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Exploring the Effect of Climate Change in Mountain Livelihoods: The Case of Sindhupalchwok

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Abstract

Mountain livelihood in Nepal becoming more vulnerable day by day. Climate change has also brought glacial lake outburst floods (GLOFs) problem in the mountain region. In this background, this study explores effect of climate change in the lives of mountain communities residing in Sindhupalchowk. The study used library method in which required data are generated from secondary sources. The published reports related to climate change, agriculture production and flow of tourists have been reviewed. The study found that impact of climate change has reduced agriculture production trend. Climate change has equally impacted the tourism sector negatively, particularly through the increased frequency of GLOFs and unpredictable weather conditions. The GLOFs has also increasing danger of glacial lake outburst floods, which threaten both community settlements and their lives. The communities are migrating to the destinations and sending remittance to support their families. Such migration based adaptation strategies can lead to the loss of skilled workers, impacting long-term community resilience. These findings highlight the importance of developing local adaptation strategies. The farming methods that can withstand climate changes, better disaster preparedness, promoting sustainable farming practices and strengthening community resilience. The study stresses the need for improved support for families unable to migrate, ensuring no one is left behind in adaptation efforts. The study also emphasizes the importance of strengthening preparedness for GLOFs through infrastructure reinforcement and early warning systems. Therefore, empirical findings of the study serves as an evidence for policymakers and organizations working to address the impacts of climate change in mountainous regions. Hence, it is better to develop and implement community based adaptation policies in high-altitude areas, focusing on alternative livelihoods.

Keywords: Keywords: Climate change impact, mountain livelihood, agriculture productivity, adventure tourism, migration

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1. Introduction

Climate change is becoming one of the biggest environmental problems. Because of anthropogenic activities, there is a huge increment in greenhouse gases, like carbon dioxide, methane, and nitrous oxide, in our atmosphere, which is warming the planet. Since the Industrial Revolution, the average temperature of Earth has gone up by around 1.2°C, leading to serious effects on ecosystems worldwide (IPCC, 2021; NASA, 2021). This increase in temperature has caused issues like rising sea levels, more extreme weather events, and changes in the environment. For instance, mountainous areas are getting more rain, which makes them prone to disasters. These effects aren't felt evenly everywhere; they're especially severe in vulnerable places like mountain regions that are very sensitive to shifts in temperature and rainfall.

Mountain areas, often called the "Water towers of the world" and the "Roof of the world," play a key part in the water cycle on Earth. Most of the major rivers start in these mountains. They supply a large amount of the freshwater that half of the world's population depends on, especially in dry areas (Immerzel et al., 2010). This fresh water comes from glaciers, melting snow, and lakes found at higher elevations. These sources feed into rivers, which are vital for farming, natural habitats, and the people living downstream. Unfortunately, the effects of global warming are causing glaciers worldwide to shrink at an alarming speed. Studies show that glaciers in high mountain regions are losing more quickly in this century than they did in earlier years, which affects water supplies, increases disasters, and impacts local economies (Zemp et al., 2019).

The Himalayas stand out as one of the areas most impacted by environmental changes, stretching over several countries, including Nepal. Often referred to as the "Third Pole" because of the large ice reserves found there, this mountain range is facing swift changes brought on by climate change. Nepal, which boasts eight of the fourteen highest peaks in the world, is especially at risk from these shifts. The Sindhupalchok District, home to places like Helambu and the Jugal Himal range in central Nepal, reflects the wider difficulties that communities in the Himalayas are encountering. This area is noted for its high-altitude scenery and reliance on agriculture, yet it is undergoing significant changes because of rising temperatures and shifts in rainfall patterns. The average yearly temperature in Nepal is rising by about 0.06°C each year, with the most substantial increases happening at higher altitudes.

In the Sindhupalchok, one of the biggest worries related to climate change is the melting of glaciers. The glaciers in the Himalayas play a vital role in providing

water for the communities below and in controlling the flow of important rivers like the Ganges, Indus, and Brahmaputra. Unfortunately, these glaciers are melting quickly, which is changing when and how much water is available. This leads to sudden bursts of more water but, over time, less water as the glaciers shrink (Bajracharya et al, 2014). This situation is alarming for farming, drinking water, and energy needs in the area. Moreover, there's the threat of glacial lake outburst floods (GLOFs). This happens when lakes created by melting ice break their natural barriers, causing massive floods that can release millions of cubic meters of water in just hours, bringing destruction to communities and infrastructure below (ICIMOD, 2011).

