# Measuring climate vulnerability of tourism-dependent livelihoods: The case of Lamgtang National Park

**Anil Bhandari[1*], Namrata Thapa Magar[2], Bhavishya Jung Thapa[2], Pabita Shahi[3], & Til Prasad Pangali Sharma[2]**

[1]*Department of Environmental Science and Engineering, KU*

[2]*Nepal Mountain Academy, Kathmandu*

[3]*Power Shift Nepal, Kathmandu*

[*]*Corresponding email: askwithanil@gmail.com*

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## Abstract

*Climate change poses significant challenges to tourism-dependent communities in mountain regions, threatening their livelihoods and well-being. However, there is a lack of comprehensive assessments that consider the multidimensional nature of vulnerability and the specific socio-cultural contexts of these communities. This study assesses the livelihood vulnerability of tourism-dependent communities in Lamtang National Park exposed to climate change using the Livelihood Vulnerability Index (LVI) and the Livelihood Vulnerability Index -Intergovernmental Panel on Climate Change (LVI-IPCC) framework. A mixed-methods approach was employed, including household surveys (n=119), vulnerability index calculations, and analysis of weather data. The purposive stratified sampling based on ecological gradient and proximity to trekking trails ensured the representativeness of the sample. One hundred nineteen households were surveyed, with respondents from the Hill Janajati ethnic group. Results showed that the majority of households (63%) were tourism-dominant, followed by agriculture-dominant (17%) and mixed livelihood (13%). The LVI results revealed a moderate vulnerability (0.365), with financial and natural capitals being the most vulnerable. The LVI-IPCC analysis showed that the community's adaptive capacity (0.537) is slightly lower than its exposure (0.564), and sensitivity is comparatively low (0.296), resulting in a low LVI-IPCC index (0.01). Weather data analysis, including the Mann-Kendall trend test, Sen's slope analysis, and multi-model ensemble projections, indicated increasing precipitation trends and a warmer, wetter future for the region. The triangulation of LVI, LVI-IPCC, forecast data, and weather station data strengthens the findings and highlights the need for targeted interventions. The projected changes in temperature and precipitation patterns for Rasuwa district and vulnerability status of tourism-dependent communities highlight the urgency of implementing climate change adaptation measures, which may include diversifying livelihoods, improving access to education and training, strengthening social support systems, and promoting sustainable land and water management practices.*

*Keywords:* adaptive capacity, climate change, livelihood vulnerability, resilience, tourism-dependent communities

## Introduction

Climate change has emerged as one of the most pressing global challenges, with far-reaching implications for ecosystems, societies, and economies. Mountain regions, such as the Himalayas, are particularly vulnerable to the impacts of climate change due to their fragile ecosystems, high dependence on natural resources, and limited adaptive capacity (IPCC, 2007). The annual maximum temperature trend in Nepal is increasing by 0.056°C/yr, while the minimum temperature trend is increasing by 0.002°C/yr, which is insignificant, according to a study on climate trend analysis by the Department of Hydrology and Meteorology (DHM, 2017). The increased maximum temperature is consistently more significant in the hilly regions from East to West and is at its lowest in the Tarai districts (MoFE, 2021a). Many climate change studies have shown that changes in precipitation and temperature patterns in the middle and high mountains are substantial (Karki et al., 2017; DHM, 2017; MoFE, 2019), and remote places of such regions rely heavily on tourism for their earnings and livelihood (World Bank, 2021).

The livelihoods of mountain-based communities in Nepal are increasingly vulnerable to the impacts of climate change, which can significantly affect the tourism potential of these regions (World Bank Group, 2022). Tourism is a crucial driver of socioeconomic growth and prosperity in Nepal, contributing to the construction of essential community infrastructures, such as schools, healthcare facilities, and roads, which support local residents' livelihoods (Munanura et al., 2016; MoFE, 2021b). However, tourism-dependent populations in protected areas have fewer opportunities to explore alternate forms of income, making them more susceptible to climate change (MoFE, 2021b). This is particularly evident in Lamtang National Park, which has the fourth-highest climate change exposure index (0.625) and a low adaptation capacity index (0.47) among the 20 protected areas in Nepal (MoFE, 2021b). Lamtang National Park, located in the central Himalayan region of Nepal, is a popular destination for trekkers and nature enthusiasts. The park is home to diverse ecosystems, ranging from subtropical forests to high-altitude alpine meadows, and supports a rich biodiversity (LNP, 2020). The local communities residing within and around the park heavily rely on tourism activities for their livelihoods, making them particularly susceptible to the impacts of climate change. As tourism-related activities become the primary source of income for local people, hyper-dependence on tourism can become a significant vulnerability concern in the context of climate change (Shen, 2009). Consequently, understanding the vulnerability of tourism-dependent communities to climate change is crucial for developing effective adaptation strategies and policies in Nepal (MoFE, 2021b).

The impacts of climate change, such as rising sea levels, increased frequency and intensity of extreme weather events, and shifts in temperature and precipitation patterns, have direct and indirect consequences for tourism and livelihoods (Scott et al., 2019). As a climate-sensitive sector, tourism is particularly vulnerable to these changes, with implications for destination attractiveness, tourist behavior, and the sustainability of tourism-dependent economies (Gössling et al., 2020). Protected areas play a crucial role in biodiversity conservation, but their establishment can positively and negatively impact local livelihoods. Ward et al. (2018) examined the impact of protected area co-management on perceived livelihood impacts in Malawi, Botswana, and Namibia, suggesting that while co-managed protected areas may be more effective overall, governance processes can lead to local perceptions of inequity. Nyaupane et al. (2020) assessed the performance of contemporary protected area governance in Nepal and found that the outcomes varied across the protected areas primarily because of their governance approaches and local contexts.

The relationship between tourism and livelihood diversity has gained increasing attention in the context of climate change. The concept of vulnerability has been widely explored in the context of climate change and tourism (Adger, 2006). Studies have highlighted the varying levels of vulnerability among tourism destinations and communities, influenced by factors such as geographical location, socio-economic conditions, and institutional support (Becken et al., 2020). Nyaupane and Chhetri (2009) assessed the vulnerability of nature-based tourism to climate change impacts in the Nepalese Himalayas, while Jamaliah and Powell (2017) conducted a vulnerability assessment of ecotourism to climate change in Dana Biosphere Reserve, Jordan. Tourism has been promoted to support biodiversity conservation and improve livelihoods in and around protected areas in many developing countries (Vedeld et al., 2012; Goodwin & Roe, 2001). Several studies have examined the impacts of tourism development on the livelihoods of destination communities, especially in rural areas (Su et al., 2018; Mbaiwa & Stronza, 2010; Kheiri & Nasihatkon, 2016; Snider, 2012). These studies show tourism's potential to enhance rural livelihoods through economic diversification, income generation, and synergies with traditional activities. However, asset levels affect individuals' ability to capitalise on these opportunities, with implications for equitable development.

Livelihood is often studied at the household level and is described as the set of various assets and activities that go toward making income for locals (Diniz et al., 2015). Numerous studies are directed at estimating the impact of climate change on the livelihood or tourism sector. However, only a few studies have connected and quantified tourism and livelihood together while both being impacted by climate change (Afandi, 2014; Gössling et al., 2020; Scott et al., 2019; Su et al., 2018; Vedeld et al., 2012; Ward et al. (2018). In 2015, the Lamtang region in Nepal experienced a catastrophic earthquake that triggered avalanches, burying 116 buildings, primarily hotels, and claiming the lives of 308 people (176 locals, 80 visitors, and 10 soldiers) (Callaghan & Thapa, 2015). The factors most vulnerable to severe climatic events and climate-induced hazards comprise tourism infrastructure, nature, tourists, and tourism-dependent people and their livelihoods (MoFE, 2021b). The Lamtang National Park management plan has stated that there is inadequate availability of off-farm employment and a low linkage to tourism activities with off-trail communities (LNP, 2020). Most of the funding and activities are targeted towards tourism management in the buffer zone to improve livelihoods, while the core tourism activity area remains in limbo to address the livelihood needs of the community not connected with the trekking trails (LNP, 2020).

