of the population had not heard about CC. Regarding land cover classification in the study area, agricultural land covered approximately 6655 hectares (43.2%), water bodies accounted for 1153 hectares (7.5%), settlement areas encompassed 1026 hectares (6.7%), and forest land covered 6580 hectares (42.7%).

Observations regarding economic status suggest a significant correlation with adaptive capacity. Individuals or communities with higher economic standing often exhibit greater resilience and adaptability to changes. This is because they often have access to things like education, healthcare, and technology, which help them adapt to different situations. Conversely, those with lower economic status face increased challenges in adapting to changes due to limited resources and opportunities. People from marginalized groups, often associated with specific castes or ethnicities, may face additional barriers in accessing resources and opportunities, limiting their adaptive capacity. Economic status, caste, and ethnicity all play a role in determining how well individuals/communities can adapt to different situations. However, adaptive capacity is not solely determined by caste or ethnicity but influenced by various factors such as access to education, social support networks, and government policies aimed at promoting equality and inclusion.

3.2 Trend Analysis of Climatic Parameters

3.2.1 Temperature Analysis

The analysis of mean temperature over a period of 34 years, from 1985 to 2019, based on seasons revealed an upward trend in temperatures for the pre-monsoon, monsoon, and post-monsoon seasons, while the winter season exhibited the lowest rate of change (-0.27 °C/decade). Specifically, the pre-monsoon season demonstrated a temperature increase at a rate of 0.2 °C/decade. The annual mean maximum temperature exhibited the highest positive Kendall's tau with the year, measuring 0.045 (Table 2).

According to NCVST (2009), the projections indicate that the pre-monsoon temperature is expected to rise by 1.7 °C by 2030, 3.1 °C by the 2060s, and 5.4 °C by the 2090s. Similarly, the monsoon temperature is projected to increase by 1.4 °C by the 2030s, 2.5 °C by the 2060s, and 4.5 °C by the 2090s. Additionally, the post-monsoon temperature is anticipated to rise by 1.2 °C by the 2030s, 2.6 °C by the 2060s, and 4.6 °C by the 2090s.

Table 2: Summary of the statistical analysis of maximum temperature

Variables	Winter	Pre-Monsoon	Monsoon	Post-Monsoon	Annual
Minimum (°C)	20.2	31.8	32.5	27.7	28.7
Maximum (°C)	25.1	36.6	35.1	31.2	31.6
Mean (°C)	22.8	34.5	33.8	29.6	30.6
Std. deviation	1.097	0.936	0.612	0.650	0.602
Kendall's tau	-0.213	0.126	0.150	0.066	0.045
Kendall's Statistics	-127	75	89	39	27
p-value	0.074	0.293	0.211	0.589	0.712
Trend (°C/decade)	-0.270	0.200	0.090	0.050	0.050
Sen's slope	-0.033	0.014	0.012	0.005	0.003
Sen's Intercept	89.092	6.664	9.511	20.068	24.404
Response	Decrease	Increase	Increase	Increase	Increase
Remarks	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant

Table 3 summarizes the statistical analysis of minimum temperature across different seasons in study area. In winter, the minimum temperature averages at 6.1 °C with a standard deviation of 0.858, showing a slight increasing trend of 0.310 °C per decade. However, this trend is statistically insignificant with a p-value of 0.038. Conversely, during the pre-monsoon and annual periods, there›s a significant increase in minimum temperature, with values of 16.5 °C and 15.8 °C respectively, and corresponding trends of 0.460 °C and 0.280 °C per decade. Both periods exhibit significant positive Kendall›s tau and p-values less than 0.01. Monsoon and post-monsoon seasons, with minimum temperatures of 24.4 °C and 13.5 °C respectively, show insignificant trends and Kendall›s tau values close to zero, indicating no significant changes. However, it›s worth noting that the pre-monsoon and annual periods demonstrate a notable upward trend in minimum temperature, while the others show no significant trend.

In the prior research conducted in the Kanchanpur district, Bhatta (2011) illustrates that the average yearly temperature in the region rise by 0.012 °C per year. Additionally, the mean minimum temperature experienced an increase of 0.026 °C per year, whereas the mean maximum temperature saw a slight decrease of -0.001 °C per year. Furthermore, Kattel and Yao (2013) noted that the warming trend was more pronounced in maximum temperatures, with minimum temperatures displaying greater variability, including positive, negative, or no changes.

