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[ORIGINAL RESEARCH ARTICLE]

Climate-Induced Disaster in Nepal: Assessing Impact of Glacial Lake Outburst Floods in Thame Valley, Solukhumbu

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Abstract

Nepal's Himalayan region is always prone to the Glacial Lake Outburst Floods (GLOFs), which is mainly caused due to climate change. In Nepal's Thame Valley, the 2024 GLOF caused massive destruction, including the loss of infrastructure, farmland, and natural landscape that has negatively impacted to the community's economy. The purpose of this study is to investigate the socioeconomic and environmental effects of the Thame GLOF, applying Key Informant Interviews methods in which participants are locals, local government officials, and business owners, and others. We found that there is a damage to tourism infrastructure, agriculture, and essential facilities, due to the community has faced severe economic loss. Socially, there exists flood related traumas amongst children, locals are worried about the loss of property, and they have expressed concerns about inadequate early warning systems and awareness programs. Local government's role is found key to manage these type of climate-induced disaster. The environmental aspects highlight the destruction of natural landscape, loss of agriculture land, drinking water contamination, and risk of other GLOFs in the study area due to global warming. These high-altitude settlements need the United Nations Loss and Damage fund to implement mitigation and adaptation strategies for climate-induced disasters. The study concludes that Himalayan settlements are always at potential risks of such disasters due to climate change, so it is urgent to initiate integrated mitigation strategies, and ensure sustainable-adaption measures in these high-risks areas. This research is useful for academicians, policy makers, and climate advocates to prepare evidence-based policies related to climate change, and lobby to develop safer Himalayan communities.

Open Access

Keywords: Climate change, glacial lake outburst floods, resilience, socioeconomic impact, Thame Valley

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Introduction

Glacial Lake Outburst Floods (GLOFs) are the increasing threat to mountainous regions around the world. It affects mostly in areas where climate change is accelerating glacial melt and creating unstable glacial lakes (Adhikari et al., 2021). Khumbu Region in Nepal is the home to some of the world's highest peaks and renowned trekking routes. This region is at high risk of GLOFs as there is increased glaciers retreat and forming new lakes. The Thame Valley, situated in this region, is especially vulnerable, with a history of glacial lakes that have posed serious risks to communities downstream. A GLOF from the Thyanbo glacial lake devastated Thame village in the Khumbu region of Nepal on August 16, 2024. The flood destroyed 14 structures, including homes and a school, and prompted concerns about the risks posed by nearby glacial lakes, which are susceptible to similar outbursts due to climate change and the instability of melting glaciers (ICIMOD, 2024)

Socioeconomic effects of GLOFs in areas like Thame Valley are profound and far-reaching. These sudden floods can devastate local economies by destroying infrastructure, farmland, and hydroelectric facilities, all of which are essential to the livelihoods of the region's residents. The floods also threaten lives, displace communities, and hinder development, affecting education, healthcare, and overall quality of life in the long term. For communities deeply rooted in the land, with limited resources for adaptation, the impacts can be devastating.

This article examines the socioeconomic and environmental effects of GLOFs in Thame Valley, focusing on how these events disrupt local economies, affect social stability, and challenge the resilience of the Khumbu region. It highlights the ways in which these communities are responding to the risks posed by GLOFs and considers strategies for increasing preparedness and mitigating the impacts on vulnerable populations.

Literature Review

Several literature provide evidences of the impact of climate change in posing threat to human lives in recent period. Khatri and Pasa (2023) reveal significant impact of climate change on livelihoods of communities residing in the Mountain, Hill, and Inner-Tarai regions of Bagmati Province. Communities' access to community resources such as land, water, forests, and energy sources has been decreasing. Furthermore, about 15 million people are exposed to potential GLOFs impacts, with populations in High Mountain Asia being the most vulnerable (Taylor et al., 2023). Climate change is accelerating glacier retreat and glacial lake expansion in the Nepal Himalayas, with temperature increases of 0.02 to 0.16 °C per year. This warming is leading to an annual shrinkage of glaciers by 1 to 5 km², mass balance losses ranging from −0.3 to −0.8 m water equivalent per year, and increased risk of GLOFs, with 45 GLOF events recorded from 39 glacial lakes (Khadka et al., 2023). Zhang et al. (2024) presented that the global glacier mass loss has accelerated, increasing the number and size of glacial lakes, which now number over 110,000, covering 15,000 km². This growth has raised the threat of GLOFs, affecting over 10 million people. While GLOFs are expected to increase with continued deglaciation, particularly in High Mountain Asia, global research efforts need to improve data collection and hazard modeling for better future risk management.

