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POST-GLOF RECOVERY ANALYSIS: A CASE STUDY OF THE 2019 EVENT IN GOLAIN GOL, LOWER CHITRAL, PAKISTAN

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ABSTRACT

This study evaluates the post-disaster recovery efforts following the 2019 Glacial Lake Outburst Flood (GLOF) event in Gollain Valley, Chitral, Pakistan. A mixed-method research approach was employed, incorporating both qualitative and quantitative data collection methods. Primary data was gathered through qualitative methods, including observations and interviews, and quantitative data through questionnaires. A total of 200 questionnaires were randomly distributed, and 4 interviews were conducted. Secondary data was sourced from books, journals, the District Census Report (DCR), and online resources. The results revealed that the government played a significant role in recovery projects within the study area, with NGOs also contributing substantially. While many recovery projects have been completed, progress on others, such as road repairs in the upper regions, remains slow due to limited funding. Insufficient financial support has been provided for fully and partially damaged houses, leaving affected residents dissatisfied with stakeholders and forcing some to continue living in temporary shelters.

Key Words: Disaster Recovery, Chitral, Glacial Lake Outburst Flood (GLOF), Disaster Management, Climate Change Adaptation

INTRODUCTION

Natural disasters, such as the Glacial Lake Outburst Flood (GLOF) events, significantly disrupt communities, causing extensive damage to property, loss of life, and long-term socio-economic challenges (Sedai, 2021). A disaster is typically defined as the interaction between a natural hazard and a vulnerable society, resulting in considerable harm within a specific geographic area over a limited time period (Blaikie et al., 2014). When these interactions lead to severe damage, injury, or fatalities, the term "disaster" is applied (Sedai, 2021).

The concept of the disaster cycle is central to understanding how communities prepare for, respond to, and recover from disasters (Sawalha, 2020). This cycle, often referred to as the disaster life cycle, encompasses a series of steps that emergency managers follow to mitigate the impact of disasters (Tay et al., 2022). These steps—preparedness, response, recovery, and mitigation—are integral to emergency management at local, national, and international levels (Wamsler & Johannessen, 2020). Preparedness strategies are designed to ensure that both emergency services and at-risk populations are ready to respond effectively when a disaster strikes (Shmueli, Ozawa, & Kaufman, 2021). Once a hazard occurs, the focus shifts to the response phase, where immediate needs such as life protection, property preservation,

emergency medical care, and the provision of essential services like food, water, and shelter are addressed (Shmueli, Ozawa, & Kaufman, 2021). Following the response phase, recovery efforts commence, focusing on long-term rebuilding and restoration (Crow & Albright, 2021). This phase can extend over months or even years as communities work to restore normalcy. Simultaneously, mitigation efforts are undertaken to reduce the risk of future disasters by incorporating lessons learned from the recent event, such as constructing earthquake-resistant buildings (Crow & Albright, 2021; Shmueli, Ozawa, & Kaufman, 2021).

The recovery phase is a critical period where efforts are made to restore both the lives of the affected population and the infrastructure that supports them (Crow & Albright, 2021). As the immediate emergency subsides, the focus shifts to long-term recovery and sustainable development. However, the transition from emergency response to recovery and eventually to development is often complex and not clearly defined (Finucane et al., 2020). The recovery phase presents numerous opportunities to enhance preparedness and prevention, thereby reducing future vulnerabilities (Gul & McGee, 2022). Ideally, recovery should seamlessly transition into ongoing development, with recovery efforts continuing until all systems are restored to pre-disaster conditions or better (Gul et al., 2024).

Several key terms are associated with the recovery process. "Restoration" refers to the process of cleaning and restoring the community to its pre-disaster state (Galderisi et al., 2022). "Rehabilitation" involves the restoration of basic social functions, including providing temporary shelters, stress debriefing for responders and victims, and economic and psychosocial rehabilitation (Phillips, Neal, & Webb, 2021). "Repatriation" describes the return of displaced individuals to their places of origin after the emergency has subsided (Galderisi et al., 2022). "Reconstruction" focuses on the restoration and improvement of facilities, livelihoods, and living conditions in disaster-affected communities, with an emphasis on reducing future disaster risks (Phillips, Neal, & Webb, 2021). Reconstruction often involves the replacement of damaged physical structures and the restoration of local services and infrastructure (Rouhanizadeh & Kermanshachi, 2020).