The overall objective of this study was to explore the livelihood diversity of tourism-dependent communities in the face of climate change. The specific objectives were to compute the LVI and LVI-IPCC of these communities, explore different aspects of climate change vulnerability to tourism-dependent livelihoods, study the climate variability of the Lamtang National Park, and contribute to the enhancement, promotion, and development of mountain tourism studies. Methodologically, the composite index approach in evaluating the determinants of livelihood is widely exercised in measuring the LVI. However, there exist limitations in selecting indicators related to the sustainable livelihood tourism framework (Shen, 2009; Afandi, 2014). Thus, considering the aspect of climate change and the implication of catastrophic events, Lamtang National Park was regarded as the best study site to explore the accumulated impact of climate change on the livelihood of tourism-dependent communities.

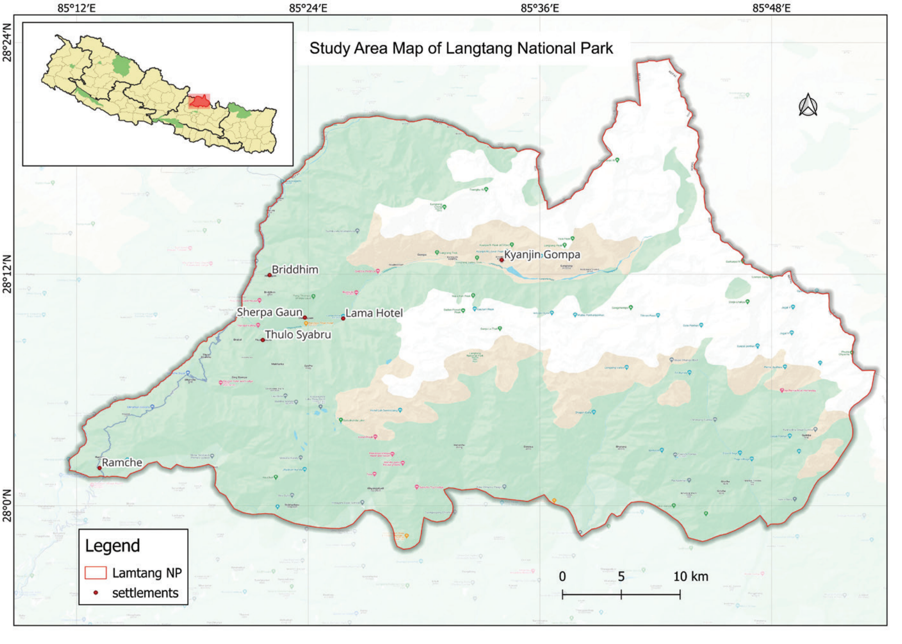
Assessing the livelihood vulnerability of these communities is essential for identifying the factors that contribute to their vulnerability and developing targeted interventions to enhance their resilience. The LVI is a widely used approach for quantifying the vulnerability of communities based on multiple indicators across different livelihood capitals, such as social, human, natural, financial, and physical (Hahn et al., 2009). IPCC vulnerability framework, which considers exposure, sensitivity, and adaptive capacity, provides another lens for understanding vulnerability (IPCC, 2007). This study aims to bridge the gap in comprehensive assessments that consider the multidimensional nature of vulnerability and the specific socio-cultural contexts of the communities by assessing the livelihood vulnerability of tourism-dependent communities in Lamtang National Park using the LVI and LVI-IPCC approaches while also analyzing secondary weather data to understand the climate change trends in the region. The findings of this study can contribute to evidence-based decision-making and inform policies and programs aimed at building resilience and promoting sustainable livelihoods of tourism-dependent communities of mountain regions facing climate change challenges.

## Study area

This research concept is designed to measure the livelihood diversity of local communities whose livelihood is partially or completely dependent on tourism activities and are further impacted by climate change. All field-based activities were concentrated in the Lamtang National Park (LNP), featuring the Gosaikunda Rural Municipality (RM) of the Rasuwa district.

**Figure 1**

*Map of study sites in Lamtang National Park*




LNP is situated in the central Himalayan region of Nepal in Province 3 and was gazetted on 9 Chaitra 2032 (26 March 1976). The Park has an area of 1,710 km$^2$ and extends over parts of Nuwakot (4.28%), Rasuwa (56.62%) and Sindhupalchowk (39.10%) districts, the southern mountainous terrain of the Nepal-China (Tibet) border. The geographical location of the Park is approximately between 85° 15' to 86° E and 28° to 28° 20' N. Lamtang National Park (LNP) is one of the nearest Himalayan National Parks from the capital city Kathmandu (LNP, 2020).

**Table 1**

*Coverage of LNP, Districts and Rural Municipalities*

| District-wise coverage of LNP (1710 km²) | | Coverage of National Park in Rasuwa District | | |
|---|---|---|---|---|
| District wise coverage | Area ($km^2$) | District Area | % coverage | RM Coverage |
| Rasuwa (56.62%) | 968.2 | 1511 $km^2$ | The national park covers 64% District area | The total area of Gosaikunda RM is 978.77 $km^2$ (out of 6 wards in Palika, except ward 1, the rest 2,3,4,5,6 placed inside the park, and the area of ward 1 is 64.51 sq km. That means (978.77-64.51) 914.26 $km^2$ is inside the park (93.4%) of land lies within the national park. |
| Sindhupalchowk (39.10%) | 668.6 | | | |
| Nuwakot (4.28%) | 73.2 | | | |

## Materials and methods

The study assessed the livelihood vulnerability of tourism-dependent communities in Lamtang National Park considering the impact of climate change. This study has adopted a mixed-methods approach. Household surveys were conducted in the Gosaikunda Rural Municipality of the Rasuwa district, with 119 households selected using purposive stratified sampling based on ecological gradient and proximity to trekking trails. The LVI was calculated using the balanced weighted average approach and the IPCC vulnerability framework. Secondary weather data was analysed to assess climate change trends and projections in the study area.

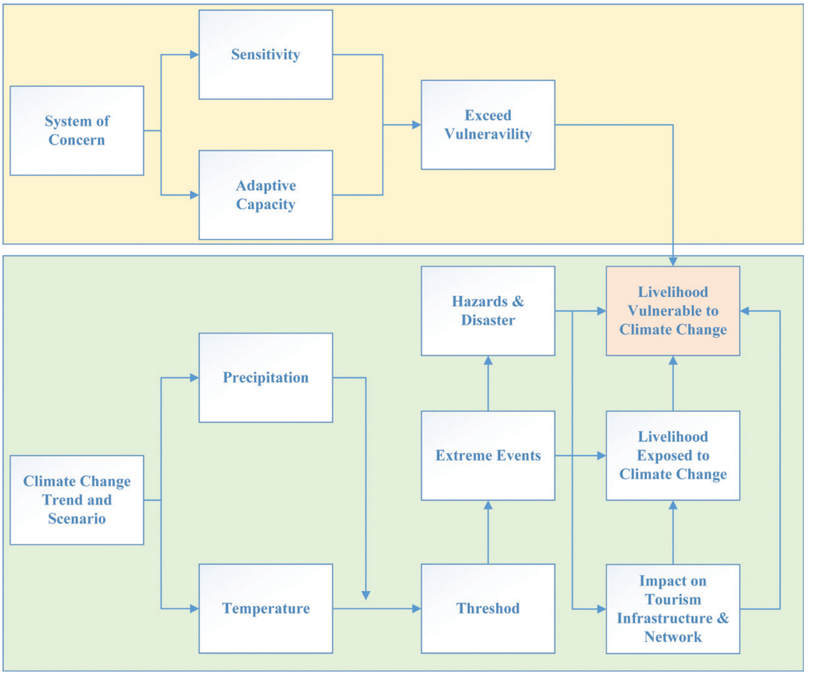
## Conceptual framework

The research presents and analyses both qualitative and quantitative data. This study has applied a sequential mixed explanation approach, which entails gathering quantitative data before collecting qualitative information to illuminate the quantitative results better (Ayana et al., 2021). The Figure 2 shows that livelihood components are grouped into vulnerability parameters to measure the LVI.

The framework is adapted and modified from the Ministry of Forests and Environment's report on "Vulnerability and Risk Assessment and Identifying Adaptation Options in Tourism, Natural and Cultural Heritage" (MoFE, 2021b). Framework illustrates three components: livelihood components, vulnerability parameters, and weather data analysis. The livelihood components are divided into five capitals: social, human, natural, financial, and physical. Each capital comprises several sub-components gathered into three vulnerability parameters: exposure, sensitivity, and adaptive capacity. These parameters are used to calculate the LVI and the LVI-IPCC, which comprehensively assess the community's vulnerability to climate change. The weather data analysis supports and validates the findings from the primary data collection.