Likewise, Bajracharya et al. (2007) underscored that mountain regions, particularly the Himalayas, are increasingly vulnerable to climate-induced disasters like flash floods, landslides, and glacial melt due to climate change. These disasters are exacerbated by unregulated human activities and population growth, emphasizing the need for a Mountain Specific Risk Management Framework and improved disaster risk reduction strategies through stakeholder collaboration, early warning systems, and adaptive technologies. Climate change is intensifying the risk of GLOFs in the Himalayas. Thame flood, caused by the bursting of two Thyanbo glacial lakes, serves as a recent example of these increasing risks. The event underscores the vulnerability of mountain communities to such floods, with growing concerns over future GLOFs, which are projected to peak by 2050. The article highlights the importance of proactive risk mitigation measures, such as early warning systems, especially as the effects of climate change become more immediate and severe.

Pandit (2024) in their study claimed that the Thame GLOF, caused by the bursting of the Thyanbo glacial lake, serves as a stark reminder of the increasing climate-induced risks in the Himalayas. This event, which damaged infrastructure and displaced communities, highlights the urgent need for better monitoring and risk reduction strategies as global temperatures continue to rise. The flood underscores Nepal's vulnerability to climate change, with rising temperatures accelerating glacial melt and increasing the likelihood of more frequent and severe GLOFs. New Spotlight Online (2024) disclosed that the rise in temperature is identified as the primary cause of the GLOF in Thame, Solukhumbu. Increased temperatures have led to accelerated snowmelt and rising water levels, resulting in two glacier lakes bursting and flooding local settlements.

In the Hindu Kush-Himalaya region,

comprehensive GLOF risk assessments are essential for effective mitigation and adaptation strategies. Combining physical modeling with social and economic vulnerability analysis can better inform planning, as past studies often lacked field-based data and failed to address the full scope of GLOF risks, including indirect damages and the need for early warning systems (Shrestha et al., 2010). GLOFs are significant natural hazards linked to climate change and land use, with their societal impacts varying based on population density and land use patterns. A study across 20 countries and 1348 glacier floods revealed a decline in the frequency of these events since the mid-1990s, but with increasing early-season occurrences, and highlighted that regions like Bhutan and Nepal experience the most severe economic consequences, emphasizing the need for monitoring and future modeling to account for climate and human activity interactions (Khatri & Pasa, 2023; Carrivick & Tweed, 2016). Glacier outburst floods are sudden releases of large amounts of water from a glacier. They are a pervasive natural hazard worldwide. They have an association with climate primarily via glacier mass balance and their impacts on society partly depend on population pressure and land use. Given the ongoing changes in climate and land use and population distributions there is therefore an urgent need to discriminate the spatio-temporal patterning of glacier outburst floods and their impacts. This study presents data compiled from 20 countries and comprising 1348 glacier floods spanning 10 centuries. Societal impacts were assessed using a relative damage index based on recorded deaths, evacuations, and property and infrastructure destruction and disruption. These floods originated from 332 sites; 70% were from ice-dammed lakes and 36% had recorded societal impact. The number of floods recorded has apparently reduced since the mid-1990s in all major world regions. Two thirds of sites that have produced > 5 floods (n = 32.

Following the 2015 earthquakes in Nepal, a study of five potentially hazardous glacial lakes revealed limited evidence of earthquake- GLOFs, but signs of increased destabilization in moraines, such as cracks and landslides, were observed. Despite the occurrence of only one small GLOF, fears of future floods and widespread panic highlighted the inadequate local awareness of early warning systems and disaster management, prompting recommendations for improved risk assessments, lake lowering techniques, and user-friendly early warning systems to mitigate future flood impacts (Byers et al., 2017)2015 in Nepal, and the second major earthquake that occurred on May 12, 2015, we conducted field-based studies of five potentially dangerous glacial lakes in Nepal-Imja Tsho, Tsho Rolpa, Dig Tsho, Panga Dinga, and Thulagi.This research was undertaken in an effort to better understand what impacts the earthquake may have had on lake stability, flood potential as well as local perceptions of the dangers that post-earthquake outburst floods pose. Although only one relatively small, earthquakerelated glacial lake outburst flood (GLOF. In another research by Samui and Sethi (2022), based on a sample of 90 households, the research finds that migrant populations are particularly vulnerable due to lower adaptive capacity and higher exposure to GLOF risks. The study recommends various mitigation measures aimed at improving socioeconomic conditions to reduce vulnerability and enhance resilience against future GLOF events.