Table 3: Summary of the statistical analysis of minimum temperature

Variables	Winter	Pre-Monsoon	Monsoon	Post-Monsoon	Annual
Minimum (°C)	6.1	16.5	24.4	13.5	15.8
Maximum (°C)	9.8	19.5	26.0	18.3	19.1
Mean (°C)	8.4	17.8	25.2	15.8	17.6
Std. deviation	0.858	0.837	0.332	1.050	0.653
Kendall's tau	0.247	0.408	0.005	0.257	0.425
Kendall's Statistics	147	243	3	153	253
p-value	0.038	0.001	0.977	0.031	0.004
Trend (°C/decade)	0.310	0.460	0.010	0.350	0.280
Sen's slope:	0.030	0.049	0.000	0.032	0.038
Sen's Intercept	-52.392	-80.688	24.544	-48.396	-58.018
Response	Increase	Increase	Increase	Increase	Increase
Remarks	Insignificant	Significant	Insignificant	Insignificant	Significant

3.2.2 Precipitation Analysis

The analysis of precipitation over a period of 34 years, from 1985 to 2019, indicated monsoon season contributes the highest proportion of rainfall among all seasons, accounting for about 85.4% of the total precipitation. In contrast, the pre-monsoon and winter seasons contribute 3.46% and 4.94%, respectively, while post-monsoon rainfall is the lowest, accounting for about 6.21% of the total rainfall (Table 4). In Nepal overall, the monsoon season received 79.6% of the total annual precipitation, whereas the pre-monsoon, post-monsoon, and winter seasons received only 12.7%, 4.2%, and 3.5%, respectively (Marahatta et al. 2009).

The annual rainfall data reveals significant fluctuations in the study area, indicating unpredictability in yearly precipitation. According to MoPE (2004), the average trend for Nepal suggests a decreasing annual average precipitation at a rate of 9.8mm per decade. The projected mean annual precipitation for Nepal does not exhibit a clear trend, with variations of -34 to +22% by the 2030s, -36 to +67% by the 2060s, and -43 to +80% by the 2090s (NCVST 2009).

Table 4: Summary of statistical analysis of rainfall from 1985 to 2019

Rainfall	Annual	Winter	Pre-Monsoon	Monsoon	Post-Monsoon
Mean (mm)	3460	143	180	2469	100
Standard Deviation	913	104	116	738	196
Maximum (mm)	5358	352	476	3764	1131
Minimum (mm)	1449	11	17	1085	0
Kendall's tau	0.18	-0.04	0.02	0.14	0.03
Kendall's Statistics	107	-25	11	85	20
p-value	0.13	0.73	0.89	0.23	0.79
Trend (mm/year)	25.47	-0.41	0.72	17.59	1.45
Sen's slope	25.927	-0.632	0.289	18.175	0.115
Sen's Intercept	-48562.682	1378.664	-428.089	-33921.850	-204.723
Response	Increase	Decrease	Increase	Increase	Increase
Remarks	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant

3.3 Adaptation Practices

In the study area, it was observed that local communities employed a variety of autonomous adaptation practices, followed by planned adaptation. Broadly, the adaptation strategies identified through interviews in the study site indicated that households in the six wards experienced water stress induced by climate variability, particularly in relation to floods. More than 80% of the RanaTharu community settlements were located in Laljhadi RM. These adaptation practices were rooted in indigenous knowledge, with some receiving support from various governmental and non-governmental programs. To address changes in the seasonal calendar caused by climate change, farmers had to adjust the timing of crop plantations. The villagers also experimented with hybrid and improved seeds from the local market to enhance production speed and quantity. Hybrid seeds were predominantly used for vegetables and staple crops, especially when home-stored seeds were insufficient. However, many farmers lacked awareness regarding the quality of seeds available in the market. Proper care, recent tools, techniques, and fertilization were essential for the successful growth of hybrid species. Some off-season crops were cultivated throughout the year. Despite the shift to new seeds for increased yield, farmers expressed concerns about the loss of nutritional value and taste in their product.