**Figure 2**

*Assessment framework for climate change implication on the livelihood of the tourism-dependent community*




*Source: Adapted and modified from MoFE 2021b.*

## Components of the LVI framework

The LVI calculation incorporates a comprehensive set of livelihood capitals, major components, sub-components, and measurement scales to assess the vulnerability of tourism-dependent communities. The five main livelihood capitals considered in the LVI are social, human, natural, financial, and physical. Each capital is further divided into major components, such as socio-demographic information, health, land productivity, assets, and road network & services, which are then divided into specific sub-components as presented in

The sub-components are measured using a variety of scales and units, depending on the nature of the data being collected. Ratios and numbers are used for sub-components like the dependency ratio and average family member in a household, while percentages are employed for women-headed households and households with members trained in vocational training. Likert scales are set for assessing support during trouble and the degree of satisfaction with water supply, and time-based measurements are used for sub-components such as the average time to reach the nearest health centre and the time to collect forest or forest-related resources. This diverse range of measurement scales and units highlights the complexity of assessing livelihood vulnerability presented in Table 2 .

By incorporating quantitative data from various livelihood capitals, the LVI provides a comprehensive understanding of the challenges tourism-dependent communities experience in climate change exposure. Including sub-components from different livelihoods, capitals ensure that the index captures the multifaceted nature of the vulnerability, considering social, human, natural, financial, and physical aspects, ultimately leading to a more accurate assessment of the communities' resilience to climate change impacts.

## Components of the LVI-IPCC framework

The LVI-IPCC framework categorise vulnerability's major components and sub-components into three factors: adaptive capacity, sensitivity, and exposure. Adaptive capacity includes socio-demographic information, social networking, social cohesion, tourism-built relations, knowledge and skills, road network and services, and infrastructure. These components assess the community's ability to adapt and cope with the impacts of climate change on their livelihoods. Sensitivity comprises health, food and nutrition, land productivity, forest, water, finance, and tourism economy, evaluating the degree to which the community's livelihoods are affected by or responsive to climate change.

Exposure consists of climate variability, natural disasters, and assets, representing the external factors and environmental stressors that the community faces due to climate change. By organising these components into the three vulnerability factors, the LVI-IPCC framework provides a comprehensive approach to assessing the vulnerability of tourism-dependent communities to climate change, considering their adaptive capacity, sensitivity, and exposure to climate-related stressors. Presented in Table 2.

**Table 2**

*Components of LVI & LVI- IPCC based on livelihood capitals*

| Livelihood | Major Components (LVI) | Vulnerability Factors (LVI-IPCC) |
|---|---|---|
| Capitals Social | Socio-demographic information | Adaptive Capacity |
| | Social networking | Adaptive Capacity |
| | Social cohesion | Adaptive Capacity |
| | Tourism-built relation | Adaptive Capacity |
| Human | Health | Sensitivity |
| | Food and nutrition | Sensitivity |
| | Knowledge and Skills | Adaptive Capacity |
| Natural | Land Productivity | Sensitivity |
| | Forest | Sensitivity |
| | Water | Sensitivity |
| | Climate variability | Exposure |
| | Natural Disaster | Exposure |
| Financial | Assets | Exposure |
| | Finance | Sensitivity |
| | Tourism Economy | Sensitivity |
| Physical | Road Network & Services | Adaptive Capacity |
| | Infrastructure | Adaptive Capacity |

## Categorising sub-components of the LVI-IPCC framework

The LVI-IPCC framework is composed of vulnerability's major components and subcomponents into three contributing factors: adaptive capacity, sensitivity, and exposure

(Table 3). Adaptive capacity encompasses various aspects such as socio-demographic information, social networking, social cohesion, tourism-built relations, knowledge and skills, road network and services, and infrastructure. These components collectively assess the community's ability to adapt and cope with the impacts of climate change. On the other hand, sensitivity includes factors like health, food and nutrition, land productivity, forest, water, finance, and tourism economy, which evaluate the degree to which the community's livelihoods are affected by or responsive to climate change. Lastly, exposure comprises climate variability, natural disasters, and assets, representing the external factors and environmental stressors that make the community vulnerable to climate change.

**Table 3**

*LVI-IPCC contributing factors for Adaptation Capacity, Exposure and Sensitivity*

| Vulnerability Factors | Major components | Sub-components |
|---|---|---|
| Adaptive Capacity | Socio-demographic information | Dependency ratio |
| | | The average family member in a household |
| | | Women headed household |
| | | The household head who has not attended the school |
| | Social networking | Support from family & relatives |
| | | Access to local governments' services |
| | | Membership in the local organisation |
| | Social cohesion | Support during the trouble |
| | | Relations with administrative officers |
| | | Trust among the neighbours |
| | Tourism-built relation | Increased social cohesion through tourism activities |
| | | Increased access to information with development in tourism activities |
| | Knowledge and Skills | Household head with smartphone |
| | | Household with its members trained in vocational training |
| | | Household with its members trained by Lamtang National Park or Buffer Zone Management Committee |
| | | Workforce in a family member |
| | Road Network & Services | Time to reach (walking) nearest land vehicle station/ motorable road |
| | | Access to grid electricity |
| | Infrasture | Better infrastructure (such as roads, electricity, water, public transport) due to tourism |
| | | Housing quality style |

| | | |
|---|---|---|
| Sensitivity | Health | Average time to reach the nearest health centre |
| | | critically ill household member in the past one month |
| | | Household members suffered severe or other infectious diseases in the past six months. |
| | Food and nutrition | Food insufficient to the family from their production |
| | | Consumption of varieties of food that do not meet the nutritional demand |
| | Land Productivity | Lack of ownership of productive land |
| | | Degradation of productive land by climate-induced disaster |
| | Forest | Insufficient forest resources |
| | | Time to get forest or forest-related resources |
| | | The availability of firewood in comparison to 3o years back has decreased. |
| | Water | Invailability of water sources |
| | | Conflicts related to water resource use |
| | | Lack of everyday availability of water |
| | | Degree of dissatisfaction with water supply |
| | Finance | Households with debt (informal) |
| | | Households with loan from any Financial Institutions (bank/finance/cooperative) or other organisations |
| | | Households that do not receive remittance |
| | Tourism Economy | Tourism income has decreased |
| | | Wage income has not changed. |
| | | Distribution of the economic benefits generated by tourism is not fair. |
| Exposure | Climate variability | Changes in the pattern of precipitation in the last 20 years |
| | | Climate hazards (landslide, flood, drought, crop pest) damage to livelihoods. |
| | | Perception of weather/climate changes in the region compared to the past decade |
| | | Mean standard deviation of average annual temperature |
| | | The mean standard deviation of average annual precipitation |
| | Natural Disaster | Death in the family due to climate-related disasters in the past 30 years |
| | | Injury to family members due to climate-related disasters in the past 30 years. |

| | | |
|---|---|---|
| | Assets | The inverse of the average land holding index |
| | | Limited to one house in a location |

*Note: Adapted from Hahn et al. (2009), Qian et al. (2022), Munamura et al. (2016), Afandi et al. (2014), Qian et al. (2017), Shi et al. (2022) and Lamichhane (2010).*

## Primary data collection

### Sample size calculation

This study employed a purposive sampling strategy combined with stratification based on the household proximity to main trekking trails and ecological gradients. The primary focus of the study was to measure the impact of climate change on the livelihood diversification of families engaged in the tourism business, and this sampling approach allowed for targeting households that met this specific criterion while also considering the potential influence of trail proximity. To find suitable households for the study, we used criterion sampling - a purposive sampling that selected only those households involved in the tourism business. Total population and household size is presented in Table 4.

**Table 4**

*Population and household size of Gosaikunda Rural Municipality*

| Source | Total Population | Male Population | Female Population | HH Size | Remarks |
|---|---|---|---|---|---|
| National Survey Report (CBS, 2021) | 7788 | 3973 | 3815 | 2038 | 42% of municipality HH are within study area Ward 3, 4 & 5 |

The sample size calculation, as shown in Table 5, was based on the total number of households across three wards (3, 4 & 5) of the Gosaikunda Rural Municipality. One of the household selection criteria was households' proximity to the main trekking trails, and popular trekking trails LNP passes through these three wards. Out of the 862 total households, 119 were sampled, representing 14% of the entire household population under investigation. The percentage of sampled households varies across the wards, ranging from 8% in Ward 5 to 48% in Ward 4, due to differences in the total number of households and the specific sampling criteria applied within each ward.