It is evident that GLOFs are becoming an increasing threat in the Himalayas due to rising temperatures, which accelerate glacier retreat and the formation of potentially hazardous glacial lakes. Studies, such as those on Tsho Rolpa in Nepal, demonstrate the importance of early warning systems, lake lowering strategies, and flood prevention infrastructure in mitigating the risks of GLOFs. However, the failure of these systems, often attributed to inadequate funding and lack of local community engagement, highlights the need for sustained investment, education, and local capacity building to ensure effective disaster risk reduction (Matambo & Shrestha, 2011)forming glacial lakes which can burst and cause destructive glacial lake outburst floods (known as GLOFs. While 14 GLOF events in Nepal have been recorded, and lakes like Tsho Rolpa, Thulagi, and Imja Tsho are identified as potentially dangerous, it is difficult to predict specific occurrences. A systematic approach to monitoring, awareness, and hazard mitigation is crucial to manage these impacts.

There has been rapid expansion of glacial lakes in the Nepalese Himalaya, with Imja Tsho, Barun Tsho, and Lumding Tsho showing significant growth rates from 2006 to 2016 due to climate change-induced glacier retreat. Continuous monitoring and proactive risk management strategies are deemed essential to mitigate potential GLOF hazards for downstream areas (Khadka et al., 2019). Experts continue to assess the risks posed by other nearby glacial lakes, which may also threaten further outbursts (see Khadka et al., 2024). Critical barriers to effective mitigation are highlighted, including poor communication, misalignment between external agendas and local priorities, undervaluation of local knowledge, and issues with coordination, indicating that integrated institutional frameworks are needed to strengthen community-based disaster response (Thompson et al., 2020).

Above research agree that GLOF is a catastrophe to human's livelihood in high Himalayas and climate change is its major cause (Bajracharya et al., 2007; Carrivick & Tweed, 2016; Khadka et al., 2019; Matambo & Shrestha, 2011; Samui & Sethi; 2022; Taylor et.al, 2023). Transboundary GLOFs are recognized as significant risks to downstream communities and infrastructure across borders, yet previous research has often neglected their cross-border implications (Khadka et al., 2024) previous GLOF research has largely overlooked the transboundary aspects of national and sub-national level GLOFs, focusing instead mostly on inventorying glacial lakes and assessing their hazards. The lack of cross-border coordination could have dire consequences for vulnerable communities and potential disaster preparedness. Assessing risk perception and vulnerability among downstream populations exposed to GLOFs is crucial for effective disaster risk reduction and management. This study examined the risk perception and vulnerabilities of Nepali communities in Bhotekoshi/Sunkoshi (Poiqu in Tibet. Pandit (2024) claims that the Thame GLOF serves as a stark reminder of the increasing climate-induced risks in the Himalayas. In this research context, Nepal faces significant but unpredictable hazards from GLOFs, particularly as glaciers retreat and glacial lakes expand due to climate change. The unusual flooding in the Thame region of the Everest area in August 2024 was caused by the outburst of two glacial lakes. This incident resulted in significant destruction, including the displacement of approximately 135 people and damage to infrastructure, such as homes and schools. This is an important research opportunity to examine the socioeconomic and environmental effects of GLOFs in the Thame Valley, by identifying the damages to local economies and social stability, and assessing how the resilient living of these communities can be ensured through climate change adaptation theory.

Climate Change Adaptation Theoretical Perspective

Adaptation mainly focuses on developing strength of communities and resilient human constructions, so that communities can adapt in the adverse impact of the climate change. This adaption embeds proper planning, vision, and knowledge for the sustainable human living (Fankhauser, 2016). Climate change adaption are usually funded through international resources, but this also face several scientific and political challenges. Developed nations such as USA withdrew its involvement and responsibility towards the Paris Agreement (Lazarou & Leclerc, 2025). Paris agreement was the landmark agreement amongst all global nations to hold the rising temperature of the earth and reduce global warming (United Nations, 2015).