The people living in Sindhupalchok are very aware of the dangers posed by changing weather. This area has already seen major shifts in how much food it can produce due to unpredictable weather, which impacts both crop health and the timing of planting. Farmers here depend a lot on the monsoon rains and the water from rivers that come from melting glaciers. When the rains don't come as expected or are too unpredictable, it results in lower crop production, which puts local food supplies at risk (Gentle & Maraseni, 2012). Additionally, rising temperatures are helping pests and diseases to spread, making the situation even worse for farmers. For those who depend on farming just to get by, these changes can lead to serious problems like rising poverty, hunger, and even the need to move away.

The effects of climate change in Sindhupalchok are not just felt in farming; they are also showing a clear impact on people's lives and their family economies. As farming becomes harder and natural disasters strike more often, many individuals find themselves needing to move away to seek work elsewhere. This movement, whether within the country or to other nations, has become a common way for families to cope with the changes brought on by climate change. Foreign remittance sent back home by these migrants plays a crucial role for families in rural areas, helping them to stay financially afloat and allowing them to prepare for disasters and recover from them (Bhandari, 2014). On the downside, this migration can lead to problems like a shortage of workers in the community, family disruptions, and a decline in traditional farming methods.

The communities in Sindhupalchok are also facing many challenges, and their ability to adapt is still quite limited. The development of infrastructure in this area often falls short in dealing with the growing dangers brought on by climate change. It's clear that government policies and actions sometimes lack the necessary timing or effectiveness. A lot of communities don't have access to early warning systems for natural disasters like GLOFs and landslides, which makes them even more vulnerable (UNDP, 2019). Moreover, the local knowledge and strategies that have

been passed down through generations are often overwhelmed by the rapid changes in the environment, leaving these communities unprepared for what lies ahead.

Mountain region of Sindhupalchok play a crucial role for sustaining local economy by supporting tourism, particularly adventure tourism and maintaining the ecosystem. The region becomes the destination for tourists because of trekking routes, natural beauty and culture. The sectors because of climate change are having increase risk such as the glacial retreat, increased chance of GLOFs and lack of predictability on weather situations which influence tourism on how adjacent the outdoor activities would be safe or not. Research by Scott et al. (2019) examines the effect of climate change on tourism in a wider context, focusing on how climate instabilities influence seasonality trends and tourist behavior. Climate change has heavily affected the adventure tourism sector in Nepal. Hikers show greater anxiety on trial viability after landslides, floods and GLOFs occurring (Nepal & Chipeniuk, 2005). These disruptions leave a ripple effect on local businesses that rely heavily on seasonal tourist arrivals as it is quite hard for Nepal to standardize in the term of tourist economy.

Climate change is deeply affecting the fragile ecosystems and communities in the Sindhupalchok. The glaciers are quickly melting, the threat of GLOFs increasing, and crops becoming harder to grow. All these changes hit hard at the livelihoods of those who rely on the area's natural resources. Therefore, this study identifies key research gaps, including the limited focus on the specific impacts of climate change on mountain regions. While much research addresses glacier melt and water supply issues, few studies explore how these environmental changes affect agriculture, migration, and the role of remittances in adaptation. Additionally, the effects of climate change on the tourism industry, particularly in terms of seasonal trends and tourist safety in adventure tourism, remain underexplored, leaving a critical gap in understanding the broader socio-economic impacts on mountain communities.

2. Objectives and Methodology

This study aims to explore the impacts of climate change on mountain communities in Sindhupalchok, focusing on three main objectives: 1) how rising temperatures and changing rainfall affect farming livelihoods, 2) how communities are adapting through migration and remittances, and 3) the influence of climate change on local tourism and the economy. The research seeks to provide insights into the challenges faced by these communities and their coping mechanisms. This study used the library method to explore the above research objectives. The required data and information were collected from secondary sources such as annual reports published by government and non-government agencies and empirical studies. Secondary

data can be very helpful for exploring these kinds of social and environmental issues (Bajracharya et al., 2014). Additionally, the study also collected information from geographic information systems (Shrestha et al., 2016), which helped to understand how far glaciers have retreated and the risks of GLOF. Tourism flow statistical data from NTB also helped to understand how climate change has been affecting adventure tourism development activities in the study area.