The recovery process encompasses various elements, including community recovery (with a focus on psychological well-being), infrastructural recovery (services and lifelines), economic recovery (financial and political aspects), and environmental recovery (Gul and McGee, 2022). Disaster recovery involves a comprehensive approach to restoring the affected community to its pre-disaster state. This process includes the provision of temporary housing, public information dissemination, health and safety education, reconstruction efforts, counseling programs, and economic impact assessments (Gul et al., 2024).

The disaster recovery process typically unfolds in several stages. The initial stage is the emergency response, which is triggered immediately after a disaster occurs. This stage involves activating recovery mechanisms, allocating responsibilities, and mobilizing resources to address the immediate needs of the affected population (Crow & Albright, 2021). Early recovery or short-term recovery bridges the gap between emergency response and long-term recovery, focusing on providing immediate services to the community and laying the groundwork for sustainable development (Phillips, Neal, & Webb, 2021). Medium and long-term recovery phases involve strategic planning and actions to address the more serious or permanent impacts of the disaster. These phases require a detailed assessment of the needs of the affected population, the formulation of strategic recovery plans, and the implementation of sector-specific programs and projects (Crow & Albright, 2021). Post-disaster recovery is a multifaceted and challenging process that involves numerous institutions at the national, regional, and local levels, as well as international cooperation (Gul et al., 2024). This phase addresses the immediate impacts of the disaster, focusing on restoring normalcy and rebuilding social and economic activities as well as fostering community growth, and implementing improvements to reduce future disaster risks (Phillips, Neal, & Webb, 2021).

A GLACIAL LAKE OUTBURST FLOOD (GLOF) OCCURS WHEN WATER SUDDENLY RELEASES FROM A LAKE FORMED BY GLACIER MELT (Rawat, Pandey, & Gupta, 2022). THESE LAKES ARE

typically impounded by natural barriers such as moraine complexes, glacial ice, or bedrock. When these barriers fail due to breaching, slope collapse, overtopping, or other mechanisms, the result can be catastrophic, particularly in high mountainous regions where such events threaten lives, livelihoods, and regional infrastructure (Rawat, Pandey, & Gupta, 2022).

GLOFs are increasingly recognized as a significant threat, especially in regions like the Himalayas, Hindu Kush, and Karakoram in Pakistan, where the retreat of glaciers due to global warming has led to the formation and expansion of numerous glacial lakes (Sarwar & Mahmood, 2024). The rapid melting of glaciers, exacerbated by rising temperatures and decreased snowfall, contributes to the instability of these natural dams (Rawat, Pandey, & Gupta, 2022). When the pressure of the accumulated water exceeds the strength of these barriers, a sudden release occurs, sending a torrent of water, debris, and boulders rushing downstream with devastating consequences (Sarwar & Mahmood, 2024).

The phenomenon of GLOF is not just a local concern but a global one, as these events have been responsible for some of the most significant floods in Earth's history, leading to extensive changes in landscape and the loss of large freshwater reserves to the oceans (Bazai et al., 2021). The increase in the number of glacial lakes, driven by both natural and anthropogenic factors, particularly climate change, has heightened the risk of such events (Sarwar & Mahmood, 2024). Human activities, including tourism and industrial emissions, further accelerate glacial melting through albedo effects, thereby contributing to the fragility of glacial lakes (Bazai et al., 2021).

Global warming, largely driven by human activities since the Industrial Revolution, has dramatically altered the climate, particularly in mountainous regions (Adamo, Al-Ansari, & Sissakian, 2021). The warming trend has been more pronounced in these areas, leading to an accelerated rate of glacial melting (Bazai et al., 2021). In Pakistan, for instance, the northern mountainous regions have experienced a temperature rise that is double that of lower elevations (Sarwar & Mahmood, 2024). The increased frequency of heatwaves and the shift in precipitation patterns, where snowfall is replaced by rain at higher altitudes, have further destabilized these regions, increasing the likelihood of GLOFs (Bazai et al., 2021).

The implications of GLOFs are severe, particularly for the communities living downstream of these glacial lakes. As populations grow and human settlements expand into vulnerable areas, the potential for catastrophic losses of life and infrastructure, including roads, buildings, and bridges, becomes more significant (Dubey et al., 2024). Historical data shows that GLOFs have resulted in thousands of deaths worldwide, with regions in Central Asia, South America, and the European Alps being particularly affected (Taylor et al., 2023). These events are unpredictable, often occurring rapidly, leaving little time for effective response or mitigation.