Climate change adaptation is today's priority for human development as no one is left behind this impact (Pelling, 2011). Similarly, Klein (1999) suggested several adaptation strategies in relation to climate change. This includes:

> "Setting up a monitoring network to enable the early warning of weather-related hazards; Changing institutional arrangements to enhance the effectiveness of political decisions; Strengthening a country's legal system to improve compliance with existing regulations; Changing fiscal arrangements to provide adaptation incentives to the private sector; Supporting the role of non-governmental organizations to ensure public involvement". (p. 13)

Klein's suggestions are important to build an adaptation framework to build safer communities in the advent of climate change. In Nepal's context, this adaption is relevant as the Himalayan country is prone to climate change induced disasters (see DanChurchAid, 2021; Kapri, 2024). Public awareness about the climatic hazard and integrated responses by concerned stakeholders are essential features of the adaptation (International Centre for Integrated Mountain Development, 2011). This research context's on socio-economic and environmental losses due to the GLOF in Nepal's Thame valley is explained through the climate change adaptation theory.

Measures and Methods

This study was carried out in the Thame Valley, a high-altitude region in the Khumbu area of Nepal. The setting is significant due to its proximity to glacial lakes and its economic reliance on tourism and agriculture, both of which are highly vulnerable to GLOF events (Pandit, 2024). This study was carried out in December 2024, after the four months of the Thame flood. Data collection for this study were carried out through Key Informant Interviews (see Ali et al., 2014), reviews of newspaper reports (Earl et al., 2004), and informal communications with locals (Swain & King, 2022). These sources provided firsthand accounts of the GLOF event and its immediate aftermath, as well as insights into the long-term socioeconomic and environmental effects on the community.

The analysis of this data was conducted using thematic analysis methods as suggested by Braun and Clarke (2008). Thematic analysis helped to identify recurring themes, such as loss of livelihoods, damage to infrastructure, and the adequacy of the relief and compensation efforts. The ethical concerns

of this research was maintained through informed consent of the participants, maintaining anonymity their identity and data, and taking permissions from concerned local government authorities in carrying out this research (Laryeafio & Ogbewe, 2023). The quality standard of this research was ensured through prolonged engagement with participants, seeking thick description from them through interviews, narrating their actual voices, and adopting a systematic research approach (see Denzin & Lincoln, 2018; Timonen et al., 2024). The second author, being a local resident of the study area, contributed authentic experiential insights and observational data regarding the impacts of the GLOFs.

Sample and Sampling Procedure

This is a qualitative- cross sectional study (Ekanayake et al., 2012), in which we conducted Key Informant Interviews with ten representatives including the flood victims and the representatives of the local government i.e. Khumbu Pasang Lhamu Rural Municipality of Solukhumbu district. We interviewed ten key informants which were Local government representatives (1 no- I1), small business owners (3 nos- I2, I3, and I4), farmer (2 nos.- I5 and I7), teacher (1 no- I6), monk (1 no- I8), government worker (1 no- I9), and retired local (1 no- I10). Information communications were done with three locals [P1], [P2], and [P3]. It is generally accepted that the sample size for qualitative research range from 10 to 20 interviews until data saturation is reached (Saunders et al., 2017). The primary objective of this interview was to reach the point of data saturation meaning new interviews didn't yield additional insights or new themes.

Measures

This study is primarily based on primary data obtained through the Key Informant Interviews. Checklists for field observation were prepared and used for the systematic recording of the responses. A simple framework was constructed for organizing and interpreting the interview data in Excel. The framework included sections for interview IDs, codes, and themes, as well as space to document quotes or observations. Each step was designed to help structure the analysis systematically. The interviews of the participants is presented under thematic headings social impact, economic impact, and environmental impact.

The Findings

As presented above, the 2024 GLOFs in Thame damaged millions of property, destroyed 20 houses, a school, and a clinic, and displaced dozens of families. Due to this unprecedented environmental disaster, the local stakeholders have faced several socio-economic and environmental consequences in the region. The KII, informal communications, and observational data are presented below.