**Table 5**

*Ward wise households and study samples*

| Ward Number | HH Size | Sample Size | % of Sample HH |
|---|---|---|---|
| 3 | 169 | 20 | 12 |
| 4 | 110 | 53 | 48 |
| 5 | 583 | 46 | 8 |
| **Total** | **862** | **119** | **14%** |

## Sample size representativeness

Out of the 862 households in the three wards (3, 4, & 5) of the Gosaikunda Rural Municipality, which have part of major trekking trails, 119 households that met the criterion of proximity to the main trekking trails were randomly sampled. While this sample size is not a probabilistic representation of the entire population, it is a purposive sample that directly addresses the research objectives.

**Table 6**

*Distance of Sample Household from the major trekking trails*

| Proximity to main trekking trails | Sample Households | % of Sample Household |
|---|---|---|
| Next to the trekking trail | 107 | 90 |
| Within 500 meters away from the trekking trail | 12 | 10 |
| Far away from major trekking trail | 0 | 0 |
| **Total** | **119** | |

## Criteria for household stratification

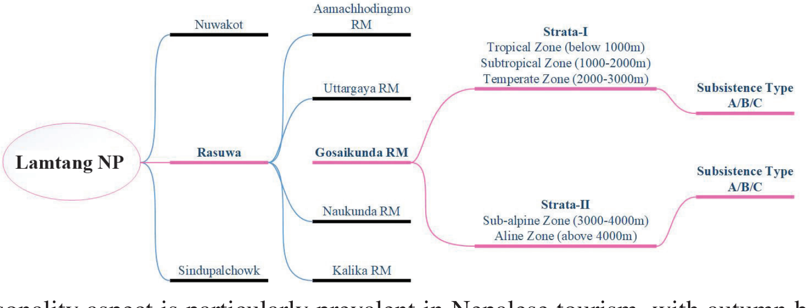
To improve the sample and capture potential variations in information, households were stratified into three groups based on their proximity to the main trekking trails and ecological gradient. Three criteria based on the proximity to the main trekking trails were:

- Households located next to the trekking trail
- Households within 500 meters of the trekking trail
- Households far away from the major trekking trail

Similarly, LNP comprises five ecological zones (LNP, 2020). Five ecological zones are further stratified into two strata, the first of which is the tropical, subtropical, and temperate zones, and the second of which is the sub-alpine and alpine zones. Based on the ecological strata, 73 households were sampled from strata-I, and 46 households were selected from strata-II. Additionally, households were classified according to the livelihood dominance as explained in Table 7.

**Figure 3**

*Sampling strategy from district to household level with ecological stratification*




The seasonality aspect is particularly prevalent in Nepalese tourism, with autumn being the most preferred season for tourists (Dhakal, 2013). This means communities that rely heavily on tourism must diversify their businesses to survive beyond the peak season. Considering this, the households in this research are classified using the criteria established by Qian et al. 2022.

**Table 7**

*Types and classification criteria of households' livelihoods*

| Subsistence Type | Classification Indicator (%) | Livelihood Mix | Representative Livelihood Activities |
|---|---|---|---|
| Type A-Tourism dominant type | Tourism Income ≥ 70 | Participate In Tourism + Short-term Employment + Farming | Operating Homestays, Hotels, Restaurants, Farmhouses, Food, Beverages, Fruit, Plantation Picking, Tourism and Transportation, Scenic Staff, Tour Guides |
| Type B: Working dominant type | Working Income ≥ 70 | Perennial Worker + Participate In Tourism | Scenic Stalls, Hotels, Restaurants, Scenic Spot Security, Shopping Malls, Working Outside, construction odd jobs, coach drivers |
| Type C: Agricultural dominant type | Agricultural Income ≥ 70 | Farming+ Short-term Employment + Participate In Tourism | Agriculture, Specialty Planting and Breeding, Temporary Employment |

*Source: Adopted and modified from Qian et al., 2022.*

### Household survey process

Based on the preliminary findings from the review of the literature, a household survey questionnaire was prepared to explore the community perception of tourism-based livelihood and the implication of climate change on such livelihood diversity. The survey team was rigorously trained on the survey questionnaire. The finalised questionnaire was further translated into Nepali, and field facilitators were trained in conducting surveys and coding the responses in MS Excel. The household survey was conveyed in March 2024 with three trained facilitators with support from local tourism entrepreneurs.

### Questionnaire development approach

The livelihood index was constructed primarily following Hahn et al. (2009) adopting the approach of a sustainable livelihood framework (SLF) (DFID, 1999). However, it is suggested that the Sustainable Livelihood Approach (SLA) cannot fully address the issues when tourism is used as a rural livelihood strategy (Shen, 2009). This is further replicated by Afandi (2014) by adopting specific indicators specially designed for tourism-based livelihood. Thus, a household survey questionnaire on tourism-based livelihood indicators is adopted from (Qian et al., 2022; Munanura et al., 2016; Afandi et al., 2014; Qian et al., 2017; Shi et al., 2022).

## Primary data analysis

### Methods for LVI calculation

To assess the LVI, study has undertaken two analysis approaches: (1) calculation of a balanced weighted average LVI (Hahn et al., 2009) and (2) computation of LVI as suggested by the IPCC framework (2007). Weather data from Rasuwa district was also examined to assess the region's climate change state. The LVI is a composite index of all significant parameters of livelihood (Hahn et al., 2009), and the IPCC vulnerability approach categorises the major livelihood indicators into exposure, sensitivity, and adaptive capacity, which are contributing factors of vulnerability (IPCC, 2001).

LVI indicators were calculated by adopting Hahn et al. (2009) in four steps (equations 1-4) and an additional calculation for the computation of LVI-IPCC (equation 5). The LVI constructs a balanced weighted average where each sub-component contributes equally to the overall index (Hahn et al., 2009). Each sub-component was measured on a different scale. They are first standardised as an index using an equation (1) acclimated from the Human Development Index to compute the life expectancy index (UNDP, 2008).

$$index_{S_d} = \frac{S_d - S_{min}}{S_{max} - S_{min}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where $S_d$ is the original sub-component indicator

$S_{min}$ & $S_{max}$ are the minimum and maximum values for each sub-component indicator.

$$M_d = \frac{\sum_{i=1}^{n} index_{S_{di}}}{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$index_{Sdi}$ are the indexed sub-component for each district that makes each major component, $M_d$ and n is the number of sub-component indicators in each major component.

$$CF_d = \frac{\sum_{i=1}^{n} w_{M_i} M_{di}}{\sum_{i=1}^{n} w_{M_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$CF_d$ is a contributing factor like exposure, sensitivity, or adaptive capacity to climate change, $M_{di}$ is the major component of each community, $w_{Mi}$ is the weight of each major component, and *n* is the number of major elements in each contributing factor.

**Calculation of LVI-IPCC**

Another method for integrating the major components into a vulnerability index was explored as attempts to develop a formula to represent the IPCC definition of vulnerability. The same major components in the composite index approach were applied to measure the IPCC's three contributing factors- exposure, sensitivity and adaptive capacity to the vulnerability.

$$CF_d = \frac{\sum_{i=1}^{n} w_{M_i} M_{di}}{\sum_{i=1}^{n} w_{M_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$CF_d$ is a contributing factor like exposure, sensitivity, or adaptive capacity to climate change, $M_{di}$ is the major component of each community, $w_{Mi}$ is the weight of each major component, and n is the number of major components in each contributing factor.

After calculating each community's exposure, sensitivity, and adaptive capacity, these values were integrated by applying the formula below.

**LVI-IPCC = (exposure-adaptive capacity)*sensitivity ……………(5)**

LVI-IPCC represent LVI as a function of vulnerability defined by the IPCC vulnerability framework, scaled from least vulnerable (-1) to most vulnerable (1).

## Secondary data collection and analysis

**Weather data**

Climate data was used to analyse the temporal pattern of temperature and precipitation, i.e., the ground station (point station) data from the Department of Hydrology and Meteorology

(DHM), to validate local perceptions of climate change. The precipitation data covers 32 years of data (1990-2022). Data was collected from the weather stations at Thamachit and Dhunche in Rasuwa district.

The future state of climate change in the Rasuwa District was analysed using the dataset employed in climate change scenarios for Nepal for the National Adaptation Plan (MoFE, 2019). The medium stabilisation scenario RCP4.5 and the very high radiative forcing scenario RCP8.5 were utilised to examine the temperature and precipitation scenarios for the medium-term (2016-2045) and the long-term (2036-2065) with the reference period of 1981 to 2010.