The autonomous adaptations observed in the study area reflect a distinct form of traditional knowledge and indigenous practices, echoing findings similar to those reported by Maharjan et al. (2011) in their studies conducted in Kailali and Kanchanpur districts.

Villagers and the local government has used the use of biological dams and plantations along the riverside to prevent the cutting of river embankments. In Laljhadi RM, each household has installed taps with the assistance of the local government and the Nepal Red Cross. Another adaptive measure taken by the villagers in response to unpredictable rainfall patterns involves the conservation of forests and the planting of perennial plants around water springs to safeguard water sources.

Due to delayed seasonal rainfall, crops are sowed a month later than the scheduled time. In certain areas of the river basin, the cultivation of water stress-tolerant crops such as groundnut, tomato, sweet potato, garlic, cabbage, bitter gourd, cucumber, and watermelon is becoming increasingly common, meeting the needs of local farmers. The local government, cooperatives, and community-based organizations has conducted training and awareness programs in the villages to promote a blend of traditional and modern farming practices and storage of seeds on the second floor of their houses and in elevated areas within buildings. Additionally, some wards receive seed bins and technical support for local seed production. In response to climate change, some communities have switched from cultivating rice to maize in certain fields, while others have adapted by growing early maturing rice cultivars such as Chaite-4, Chaini, Hardinath, Radha-4, Anjana, and Nimoi to mitigate the impact of floods.

The adaptation practices observed in the study area are closely connected with the social and economic status of the local communities. The predominant reliance on agriculture as the primary source of income, with a majority of respondents engaged in cropland production and cultivating lands along the riverbanks, underscores the close link between livelihood strategies and adaptation efforts. Additionally, the distribution of landholdings into small, medium, and large categories reflects disparities in economic resources, influencing the ability to adopt certain adaptation measures such as experimenting with hybrid seeds or implementing conservation practices. Furthermore, the prevalence of traditional energy sources like firewood among households, coupled with varying literacy rates, highlights the need for tailored awareness and support programs to enhance adaptive capacities across different socioeconomic levels.

3.4 Vulnerability assessment of the community

3.4.1 Adaptive Capacity

The adaptive capacity of each ward was assessed by averaging key indicators, namely the availability of natural resources, demographic factors, physical infrastructure, and the presence of social and financial institutions within the ward. The measured adaptive capacity varied between 2.01 and 3.68, with the highest capacity observed in ward 3 and the lowest in wards 1 and 6. The primary factors influencing community adaptive capacity were identified as knowledge of CC and the availability of infrastructure facilities. While a significant portion of respondents were affiliated with social institutions, only a small number were knowledgeable about CC and had access to communication means. Physical infrastructure, representing the tangible resources, plays a crucial role in enhancing adaptive capacity. Social capital indicators, encompassing individual networks and mutual trust, are essential for dealing with climate impacts (Ludena & Yoon 2015).

Furthermore, a majority of individuals relied on agriculture and daily wages for their livelihood, with a limited number engaged in government service and business. Notably, ward 3 exhibited a comparatively higher per capita income. At the local level, adaptive capacity is influenced by factors such as access to political power, specific beliefs, and cultural customs *(Cutter et al. 2000).*

3.4.2 Exposure Index

Climate exposure indicators encompass temperature rise, heavy precipitation, drought, and sea-level rise (IPCC 2014). The exposure index was formulated by averaging these four key indicators, with temperature fluctuations, precipitation patterns, the presence of indicator species, and the incidence of climate-induced disasters serving as primary criteria for its calculation within the community. The resultant exposure index ranged from 2.35 to 3.87. An index based on respondents' perceptions indicated that wards 1 and 6 exhibited the lowest vulnerability to climate change, while ward 3 demonstrated the highest exposure. This heightened exposure in ward 3 can be attributed to the altered course of the Doda River, which now divides the ward into two nearly equal halves. Riverside wards were notably more vulnerable to climate-induced disasters, particularly flood events, exacerbated by the river's change in path.