Social Effects of the GLOFs

The 16 August 2024 GLOFs in Thame completely swept away the houses of 20 locals including that of the renowned Sherpa Everest summiteers Apa Sherpa and Kami Rita Sherpa. Fortunately, there were no human casualties. We conducted this study after the four months of the flood, when the locals were completely relocated to Upallo Thame with their relatives. We talked to these locals to assess the impacts of the flood in their lives and livelihood. People had never thought that they would have to leave all their land, houses, cattle, and displaced to the new place. They had years of nostalgic memories in Thame, which they could not easily leave behind. [I6] shared, "The relocation efforts faced resistance due to deep-rooted social ties, making it challenging for affected individuals to move to safer areas". [P1] added, "Moving to safer areas was difficult: our roots are here".

Likewise, [I5] explained "The flood had profound social consequences, reshaping community dynamics and individual well-being." This was further evident by observing the behaviors of some senior citizens in the study area. We saw psychological distress amongst the residents expressing fear during heavy rains and reduced trust in local warning systems. [P1] mentioned, "Many are still fearful whenever it rains heavily. Children feel afraind to gather and play in open spaces". A teacher [I6] shared "The children lost their elementarily school. This has deeply shocked them". This shows the need of psychological counseling and support to these flood affected people. The government mechanism also requires to properly implement the early warning system in Thame in order to ensure the flood related insecurity of these people.

Despite above mentioned traumas, [I9] commented, "The disaster also triggered a strong sense of community solidarity, as people came together to support each other, rebuild homes, and share resources". People living in neighboring settlements, army, and police, were immediately mobilized in the flood affected area to help and rescue people. Interestingly, people used social media to make the Thame news widespread and bring this incident into national attention. In this regards, [I8] mentioned, "Technology played a crucial role in crisis communication, with social media and mobile phones enabling real-time information sharing, enhancing

preparedness, and fostering collective action". [P1] added, "With social media, we knew about the flood instantly, even those far away could respond. Everyone was sharing updates, calling each other to stay safe and evacuate if needed. We didn't have this technology years ago-it's helping us manage emergencies better now". However, there are some dissatisfactions amongst residents regarding quick response of the central government. [P2] mentioned, "Relief came late: we were already struggling". [I4] shared, "the delayed institutional response and insufficient aid distribution highlighted governance challenges". Besides, the proper use of communication technology was effective in the Thame to concentrate the support mechanism, mobilize the local governments, and bring the Thame GLOF into national and global attentions. We observed that the health clinic in the study area was completely washed away by the flood, due to which the treatment service was stopped and medicine were completely damaged.

Economic Effects of the GLOFs

There are several economic consequences in the lives of people after any natural disaster. Thame flood had caused some unique economic loss in the reason. We found that, due the flood on 16 August, the Mapya- Khumbu Miteri brdge was damaged which caused food crisis in the Khumbu region. This resulted supply and demand imbalance in the Khumbu which is internationally renowned as the Everest trek region. [I1] added, "Our local government was cautious that this economic catastrophe does not cause social and political unrest, so we cordially coordinated with provincial and federal government to immediately provide relief to the people. Accommodation to the half of the rescued people were arranged in the local community building." [P2] mentioned, "(From the local government) We received tarpaulin, some money, and built barriers to protect our houses from future floods." There was effort by the local and other layers of government in providing financial relief to the flood victims. [P5] detailed "15 households whose houses were completely damaged received Rs 50,000 support, and 31 households whose houses were partially damaged received Rs 10,000 each. Our rural municipality and the District Disaster Rescue Committee coordinated this monetary assistance."

[I6] explained, "Namche tourist trail was damaged due to the flood. Locals, which was represented by the Tole Bikas Samiti, constructed alternative trail for tourists". This did not stop the tourists' movement in the Everest region, continuing to function the local economy. The flood severely disrupted local economies, causing loss of income and long-term financial instability. Infrastructure damage, including the destruction of trekking trails and schools, negatively impacted tourism and education, key economic drivers in the region. [I7] mentioned, "Agricultural losses were substantial, with washed-away crops and livestock leading to unemployment and increased dependence on aid". [P3] added, "Our crops were washed away, leaving us helpless". Reduced market access due to damaged bridges and roads further worsened economic conditions, increasing travel costs and delaying relief efforts. [I2] informed, "We lost our bridge, isolating us for weeks"". During the field visit, we witnessed the local power house project was also damaged due to the flood causing a huge loss. These economic hardships forced communities to rely on limited resources and struggle to rebuild their livelihoods.