In light of these challenges, there is a growing interest among researchers in understanding the causes and mechanisms of GLOFs to develop strategies for predicting and mitigating their impacts (Dubey et al., 2024). The rapid warming of the last few decades, which has been much higher than anticipated, underscores the urgency of addressing the risks associated with glacial lake outbursts (Taylor et al., 2023). The formation and expansion of glacial lakes, coupled with the increased likelihood of their sudden release, represent a significant natural hazard that poses a serious threat to downstream communities and infrastructure (Bazai et al., 2021). As such, GLOFs remain a high-risk disaster with the potential to cause widespread damage and disruption.

Shahid (2024) conducted a study focusing on the Hassanabad settlement in Hunza, Pakistan, which has experienced five Glacial Lake Outburst Floods (GLOFs) between 2019 and 2022. This research aimed to assess the impact of these floods, explore the varying levels of vulnerability within the settlement, and evaluate the effectiveness of local adaptation strategies. The study employed a combination of spatio-temporal analysis and qualitative fieldwork. The findings revealed that areas situated closest to the Hassanabad ravine, or 'nullah,' have been severely affected by land erosion and remain highly vulnerable to future GLOF events. The research also highlighted the critical role of community-led disaster risk management (CBDRM) initiatives in mitigating the impact of these floods on local residents. Haider et al. (2024) explore the vulnerability of Sosot Village in Ghizar District, Gilgit-Baltistan, a community that has experienced significant glacial lake outburst flood (GLOF) events, particularly the devastating 2012 event, which resulted in monetary losses of approximately 100 million Pakistani rupees. The study identifies high temperatures as a key factor triggering these GLOFs. Despite the village's social cohesion and focus on education, the community struggles to achieve economic resilience. The recurring GLOFs lead to the loss of infrastructure, livestock, and agricultural productivity. The study employs the Flood Vulnerability Index (FVI) to assess the village's vulnerability, considering social, economic, environmental, and physical factors.

In another study, Rinzin et al. (2023) conduct an in-depth assessment of the susceptibility, hazard, exposure, vulnerability, and risk associated with glacial lake outburst floods (GLOFs) for four potentially hazardous glacial lakes—Bechung Tsho, Raphstreng Tsho, Thorthomi Tsho, and Lugge Tsho—within the Lunana glacier complex in the Phochu basin of Bhutan. The study offers a comprehensive evaluation of the risks posed by these glacial lakes in the Bhutan Himalaya.

Aslam et al. (2022) conducted an empirical investigation into how communities in the remote, mountainous region of Gilgit-Baltistan, Pakistan, perceive the risks associated with climate change and glacial lake outburst floods (GLOFs). The study focused on vulnerable populations in the Ghizer District and utilized a quantitative approach, gathering data through household surveys to assess local risk perceptions related to these environmental threats.

Khalid et al. (2021) provide a qualitative analysis of gendered vulnerabilities in the rural community of Hassanabad in Hunza Valley, Northern Pakistan, following the Shishper glacier lake outburst floods (GLOFs) of 2019 and 2020. The study draws on empirical data collected through semi-structured interviews with men and women from various age groups in the village, highlighting the distinct experiences and challenges faced by each gender in the aftermath of these disasters.

This study aims to analyze the post-disaster recovery process after the 2019 GLOF event in Gollain Gol valley, District Chitral Lower of Khyber Pakhtunkhwa Provincein Pakistan. The specific objectives of the study are 1) to evaluate the extent of damage caused by the 2019 GLOF in Golain Gol, including the impact on infrastructure, livelihoods, and the environment in Lower Chitral, Pakistan. 2) to investigate the response strategies and recovery measures implemented after the 7th July, 2019 GLOF event, focusing on their effectiveness in restoring the affected community and reducing future vulnerability and 3) To explore the challenges faced during the long-term recovery process, including social, economic, and environmental factors, and to identify opportunities for enhancing resilience in the Golain Gol region.

Methods and Materials

Study Area

Golain Valley is geographically positioned between the latitudes 35°48'5.091"N to 36°6'8.429"N and longitudes 72°9'8.818"E to 72°14'52.629"E. To the north, it is bordered by Mori Payeen, while Ghochhar Sar Peak lies to the south. Sor Laspur is situated to the east, and Kaghozi and Chitral city are located to the west. The valley spans an area of 528.93 square kilometers and is home to a population of 3,525 people residing in eight main villages. Golain Valley, located 25 kilometers east of Chitral along the main Chitral-Mastuj Road, is renowned for its hydroelectric power project with a capacity of generating 108 MW. Covering an area of 528.93 square kilometers, the valley includes at

least seven smaller catchments that extend southeastward. The region is home to 53 glaciers, ranging in elevation from 6,143 meters to 3,917 meters above sea level. Known for its lush green meadows and pastures, Golain Valley holds significant potential for electricity production and provides clean drinking water to Chitral town, currently meeting about 80% of the potable water needs for its approximately 80,000 residents.