In the lowland region of Nepal, especially in the Terai flatland where rivers from higher elevations converge, the frequency of flood-related events and fatalities is highest (Pradhan & Shrestha 2007). Within Laljhadi RM, the Doda River experiences routine riverbank erosion and flooding during the rainy season. This has become an integral part of life for the local residents, who face persistent challenges in commuting to nearby villages due to the absence of a bridge over the river. Moreover, the river's altered course contributes to continuous erosion of lands near human settlements, affecting agricultural lands in villages such as Balmi, Dunga, Chandrapur, and Parsiya. The introduction of invasive species, including Ageratum houstonianum and fall armyworm, poses an additional threat to biodiversity in agriculture, river basin areas, and forests. These invasive species are gradually displacing native counterparts, impacting the ecosystem in the long run.

3.4.3 Sensitivity Index

The sensitivity index for each ward in Laljhadi RM was determined by averaging six key indicators. These indicators included agriculture and food security, forest and biodiversity, human settlement, water availability, energy demand, and the gender ratio of the area. The calculation aimed to assess the community's overall sensitivity to various factors. Across the rural municipality, the sensitivity index ranged from 3.15 to 3.75. Ward 4 attained the highest sensitivity score, while Ward 1 registered the lowest value. Notably, the sensitivity was observed to be particularly elevated in wards situated in close proximity to the Doda River.

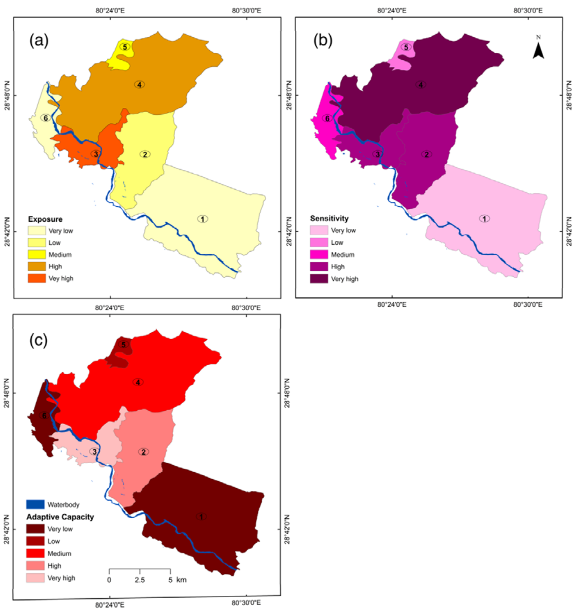

Fig. 2: Map showing the scored vulnerability indices in Laljhadi RM (a) Adaptive Capacity (b) Exposure, and (c) Sensitivity

The heightened sensitivity to climate change in wards 3 and 4 is attributed to human settlements along the riverside and the reduction of forest resources. Our study, which considers vulnerability as a function of exposure, sensitivity, and adaptive capacity, underscores that the primary contributor to vulnerability in Laljhadi RM is the inadequate adaptive capacity, followed by climatic exposure, as detailed in Fig. 3. This finding aligns with a similar study on the spatial assessment of population vulnerability to climate change in Nepal, conducted by (Mainali & Pricope 2017). Their research revealed a distinct vulnerability pattern, with higher vulnerability observed in the western and northwestern regions of Nepal. Despite the Doda River coursing through ward 1, the residents there exhibit lower sensitivity to floods. This is attributed to the continual displacement experienced by locals since the 2008 flood, prompting many to relocate to forested areas, thereby reducing their vulnerability to flood events. The adverse impacts of climatic risks and hazards, particularly floods, riverbank erosion, and windstorms, are notably severe on infrastructure such as buildings, bridges, roads, foot trails, etc.