In addition, this environmental disaster has reinstated a narrative as underscored by a small business owner [I3], "Now, it's not safe to stay in Himalayas. Anything can happen at any time". A government worker [I9] angrily mentioned "We lost houses, clinic, school, and a hotels, road, and bridge. This will cost millions of dollars to rebuild. Who will compensate this loss to us?" We also observed that the flood came with huge flow of debris which resulted in damaging the study area in no time. It was difficult for us to find out the details about the exact figure on the economic losses caused due to the flood.

Environmental Effects of the GLOFs

The devastating flood in Thame was caused due to the GLOFs in Nepal's High Himalayas. GLOFs are mainly caused due to the global warming and climate change. The flood not only caused social and economic disruption but also had severe environmental consequences. A participant [I10] stated, "Water contamination was a significant issue, as the outburst of lakes polluted drinking water sources, increasing health risks and forcing residents to rely on bottled water". Infrastructure damage further worsened environmental conditions, making access to clean water and sanitation more difficult. This situation led to increased health risks and limited access to clean water.

[I6] highlighted, "The destruction of natural landscapes, such as trekking trails and agricultural fields, disrupted local ecosystems, threatening both biodiversity and livelihoods". [I1] disclosed, "There are five glacial lakes above the Thame valley. The 16 August flood was caused due to bursting to two of the lakes. One of the lake is safe and the other two still pose a threat to us which could cause unexpected losses for us". This nature of climate-induced disaster is likely occur in the future causing significant damages to natural resources and communities.

An old monk [I8] remembered his bygone days, "Four decades ago, Thame was hit by the similar kind of flood. That disaster killed almost a dozen of people. The physical destruction was huge than now. We are thankful to the god, that no one was hurt this time". This narrations indicated that GLOFs in the Thame is a recurring phenomenon which has made the lives more vulnerable in this Himalayan settlement. A local government representative [I1] mentioned, "We supported the victims as much as we could. We also have resource constraints, and lack equipment to facilitate the rescue operations. We sought help from Nepal police, and Nepal Army to rescue people and relocate them to safer places". The destruction of natural landscapes further disrupted local livelihoods and ecosystems, and buried the beautiful Thame village under the debris. These environmental challenges underscored the urgent need for sustainable disaster management and improved water security measures. The Thame flood has again sparked the climate change debate nationally and internationally.

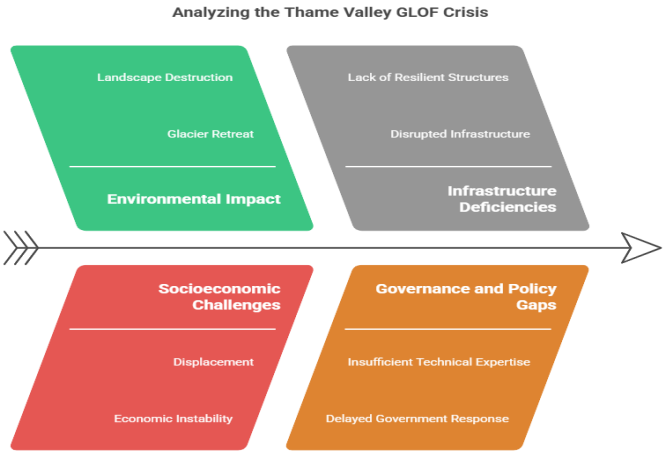
In summary, the 16 August 2024 GLOF in the Thame caused severe social, economic, and environmental destruction. The flood's impact extended beyond immediate destruction, creating long-term challenges for affected communities. This event reignited debates that Nepal's status to prepare and tackle climate-induced disasters such as GLOFs is not sufficient. Innocent people in Himalayan settlements, who have no any role in climate change, are the victim of this climatic disaster. The concerns of providing loss and damage climatic-fund, safeguard of these vulnerable Himalayan communities, and uses of technologies to early warn these people are essential to enhancing resilience against future disasters.