**Weather data analysis and presentation**

The non-parametric Mann-Kendall trend test (Kendall, 1975; Mann, 1945) and Sen's slope (Sen, 1986) analysis was employed due to its insensitivity to the normal distribution of data time series and outliers, this statistical model was used for patterns identifying in hydro-meteorological data time series.

The null hypothesis for this test is that there is no trend, and the alternative hypothesis is that there is a trend in the two-sided test or an upward trend (or downward trend) in the one-sided test. For the time series x1, .., xn, the MK Test uses the following statistic:

$$S = \sum_{i=1}^{n-1} \sum_{j=k+1}^{n} sign\left(x_j - x_i\right)$$

To assess projected changes in temperature and precipitation for Rasuwa district, multi-model ensemble projections from global or regional climate models were analysed for medium-term (2016-2045) and long-term (2036-2065) periods relative to the 1981-2010 reference period mean. Two Representative Concentration Pathway emission scenarios (RCP4.5 and RCP8.5) were considered. The multi-model mean temperature and precipitation projections were presented as time series plots, with the model spread shown as color-shaded uncertainty bands. This approach allows for quantifying the magnitude and range of potential future climate changes in the study area.

## Result and discussion

**Respondent demographics by age, gender, and ethnicity**

The demographic characteristics of the survey respondents presented in Table 8 describe a diverse age distribution and gender composition, with all respondents belonging to the Hill Janajati ethnic group. Most respondents were 50-59 years (42 respondents), followed by the 40-49 age group (38). The 30-39 age group had 18 respondents, while the 60 and above age group had 19 respondents. The youngest age group, 18-29 years, had the least respondents, with only 2 individuals.

The gender distribution of the respondents shows that 96 out of the total 119 respondents were male, while 23 were female. Notably, 25 (21%) were women-headed, while 94 (79%) were male-headed. This information provides insight into the gender dynamics of the surveyed households and the representation of women in decision-making roles within the community. The ethnic homogeneity among the respondents, who all belong to the Hill Janajati ethnic group, is an essential factor to consider when interpreting the survey results.

**Table 8**

*Number of respondents by age group and sex*

| The age group of the respondent | No of respondent | Male | Female |
|---|---|---|---|
| 18-29 | 2 | 2 | 0 |
| 30-39 | 18 | 11 | 7 |
| 40-49 | 38 | 28 | 10 |
| 50-59 | 42 | 38 | 4 |
| 60 & above | 19 | 17 | 2 |
| **Total** | **119** | **96** | **23** |

**Marital status distribution of survey respondents**

The majority of the respondents, 92 out of 119, were married at the time of the survey. The second-largest group among the respondents was widowed individuals, with 19 respondents falling into this category. Unmarried individuals constituted a smaller proportion of the respondents, with only 7 out of 119 identifying as unmarried. Lastly, only one respondent reported being divorced, suggesting that divorce is relatively uncommon or stigmatised within the community (Table 9).

**Table 9**

*Marital status of the respondent*

| Marital Status | No of respondent |
|---|---|
| Married | 92 |
| Unmarried | 7 |
| Widowed | 19 |
| Divorced | 1 |

**Household engagement according to livelihood dominance**

The status of livelihood dominance of household's presented in the Table 10. Most households (63%) in the study area are tourism-dominant, with tourism income constituting ≥70% of their total income. Representative activities for this group include operating homestays, hotels, restaurants, farmhouses, food and beverage sales, fruit plantation picking, tourism transportation, and working as scenic staff or tour guides. Agriculture-dominant households, where agricultural income is ≥70%, comprise the second-largest group at 17%. Their representative activities include agriculture, speciality planting and breeding, and temporary employment. Mixed livelihood households, with no single income source ≥70%, constitute 13% of the sample. The smallest group is working-dominant households (7%), where working income is ≥70%. Their representative activities include working in scenic stalls, hotels, restaurants, scenic spot security, shopping malls, outside jobs, and construction jobs. This distribution underscores the high dependence on tourism for livelihoods in the study area.

**Table 10**

*Household engagement according to the livelihood dominance*

| Subsistence Type | Classification Indicator (%) | Livelihood Mix | Representative Livelihood Activities | Total HH |
|---|---|---|---|---|
| Type A-Tourism dominant type | Tourism Income ≥ 70 | Participate In Tourism + Short-term Employment + Farming | Operating Homestays, Hotels, Restaurants, Farmhouses, Food, Beverages, Fruit, Plantation Picking, Tourism and Transportation, Scenic Staff, Tour Guides | 75 (63%) |
| Type B: Working dominant type | Working Income ≥ 70 | Perennial Worker + Participate In Tourism | Scenic Stalls, Hotels, Restaurants, Scenic Spot Security, Shopping Malls, Working Outside, construction odd jobs, drivers | 8 (7%) |
| Type C: Agricultural dominant type | Agricultural Income ≥ 70 | Farming+ Short-term Employment + Participate In Tourism | Agriculture, Specialty Planting and Breeding, Temporary Employment | 20 (17%) |
| Mixed livelihood type | No single income source is ≥ 70% | | | 16 (13%) |

**Comprehensive assessment of the LVI**

The LVI calculation is organised according to the five livelihood capitals: social, human, natural, financial, and physical. Each capital is further divided into major components and sub-components, providing a detailed analysis of the factors contributing to the vulnerability of the surveyed community (Table 11).

**Table 11**

*LVI of major components and livelihood capitals*

| Livelihood capital | Major Components | Vulnerability score | Weighted Average Vulnerability Score for respective livelihood Capital |
|---|---|---|---|
| Social | Demographic Vulnerability | 0.27 | 0.304 |
| | Network Vulnerability | 0.66 | |
| | Social vulnerability | 0.18 | |
| | Tourism-built relation vulnerability | 0.025 | |
| Human | Health vulnerability | 0.075 | 0.348 |
| | Food and nutrition vulnerability | 0.38 | |

| | | | |
|---|---|---|---|
| | Knowledge and Skills vulnerability | 0.535 | |
| Natural | Land Productivity vulnerability | 0.51 | 0.42 |
| | Forest vulnerability | 0.36 | |
| | Water vulnerability | 0.095 | |
| | Climate vulnerability | 0.62 | |
| | Vulnerability to natural disaster | 0.57 | |
| Financial | Assets Vulnerability | 0.43 | 0.43 |
| | Finance Vulnerability | 0.37 | |
| | Tourism Economy vulnerability | 0.49 | |
| Physical | Road Network & Services Vulnerability | 0.25 | 0.28 |
| | Infrastructure Vulnerability | 0.311 | |
| | | **LVI** | **0.365** |

The weighted average vulnerability score for financial capital has the highest vulnerability score of 0.43, followed closely by natural capital of 0.42. This suggests that the community faces significant challenges related to land productivity, forest resources, water availability, climate variability, and exposure to natural disasters. Additionally, financial aspects such as asset ownership, access to finance, and dependence on the tourism economy contribute to the community's vulnerability. Human and social capital have moderate vulnerability scores of 0.348 and 0.304, respectively. Within human capital, knowledge and skills vulnerability stands out with a high score of 0.535, indicating a need for improved education and training opportunities. Food and nutrition vulnerability also require attention, with a score of 0.38.

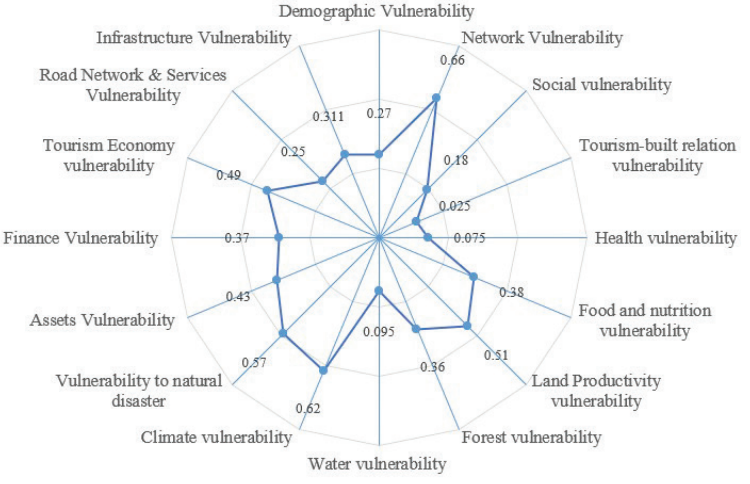
Regarding social capital, network vulnerability is exceptionally high at 0.66, highlighting the importance of strengthening social support systems and access to government services. Physical capital has the lowest vulnerability score among the five capitals at 0.28. However, this should not be overlooked, as sub-components such as road network and services vulnerability (0.25) and infrastructure vulnerability (0.311) still contribute to the community's overall vulnerability.