The valley is well-known for its lush green meadows and pastures. The local population primarily speaks Khowar and Urdu. The main villages within Golain Valley include Istoor, Birmogh, Shamkan, Izghoor, Chashma, Golain Payeen, Bobhaka, and Dangari Koro. Historically, according to local inhabitants, Golain Valley was once sparsely populated and primarily used for grazing livestock. The region's residents traditionally kept sheep, goats, and other domestic animals. The entire population of Golain Gol follows the Sunni Muslim sect, with no other religious groups present in the area.

The literacy rate in Golain Gol Valley is approximately 72%, with 40% male literacy and 32% female literacy. Compared to other regions in Lower Chitral, Golain Gol Valley is considered one of the most underdeveloped and backward areas, facing challenges such as rough roads, inadequate water irrigation channels, and over 10 small bridges that are vulnerable to water flow from the glaciers. Golain Gol experiences all four seasons, with rainfall typically beginning in February and March. Monsoon rains occur from late June to mid-August, and significant snowfall is observed annually between December and January.

Rogheli Gol is located at 36°13'50.28"N and 72°22'36.18"E, at an elevation of 8,400 feet above sea level. According to a PMD report, the temperature in Chitral and its surroundings remains high, which could accelerate glacier melt and increase river flow. Rogheli Gol, situated 8 kilometers from the main Chitral-Mastuj Road at an altitude of 7,500 feet, is home to several glaciers, including Khundar, Hongyak Gol, Kakeli, and Payosadar glaciers. These glaciers feed two glacial lakes located about 1 kilometer below, near Rogheli village in Golain. Most of the glaciers in Rogheli Gol are classified as C-Type and are found at altitudes ranging from 13,500 to over 15,000 feet above sea level. On July 7, 2019, at 5:00 pm, a Glacial Lake Outburst Flood (GLOF) event occurred in Rogheli, Golain Valley. According to the PMD report, the lake began forming on June 3, 2019, in the glacier of Nalla at Rogheli, at an elevation of 4,500 meters above sea level.