3. Results and Discussions

Results and discussions of the study have been highlighted into four section such as agriculture productivity, effects on trekking seasons, community strength and weakness and migration as a livelihood adaptation strategy.

3.1. Agriculture Productivity

Over the last twenty years, agricultural productivity has dropped significantly. This decline is mainly due to unpredictable weather, rising temperatures, and changes in rainfall. Traditional crops such as rice, wheat, and maize are struggling as their growing seasons have become hard to predict. There has also been a rise in pest problems and plant diseases, making crop losses even worse. Warmer temperatures and inconsistent rainfall have allowed pests that once couldn't survive in this area to thrive. Increasing water shortages are another issue, as melting glaciers are causing a decline in water flow from mountain streams, which are essential for irrigation. This situation is leading to more crop failures and a decline in food security.

Climate change is seriously affecting farming in the Sindhupalchok District. As a result, traditional ways of farming are becoming less common. This situation puts food security and people's incomes at risk in the area.

Table 1: Decline in Agricultural Productivity over Time

Year	Average Crop Yield (Tonnes)	Percipitation Changes (%)	Temperature Increase (°C)
2000	3.5	-15	+0.8
2010	3.0	-18	+1.0
2020	2.5	-20	+1.2

3.2. Effect of GLOFs on Tourism Income

Weather changes have made trekking seasons shorter. As a result, the number of tourists during these times has decreased, which means less income for guides,

porters, and lodges that depend on trekking visitors. So for the betterment of the livelihood local communities migrate to an adaptation strategy as tourists are very low in number and production from agriculture declines the economic stability. The relationship between the increase in GLOF events**,** decline in tourist numbers during peak trekking seasons, and the impact on tourism income.

Table 2: GLOFs Events Frequency

Year Range	GLOFs Events (Frequency)	During Peak Season	Impact on Tourism Income	Source
2000-2005	Low	High	Stable income for tourism operators and local businesses.	Ministry of Tourism Nepal (2006)
2006-2010	Moderate	Moderate	Minor income decline due to rising safety concerns among tourists	ICIMOD Report on Climate Risks (2011)
2011-2015	High	Decreased	Noticeable reduction in income as trekking concerns increased.	Department of Hydrology and Meteorology Nepal (2016)
2016-2020	Very High	Low	Significant income loss for tourism operators and local businesses.	Ministry of Forests and Environment, GLOF Impact Study (2021)

This table provides a correlation between GLOFs frequency and tourist numbers in Sindhupalchok. It shows the declining income of tourism operators and local businesses due to increased safety concerns in the region.

3.3. Community Strength and Weakness

In Sindhupalchok, where many high-altitude communities reside, the effects of climate change are becoming very clear. Temperatures are going up, which is causing glaciers to melt faster. This shift leads to changes in how much water is available and brings more natural disasters, like glacial lake outburst floods, to the area. The altered weather patterns are making it hard for locals to farm, which is their main way to earn a living and secure food. This study aims to explore how climate change is affecting the social, economic, and environmental aspects of these mountain communities in Sindhupalchok District and what it means for their future

wellbeing. Climate change poses a crisis regarding the environment and also tourism in Sindhupalchok district. More GLOFs events increasingly put trekking paths and tourist facilities at risk. At the same time, a localized drop in agricultural output (due to adverse weather) has also reduced the food available for tourists increasing costs for both guest and hosts. The consequences of such challenges are economic instability in a region incredibly reliant on tourism-based jobs and income.

Migration and the money sent back home can help communities, but they also bring challenges for their future. As more people, especially the youth, leave for other places, the local knowledge and traditional ways of looking after the environment may fade away. Communities that receive a lot of money from family members working away can adjust better to the impacts of climate change. They can improve their farming methods, strengthen their homes against disasters, and create small businesses for extra income. But for those who can't migrate, the risk of climate change remains high. GLOFs are a serious threat to both infrastructure and agriculture in the area. As glaciers continue to melt, the danger is likely to grow, putting already fragile communities in even more jeopardy.