The LVI, the weighted average of all five livelihood capitals is 0.365. This value indicates a moderate level of overall vulnerability for the surveyed community. It is essential to recognise that the LVI provides an outlook of the current vulnerability status and can serve as a baseline for monitoring changes over time and evaluating the effectiveness of interventions to reduce vulnerability. This information can help policymakers, development practitioners, and community leaders identify targeted interventions and strategies to enhance the resilience and adaptive capacity of the community vulnerable to climate change and other livelihood challenges.

The radar chart (Figure 4) visually represents the dimensional indices for seventeen different sub-components of livelihood vulnerability. Each sub-component is plotted on a separate axis, with the axis values ranging from 0 to 1. The chart shows that certain sub-components, such as network vulnerability, climate vulnerability, and knowledge and skills vulnerability, have relatively high dimensional indices, indicating a greater vulnerability to livelihood. On the other hand, sub-components like tourism-built relation vulnerability, water vulnerability, and infrastructure vulnerability have lower dimensional indices, suggesting a lesser vulnerability impact on livelihood vulnerability. Regarding financial aspects, assets vulnerability and finance vulnerability have moderate dimensional indices, while tourism economy vulnerability shows a slightly higher index, highlighting the significance of the tourism sector in the community's livelihood vulnerability.

**Figure 4**

*LVI score of different sub-components*




## LVI-IPCC vulnerability assessment

A detailed vulnerability assessment is based on the IPCC framework, which considers three key components: adaptive capacity, sensitivity, and exposure. Table 12 calculates vulnerability indices for each element of LVI-IPCC by aggregating the scores of various sub-components, providing a comprehensive understanding of the community's vulnerability to climate change.

**Table 12**

*Calculation of LVI-IPCC components*

| Vulnerability Factors | Vulnerability Index |
|---|---|
| Adaptive Capacity | 0.537 |
| Sensitivity | 0.296 |
| Exposure | 0.564 |
| **LVI-IPCC= (exposure-adaptive capacity)*sensitivity = (0.564-0.537)*0.296= 0.01** | |

The adaptive capacity index, which represents the community's ability to cope with and adapt to the impacts of climate change, is 0.537. This moderate value suggests that the community possesses some resources and strategies to respond to climate-related challenges. The community's moderate adaptive capacity indicates the opportunities to enhance its resilience and coping mechanisms. Strengthening adaptive capacity can involve investments in education, infrastructure, social networks, and livelihood diversification.

The sensitivity index, which measures the degree to which the community's livelihoods and well-being are affected by climate change, is 0.296, which is relatively low. This indicates that the community's livelihoods and well-being are less sensitive to climate variability and extremes than other factors. It is essential to acknowledge that even a low sensitivity index can significantly impact the community, particularly when combined with high exposure levels. The low sensitivity index indicates that the community's livelihoods and well-being are relatively less vulnerable to climate variability and extremes. However, it is essential to recognise that sensitivity can vary across different sectors and social groups within the community.

The exposure index, which quantifies the extent to which the community is exposed to climate change-related hazards and stressors, is 0.564, and it has the highest vulnerability score among the three components. This high exposure index underscores the community's vulnerability to climate-related risks such as changes in temperature, precipitation patterns, and the frequency and intensity of extreme weather events. The high exposure index emphasises the urgent need to reduce the community's exposure to climate-related hazards.

The LVI-IPCC index, calculated by combining the exposure, adaptive capacity, and sensitivity indices, assesses the community's vulnerability to climate change. The LVI-IPCC index is 0.01 in this case, indicating a relatively low vulnerability. This low value suggests that the community's adaptive capacity is slightly lower than its exposure, and the sensitivity is comparatively low. However, it is crucial to interpret this result with caution, as it does not imply that the community is resilient to the impacts of climate change. By enhancing adaptive capacity, reducing sensitivity, and minimising exposure, policymakers and development practitioners can work towards building a more resilient community better equipped to face the complexities of climate change.

## Climate variability

### Scenarios of temperature and rainfall in Rasuwa district

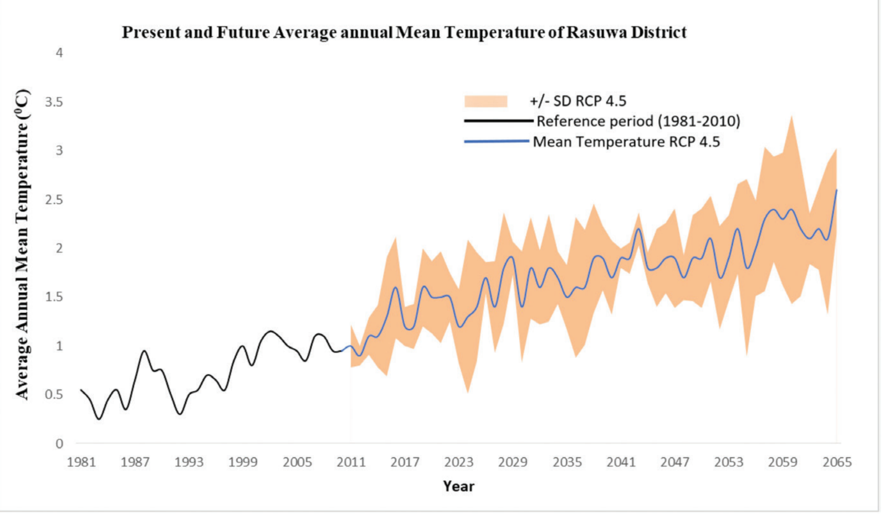
This analysis examines the output of global and regional climate models to quantify projected deviations in key climate variables over Rasuwa up to 2065 under different concentration pathways (MoFE, 2019). Observed precipitation data from local meteorological stations was also analysed for detectable trends amidst natural variations. The findings aim to support evidence-based decision-making for climate adaptation to support resilient tourism development in the Rasuwa district.

### Projected temperature scenario of Rasuwa

The average temperature for the reference period of 1981 to 2010 is 0.7 °C. The projected changes in average annual temperature RCP 4.5 (Figure 5) in the medium-term (2016-2045) and the long-term (2036-2065) are 0.88°C and 1.26°C respectively. The coloured band represents the standard deviation resulting from the selected GCMs. The black line represents the reference period.

**Figure 5**

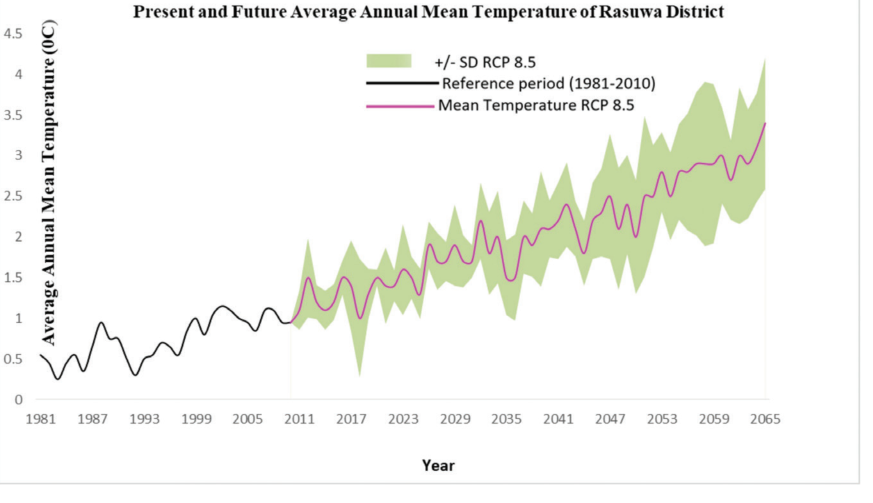
*Multi-model temperature ensemble under RCP4.5 (dark blue) for 1981-2065*




The projection for RCP 8.5 shows that the medium-term period will be warmer by 1 and 1.74°C in the long-term period, presented in Figure 6. The coloured band represents the standard deviation resulting from the selected GCMs. The black line represents the reference period.