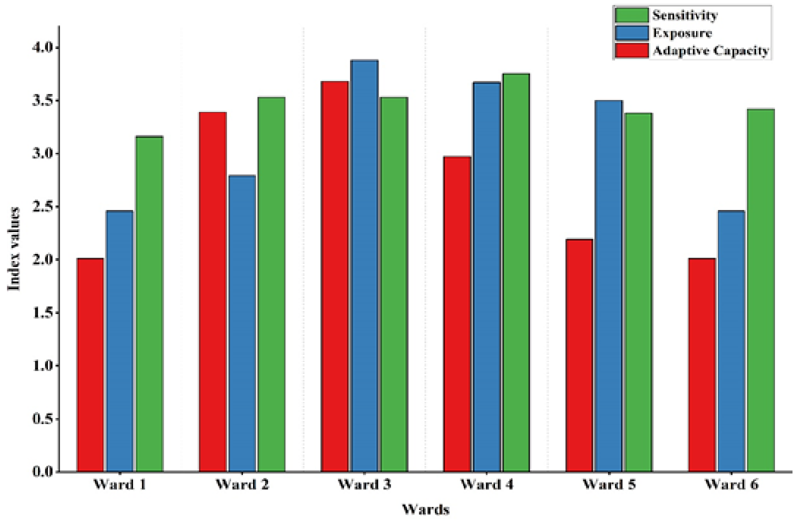

Fig. 3: Result of vulnerability components: adaptive capacity, exposure, and sensitivity of six wards of Laljhadi RM

3.4.4 Vulnerability map

Vulnerability assessments were done to identify and understand the most vulnerable wards of Laljhadi RM based on ranking the components of Adaptive capacity, Exposure, and Sensitivity. The vulnerability index of six wards showed a very high exposure and low adaptive capacity of the area which increased the vulnerability of the area. The highest vulnerability was in ward 3 and it was comparatively least in ward 1 as shown in Table 5.

Table 5: Vulnerability of six wards of Laljhadi RM

Ward	Vulnerability score	Rank
1	5.2	6th
2	11.1	3rd
3	16.8	1st
4	13.6	2nd
5	8.7	4th
6	5.6	5th

The research focused on conducting a vulnerability assessment grounded in community knowledge. By employing participatory methodologies, the aim was to comprehensively address the intricacies of individuals' lives, beginning with their comprehension of the situation, the information available to them, and various factors including local knowledge, personal experiences, skills, household composition in terms of gender and age, and existing coping mechanisms. These factors collectively influence how people adapt to changes in order to mitigate risks and shape their perception of risk, as articulated by Slovic (1992).

The high exposure in lowland Terai is due to the high coefficient of variation of precipitation and a higher rate of temperature increase regionally. The spatial distribution of annual average precipitation aligns with the noted higher coefficient of variation in monsoon rainfall in Nepal, as highlighted by Duncan *et al.* (2013). Given the low-lying nature of this area, recurrent flooding becomes a prevalent occurrence during periods of rainfall. The vulnerability map for Laljhadi RM is depicted in the following Fig. 4.

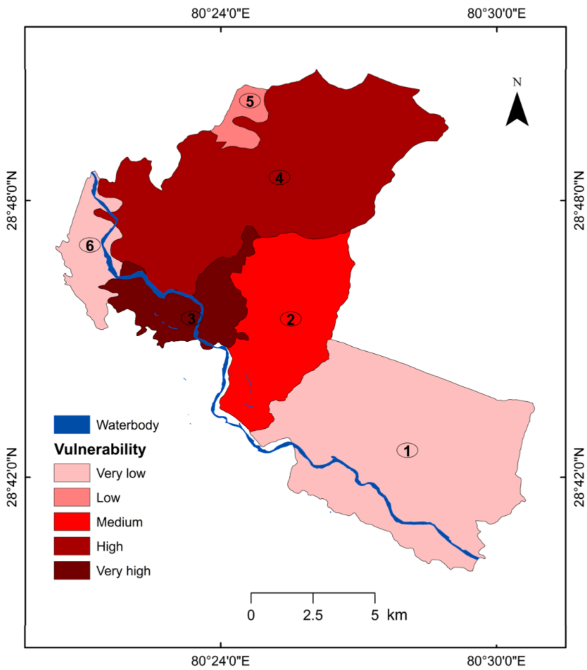

Fig. 4: Map showing the vulnerability of Laljhadi RM

The impact of floods is far-reaching, encompassing the devastation of lives, livelihoods, and critical infrastructure. In a parallel manner, feeder roads and embankments have also been obliterated by the floodwaters. Essential elements of community life, such as the provision of drinking water and electricity, the integrity of schools, and the stability of public buildings, have crumbled in the face of this natural disaster. Furthermore, the flood has resulted in the loss of numerous private residences, properties, domestic animals, and standing crops, all of which have been swept away by the force of the flood. The outcome of these floods is marked by extensive damage, affecting not only individual well-being but also the foundational components that sustain communities.