3.4. Migration as Livelihood Adaption Strategy

The research findings indicates that climate change is pushing people from the mountain communities of Sindhupalchok to move, whether inside the country or to other places. Families struggling with lower farming income are sending their members to cities or even overseas to find work. The money sent back home by these migrants has become really important, helping to make up for the lost farming income and strengthening family stability. This extra money allows families to improve their farming methods, build better infrastructure, and get ready for possible disasters. Migration is increasingly seen as a way to cope with these changes, with money sent home becoming an important source of support. However, there's worry about how this could affect the community in the long run, especially since it leads to fewer workers available locally.

Table 3: Migration Patterns and Remittance Flows

Year	Households with Migrants (%)	Average Annual Remittance (US$)
2005	*30*	*800*
2015	*45*	*1,500*
2020	*60*	*2,200*

The ability to handle the effects of climate change varies across the district. Households that receive remittances tend to be better equipped to face these

challenges, while those who cannot migrate find themselves in a more vulnerable position.

3.5. Critical Reflections

This research critically examines the profound impacts of climate change on the economic, social, and environmental systems in the high-altitude areas of Sindhupalchok, particularly focusing on agriculture, migration, and tourism. The study highlights how rising temperatures and changing rainfall patterns have led to reduced crop yields, forcing many people to migrate in search of alternative livelihoods. While migration provides a temporary solution, it results in the depletion of the local workforce and the erosion of traditional farming knowledge, which is vital for managing mountain ecosystems.

The findings also underscore the growing threats posed by climate change to the tourism sector in Sindhupalchok. Increasing occurrences of GLOFs and erratic weather patterns are making trekking more hazardous and shortening the tourist season, adversely affecting businesses dependent on tourism revenue. The study further reveals that the rise in GLOFs exacerbates the challenges faced by local communities, threatening lives, infrastructure, and agricultural land, thus increasing the reliance on remittances from family members working abroad. This shift signifies a profound change in the region's economic structure, with remittances playing an increasingly central role in sustaining livelihoods.

The results of this study align with previous research, such as that by Bajracharya et al. (2014), which highlighted the adverse effects of glacier melt on water supplies and agriculture, and Gentle and Maraseni (2012), who identified migration as a common adaptive strategy in rural Nepal. However, this research extends the understanding of climate change impacts by focusing on the tourism sector, which has been less explored in prior studies. By concentrating on Sindhupalchok, this study reveals the unique challenges of the region, including agriculture decline, GLOF risks, and migration, and provides new insights into local adaptation strategies, particularly the uneven distribution of resources and opportunities among households.

4. Conclusion

This research looks into how climate change affects the mountain areas of Sindhupalchok District, especially in terms of farming, moving away, and how communities cope. The results show that farming is struggling a lot because of shifts in temperature and rainfall, more pests, and a lack of water as glaciers melt.

The study also finds that many families are choosing to migrate as a way to adjust, with the money they send back home helping their families and strengthening the community. Yet, the threat of floods from melting glaciers and the uneven chances for migration are making it harder for some communities to adapt to the changes brought on by climate issues. The research shows that climate change is rapidly altering the environment in Sindhupalchok, with serious consequences for the tourism industry. The increase in GLOFs and changes in weather patterns are reducing the safety and appeal of trekking, which directly affects local livelihoods. Overall, this research emphasizes the importance of developing effective climate adaptation plans that cater to the specific needs of mountain communities in Sindhupalchok blending immediate actions with long-term strategies. The study suggested to develop and implement community based adaptation policies in high-altitude areas, focusing on alternative livelihoods.

5. Implications

This research contributes valuable knowledge for developing more effective adaptation strategies for mountain communities. It emphasizes the need for promoting sustainable farming practices, disaster preparedness, and strengthening community resilience. The study highlights the need for climate-friendly farming practices in Sindhupalchok, such as drought-resistant crops and improved irrigation. It also emphasizes the importance of strengthening preparedness for GLOFs through infrastructure reinforcement and early warning systems. Migration based adaptation strategies of the communities can lead to the loss of skilled workers, impacting long-term community resilience. The research calls for targeted climate policies in high-altitude areas, focusing on alternative livelihoods to reduce reliance on farming and migration. Additionally, it stresses the need for improved support for families unable to migrate, ensuring no one is left behind in adaptation efforts. Therefore, the empirical findings of the study serves as an evidence for policymakers and organizations working to address the impacts of climate change in mountain livelihood.

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