**Figure 6**

*Multi-model temperature ensemble under RCP8.5 (pink) for 1981-2065*



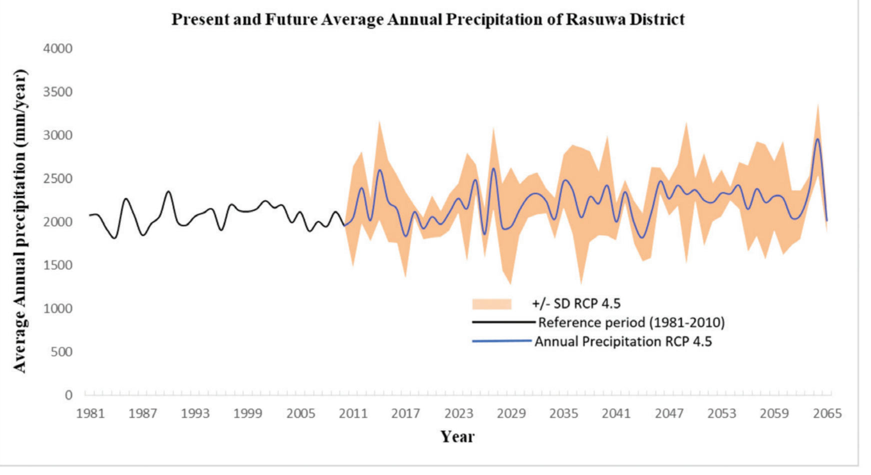

## Projected Precipitation Scenario of Rasuwa

The average precipitation for the reference period of 1981 to 2010 is 2054 mm. The projected changes in average annual precipitation (%) RCP4.5 (Figure 7) in the medium-term (2016-

2045) and the long-term (2036-2065) are 4.33 and 9.6 respectively. The coloured band represents the standard deviation resulting from the selected GCMs. The black line represents the reference period.

**Figure 7**

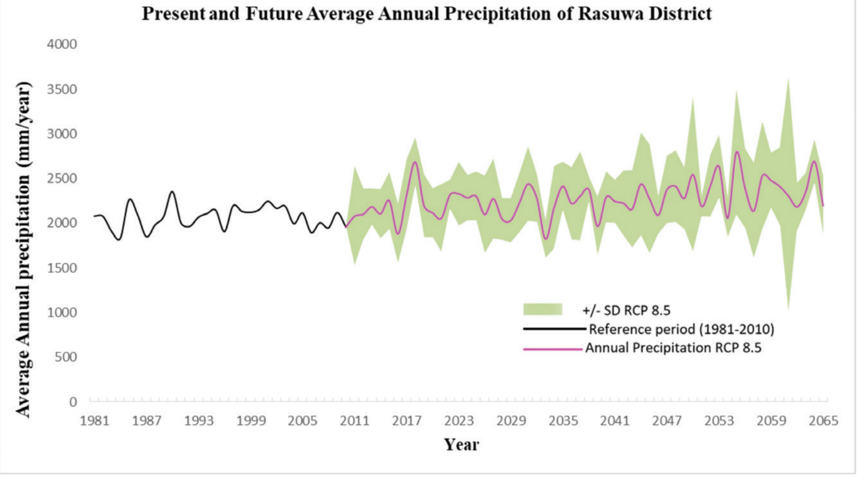
*Multi-model ensemble of precipitation under RCP4.5 (dark blue) for 1981-2065*




The coloured band represents the standard deviation resulting from the selected GCMs. The black line represents the reference period. The projection for RCP8.5 shows that the medium-term period will be wetter by 7.91% and 13.09% in the long-term period presented in Figure 8.

**Figure 8**

*Multi-model ensemble of precipitation under RCP8.5 (pink) for 1981-2065*




*Source: MoFE, 2019.*

The climate projection results for the Rasuwa district indicate a warmer and wetter future under both RCP4.5 and RCP8.5 emission scenarios. For the medium-term (2016-2045) period, the multi-model mean temperature is projected to increase by 0.88°C under RCP4.5 and 1.0°C under RCP8.5 relative to the 1981-2010 reference period mean of 0.7°C. The projected warming is greater for the long-term (2036-2065) period, reaching 1.26°C under RCP4.5 and 1.74°C under RCP8.5. Precipitation is also projected to increase, with the multi-model mean showing a 4.33% increase for the medium-term and 9.6% for the long-term under RCP4.5, compared to the reference period mean of 2054 mm. Under RCP8.5, precipitation increases are projected to be even higher, at 7.91% for the medium term and 13.09% for the long term. These projections suggest that Rasuwa district is likely to experience substantial changes in climate in the coming decades, with implications for water resources, ecosystems, and livelihoods.

## Weather data analysis

This study has statistically tested precipitation data from 1990-2022 to study the region's annual and seasonal rainfall trends. Data was collected from the precipitation monitoring stations at Thamachit and Dhunche in Rasuwa district. Details of the geographic coordinates and elevation of these two stations are outlined in Table 13.

**Table 13**

*Weather stations of Rasuwa District*

| Station Index | Location | District | Latitude | Longitude | Elevation (m) |
|---|---|---|---|---|---|
| 1054 | Thamachit | Rasuwa | 28.1835 | 85.30183889 | 1770 |
| 1055 | Dhunche | Rasuwa | 28.1053 | 85.3076915 | 2005 |

The average annual precipitation for the analysis period is higher at Dhunche station (1859 mm) than at Thamachit station (751 mm). There is also higher rainfall in winter, spring, and the summer monsoon at Dhunche compared to Thamachit. However, there is considerable year-to-year variability in precipitation, as shown by the high standard deviations relative to the mean values. For example, at Dhunche, the standard deviation of annual rainfall is 535.9 mm compared to a mean of 1859 mm. This highlights precipitation distributions from these two stations were further analysed to detect significant trends amidst the high rainfall variability in the district.

**Table 14**

*Summary statistics of weather data*

| Variable | Thamachit | | | | Dhunche | | | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean | Std. deviation | Min | Max | Mean | Std. deviation |
| Annual | 193 | 2158.2 | 751.0 | 563.0 | 373.8 | 2625.6 | 1859.0 | 535.9 |
| Winter | 0.10 | 221.9 | 39.1 | 51.7 | 0.0 | 237.2 | 80.3 | 70.5 |
| Spring | 3.60 | 261.6 | 69.5 | 75.6 | 0.0 | 329.2 | 186.3 | 75.5 |
| Monsoon | 157.6 | 2088.0 | 627.0 | 496.4 | 236.8 | 2331.2 | 1533.2 | 467.4 |
| Autumn | 0.0 | 126.4 | 15.4 | 29.4 | 0.0 | 172.6 | 59.1 | 47.4 |

The results of Mann-Kendall and Sen's slope analysis of precipitation trends at Thamachit station are presented in Table 15. The annual precipitation data analysis reveals an increasing trend, with Kendall's tau of 0.428 and a p-value of 0.001. This upward trend of 36.622 mm per year from 1990-2022 is statistically significant.

For the winter season, precipitation has increased at a rate of 1.533 mm annually, as evidenced by the p-value of 0.003 and Sen's slope estimate. Similarly, the spring rainfall trend is upwards at 1.865 mm per year.

The summer monsoon precipitation has shown the most pronounced increasing trend in Thamachit, rising at 30.464 mm per year as Kendall's tau of 0.411 and low p-value of 0.001 denote.

Thus, Thamachit station has witnessed rising precipitation across annual and seasonal metrics over the past three decades. Only autumn lacked a discernible trend. This has implications for water resources planning for Rasuwa district.

**Table 15**

*Annual and seasonal Mann-Kendall trend test (Two-tailed test) and sen's slope calculation of precipitation data from Thamachit Station*

| Series\Test | Kendall's tau | p-value | Sen's slope |
|---|---|---|---|
| Annual | 0.428 | 0.001 | 36.622 |
| Winter | 0.376 | 0.003 | 1.533 |
| Spring | 0.363 | 0.004 | 1.865 |
| Monsoon | 0.411 | 0.001 | 30.464 |
| Autumn | -0.022 | 0.878 | 0.000 |

The annual precipitation time series graph for 1990-2022 visually depicts the long-term increasing trend in rainfall at Thamachit Station. The high year-to-year variability can be seen. The overlaid linear trendline indicates the rising trend, consistent with the statistically significant positive Kendall's tau value and Sen's slope estimated in Table 15.