Key factors that affect how well a community can adapt to climate change include understanding climate change and having the right infrastructure in place. Physical infrastructure, like buildings and roads, is especially important because it provides tangible resources needed to bounce back from challenges. Other factors that influence adaptive capacity are having political influence, cultural beliefs, and traditions. This shows that adapting to climate change involves a variety of different aspects within communities.

Vulnerability assessment reveals that inadequate adaptive capacity, coupled with climatic exposure, contributes significantly to vulnerability within the community. Specifically, factors such as limited knowledge of climate change, infrastructure deficiencies, and economic disparities exacerbate vulnerability. For instance, wards situated along riverbanks face heightened exposure to climate-induced disasters like floods, compounded by inadequate infrastructure and economic resources. Sensitivity to climate change is particularly elevated in areas with human settlements near riversides, emphasizing the interconnectedness of socioeconomic factors and vulnerability.

In the face of significant vulnerabilities, the community has demonstrated resilience through a variety of adaptation practices. These encompass both indigenous knowledge-based strategies and planned adaptations facilitated by governmental and non-governmental initiatives. Farmers have responded to these challenges by diversifying their crops, focusing on alternative cash crops in riverside areas, and adopting early-maturing hybrid varieties to mitigate flood risks. Villagers and local authorities have also taken short-term measures like constructing biological dams and establishing plantations along riverbanks to prevent erosion. However, persistent challenges, such as seed quality concerns and the diminishing nutritional value of crops, underscore the necessity for targeted awareness programs and supportive mechanisms. The interplay of socioeconomic factors, climatic exposure, and adaptive capacity underscores the complex dynamics influencing community vulnerability and resilience. While economic disparities and infrastructure deficiencies pose challenges, community-driven adaptation practices and collaborative efforts offer pathways towards building adaptive capacity and mitigating climate risks.

4. Conclusion

The socio-economic analysis reveals that most respondents belong to the RanaTharu community, primarily engaged in agriculture with notable disparities in literacy rates, landholding sizes, and income sources. Economic status directly affects adaptive capacity, with wealthier individuals or communities exhibiting greater resilience. Conversely, those with lower economic status, especially marginalized groups, face heightened challenges in adaptation due to limited resources. Climatic trends, especially rising temperatures and erratic precipitation, pose significant challenges for agriculture and water management, exacerbating vulnerability.

Moreover, the study area has experienced significant climate shifts affecting local livelihoods, including reduced rainfall frequency, increased floods, prolonged dry spells, delayed monsoons, and intense late summer rains. Recent years have observed an increase in hot summer days and relatively cold winter days, indicating temperature extremes. This climatic variability has adversely impacted community livelihood resources, particularly in riverside wards facing higher vulnerability. Continuous flooding since 2008 has led to community displacement, forcing people to shift to elevated areas, affecting their sensitivity to flood events. Agricultural land near rivers suffers from inundation and deposition of sand and residue, rendering it unproductive.

Traditional farming practices are threatened to CC, leading farmers to cultivate alternative cash crops in riverside areas and adopt early-maturing hybrid crops to escape floods. To prevent river embankment cutting, villagers and local governments employ biological dams and plantations along the riverside. While short-term adaptation practices have been implemented, the communities lack additional financial resources to address long-term CC challenges. There is a growing interest in modern farming technology, but location-specific adaptation technologies require investment in research at both higher and community levels. Vulnerability assessments show low adaptive capacity across all wards, with specific vulnerabilities varying by hazard and community. Wards 3, 4, and 2 of Laljhadi RM exhibit the highest vulnerability. This research emphasizes that overall exposure to climatic stresses may remain consistent across small-scale settlements, but hazard-specific exposure varies. Communities reliant on natural resources for food, income, and water, such as the Rana and Tharu communities, are highly sensitive to climate-induced hazards. This underscores the importance of community-driven approaches in fostering resilience to climate change.

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