"Thame Flood" Meaning Making: Ringing the Alarm Bell on Climate Change

The GLOF event in Thame Valley illustrates the extreme socioeconomic and environmental impacts of climate change-induced GLOFs in the High-Himalayan settlement (see Figure 1). Climate change is responsible for glacier retreat, the expansion of glacial lakes increases the vulnerability of communities living in these regions (Khadka et al., 2023; Zhang et al., 2024). The environmental changes observed in the Thame Valley includes destruction of the natural landscapes, contamination of water sources, and collection of debris in human settlements. This scenario evident that GLOFs pose a significant threat to both human livelihoods and natural resources (Shrestha et al., 2010; Carrivick & Tweed, 2016). These findings advocate the need of resilient infrastructure, early warning system, disaster risk management framework and community-based approaches to reduce the negative impact of such climate-induced disasters.

Figure 1

Analyzing the Thame Valley GLOF Crisis (developed by the authors)



The socioeconomic consequences of the Thame GLOF explored the vulnerabilities such as displacement, economic instability, and the loss of livelihoods. Bajracharya et al. (2007) also demonstrated that, the Himalayas are particularly at high risk to climate-induced disasters, which are compounded by socio-economic factors such as unregulated human activity and limited resources. Relocation was effectively managed in the Thame due to the lesser number of displaced population. However, relocation of affected individuals was challenging when there is the disruption of critical infrastructure, such as schools and clinics, which further exacerbate these vulnerabilities. These socio-economic challenges highlight the need for targeted adaptation strategies, including financial assistance, community support systems, and resilient infrastructure. This support mechanism will help communities recover and reduce future risk exposure. One important findings of this research is the immediate and leadership roles of local governments in the disaster management and providing reliefs to the affected people.

The 2015 Constitution of Nepal has also delegated disaster management authorities to the local governments (Ministry of Law, Justice and Parliamentary Affairs, 2015). However, this finding shows that these governments lack technical expertise and sufficient fund in order to handle these climate induced disasters. Likewise, these governments need Disaster Management Plans and laws to institutionally tackle the climate induced crisis (The Asia Foundation, 2019). United Nations' Loss and Damage fund to the developing countries such as Nepal is very urgent to ensure the safe living and build confidence of these

vulnerable communities (see Pill & Hammersley, 2024).

Climate Change Adaptation Theory (see Biagini et al., 2014; Fankhauser, 2016) in this research's context offers valuable insights into the need for adaptive measures that enhance the resilience of mountain communities. As the study reveals, the Thame GLOF highlighted the deficiencies in disaster management and the lack of adequate early warning systems (see Klein, 1999; Shrestha et al., 2010). There seems to be delayed responses from the central government and insufficient aid distribution. Global temperature is likely rise in coming years (Kahn, 2016). There needs proper adaptive mechanism to these climate-induced hazards which requires technological advancements, governance improvements, and the active participation of local communities (Pelling, 2011; Klein, 1999). The flood's impact in Thame emphasizes the necessity of fostering community bonding, strengthening institutional frameworks, and utilizing technology for crisis communication. These adaptive features are essential to enhance future preparedness and response. It is crucial to develop an integrated disaster management strategy that focuses on prevention, early warning systems, and long-term adaptation measures. This climatic hazard has alerted every stakeholders to prepare and implement climate change adaptation strategies to safeguard vulnerable communities in Nepal's mountainous regions.

Thus, the findings of this research reveal multifaceted effects, including economic losses, displacement, infrastructural, environmental, and social challenges in the Thame valley. This climatic calamity is an alarm bell which need to be immediately addressed through climate change adaptation measures.

Conclusion

In conclusion, the 2024 GLOF in Thame highlights the severe social, economic, and environmental impacts of climate-induced disasters on Nepal's high-altitude communities. It is urgent need for applying climate-change adaptive measures such as improved early warning systems, resilient infrastructure, and sustainable disaster management. As climate change accelerates GLOFs risks, collaborative efforts among policymakers, researchers, and local stakeholders are crucial. Local governments require to be technically and financially resourceful in order to handle these climatic catastrophes and help the affected people in their adaptation. Global funding such as Loss and Damage funds should priorities these vulnerable Himalayan settlements. Further studies are needed to assess mitigation measures and enhance intergovernmental coordination to handle the climate-induced disaster. This research is significant in informing disaster risk reduction, advancing knowledge on climate hazards, and strengthening community resilience in vulnerable Himalayan regions.

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