**Figure 9**

*Annual precipitation trend of Thamachit station*

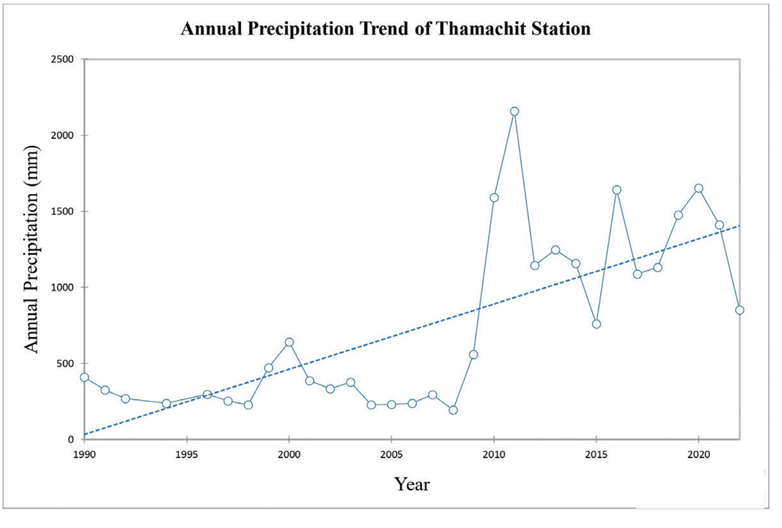


Table 16 presents the results of the Mann-Kendall and Sen's slope tests for precipitation data from the Dhunche weather station to detect trends. On an annual timescale, Dhunche shows a positive Kendall's tau value of 0.192, indicating an increasing trend. Still, with a p-value of 0.149, this annual trend is not statistically significant from 1990-2022.

Based on Sen's slope estimate, seasonal analysis shows that winter precipitation has increased by 2.067 mm per year. However, Kendall's tau of 0.167 and p-value of 0.209 indicate that winter trends also lack significance in rising trends. Similarly, spring and monsoon seasonal trends are positive but statistically insignificant according to the p-values. Only autumn shows no discernible trend.

**Table16**

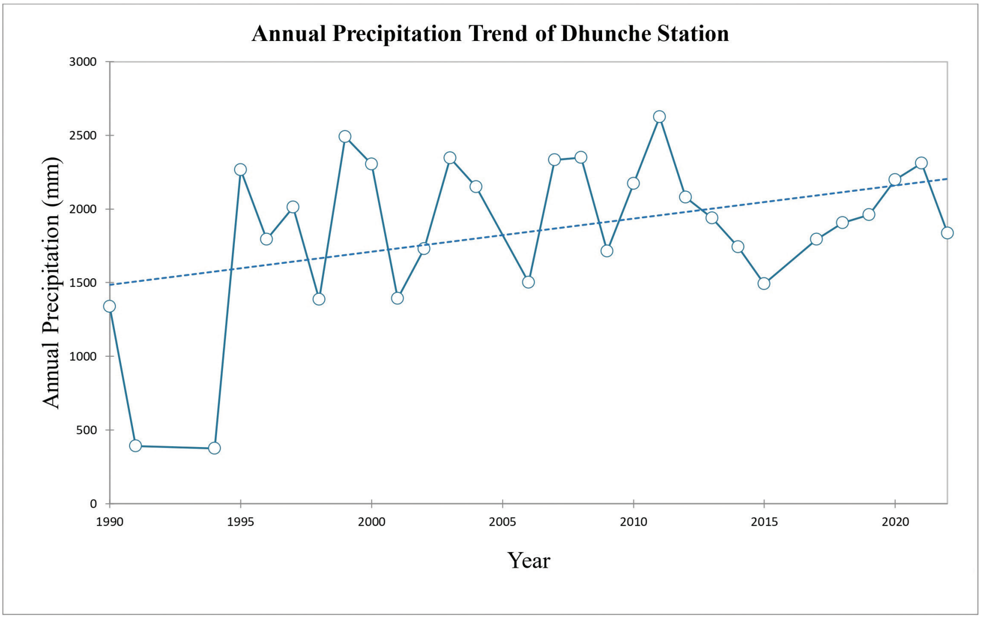
*Annual and seasonal Mann-Kendall trend test (Two-tailed test) and sen's slope calculation of precipitation data from Dhunche Station*

| Series\Test | Kendall's tau | p-value | Sen's slope |
|---|---|---|---|
| Annual | 0.192 | 0.149 | 12.457 |
| Winter | 0.167 | 0.209 | 2.067 |
| Spring | 0.153 | 0.252 | 1.493 |
| Monsoon | 0.163 | 0.223 | 9.082 |
| Autumn | 0.010 | 0.955 | 0.051 |

The annual precipitation plot for Dhunche Station from 1990-2022 shows high interannual variability. The linear trendline depicts a directional increasing trend. However, statistical testing shows that increasing tendency is not statistically significant.

**Figure 10**

*Annual precipitation trend of Dhunche station*



## Conclusion

Mountain regions are particularly vulnerable to the impacts of climate change, with far-reaching implications for the livelihoods and well-being of tourism-dependent communities. Recognizing the pressing need for comprehensive assessments that consider the multidimensional nature of vulnerability and the specific socio-cultural contexts of these communities, this study aims to provide a holistic understanding of the vulnerability of communities in Lamtang National Park by employing a mixed-methods approach that combines the LVI, the LVI-IPCC framework, forecast data and weather station data analysis and presentation.

The Gosaikunda Rural Municipality of Rasuwa district was selected as a study area based on its ecological gradient and proximity to major trekking trails. A total of 119 households were surveyed, with 73 households sampled from the tropical, subtropical, and temperate zones and 46 households from the sub-alpine and alpine zones. The majority of the respondents were male (96 out of 119), and 21% of the households were women-headed. All respondents belonged to the Hill Janajati ethnic group; most were married (92 out of 119). The study's mixed-methods approach, which included household surveys, LVI and LVI-IPCC calculations, and analysis of secondary weather data, allowed for a comprehensive understanding of the community's vulnerability. The purposive stratified sampling based on ecological gradient and proximity to trekking trails ensured the representativeness of the sample, while the customized MS Excel database application facilitated efficient data entry, cleaning, validation, and analysis.

The LVI results revealed that the surveyed community has a moderate overall vulnerability, with a weighted average index of 0.365. Financial and natural capitals had the highest vulnerability scores, while physical capital had the lowest. The LVI-IPCC analysis showed that the community's adaptive capacity (0.537) is slightly lower than its exposure (0.564), and sensitivity is comparatively low (0.296), resulting in a relatively low LVI-IPCC index of 0.01.

The weather data analysis provided valuable insights into the climate change trends and projections in the study area. The Mann-Kendall trend test and Sen's slope analysis of precipitation data from two stations in Rasuwa district revealed increasing trends in annual and seasonal rainfall, particularly at the Thamachit station. The multi-model ensemble projections under RCP4.5 and RCP8.5 emission scenarios indicated a warmer and wetter future for the district, with substantial changes in temperature and precipitation expected in the coming decades.

The triangulation of LVI, LVI-IPCC, forecast data analysis, and weather station data analysis strengthens the study's findings. The increasing trends in precipitation and the projected warmer and wetter future align with the community's high exposure to climate variability and natural disasters, as demonstrated by the LVI and LVI-IPCC results. The moderate adaptive capacity and low sensitivity suggest that targeted interventions focusing on enhancing livelihood capitals, particularly financial and natural capitals, could improve the community's resilience to climate change impacts.

The assessment of livelihood vulnerability using the LVI and LVI-IPCC approaches provided valuable insights into the multidimensional nature of the challenges faced by tourism-dependent communities in Lamtang National Park, encompassing social, human, natural, financial, and physical aspects of livelihoods. The findings underscore the need for targeted interventions and strategies to enhance these communities' resilience and adaptive capacity in the context of climate change, particularly in addressing vulnerabilities related to network support, climate resilience, knowledge and skills development, land productivity, and natural resource management. The projected changes in temperature and precipitation patterns for Rasuwa district highlight the urgency of implementing climate change adaptation measures, which may include diversifying livelihoods, improving access to education and training, strengthening social support systems, and promoting sustainable land and water management practices. Policymakers, development practitioners, and community leaders should work together to address these identified vulnerabilities and develop comprehensive strategies to build resilience and ensure the long-term sustainability of tourism-dependent communities exposed to climate change.

## Acknowledgement

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