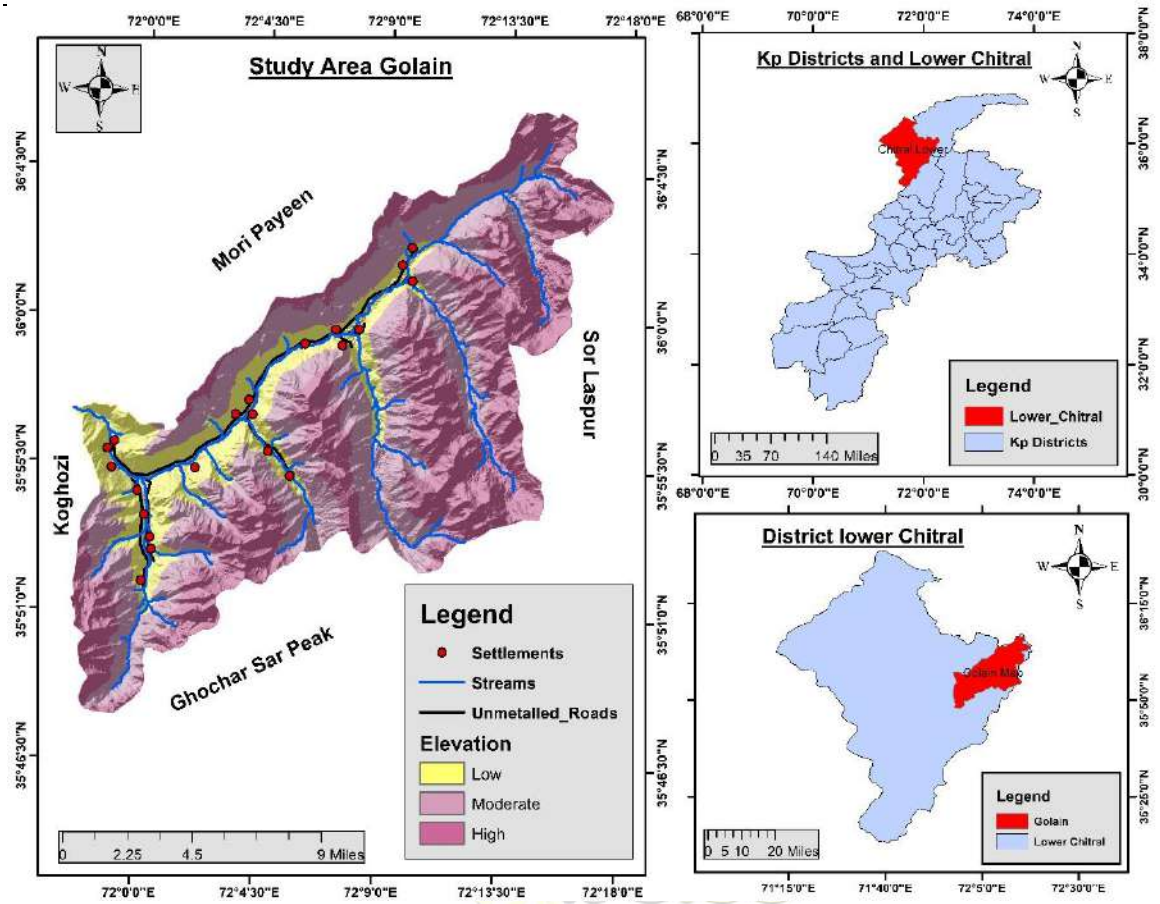


Figure 1: Location Map of the Study Area, Golain Gol, Chitral Lower

Golain Valley is highly vulnerable to natural disasters, largely due to the presence of numerous glaciers and glacial lakes. The valley's challenging topography and limited accessibility further increase its susceptibility to disasters. Even a minor flood in the Golain stream can destroy the only link road, which runs along the stream's edge, a situation that occurs annually. The history of natural disasters in the valley dates back to the earliest human settlements. The steep slopes contribute to frequent avalanches and mudslides, while rock falls and torrents are common, especially in early summer. In recent years, GLOFs have also emerged as a significant threat to life and property in the valley. Key assets in Golain Valley that are highly vulnerable to GLOFs and flash floods include a 112 MW hydropower station, over 150 households with a population of 1,000 people, the main Chitral-Mastuj Road, and agricultural lands.

Table 1: Socio-economic and Ecological Details of the Valley/Study Area (DDMU Chitral, 2019).

Area (km²)	529	Languages
Population	3515	Khowar and Urdu
Total HHs (Households)	370	
No. of main villages	8	
% of the population below the poverty line	45	
Literacy rate (%) men	40	
Literacy rate (%) women	32	

Average landholding (kanal per household)	20.5		
Valleys	3 Sub Valleys	Villages	1
Villages/Hamlets	10	Administration	KUH UC
Passes	4 (chakoli, Rogheli, Birmogh & shaciokoh passes	On-farm income (%)	70
		Off-farm income (%)	30
Average monthly HH income			20,000/PKRs
Main sources of livelihood: Agriculture/livestock, off-farm employment/seasonal labor (unskilled), aquaculture, apiculture, potato production			

GLACIERS AND GLACIAL LAKES:

No of Glaciers	53
No of Glacial Lake	9
Covered Area of Glacial Lakes	261735 sq Meters
Potentially Dangers Lakes	2

GLOF hazard in Chitral

From July 15th to 28th, 2015, various parts of Chitral district were struck by glacial floods that unleashed massive volumes of water, devastating villages, roads, bridges, and other infrastructure. The floods also severely disrupted the drinking water supply. While such events are rare, climate change has increased the vulnerability of northern districts in Khyber Pakhtunkhwa, including Mansehra, Chitral, Battagram, Kohistan (Upper and Lower), Torghar, and Shangla. These areas have already been highlighted by NDMA and PDMA during different phases of monsoon contingency planning. In Chitral alone, 32 people have been reported dead in various incidents related to the floods.

Glacial Lake Outburst Floods (GLOFs) pose significant threats to livelihoods, as they can trigger sudden floods, ravage cropland, and disrupt communication networks to communities located below and across the glaciers. The damage caused by these floods can extend far from the initial outburst, impacting settlements and farmland over large areas. In Golain Valley, where residents have long faced flood hazards, the situation has worsened with the increasing frequency of these events, likely driven by global climate change in recent years.

The primary impact of glacial floods is on agricultural land, which directly affects the economy and livelihoods of local people. Additionally, the destruction of infrastructure hampers tourism, trade, and marketing across the region. For instance, when a bridge was damaged during a flood, the blockage of the Mastuj road forced people to manually transport their goods, leading to increased physical and mental strain. Much of the damage during GLOF events is linked to the large amounts of debris carried by the floodwaters. In a particularly severe event in the Golain basin, heavy debris flows, including large boulders, destroyed key infrastructure and severely impacted the Golain hydropower plant. The formation of an upstream lake further

affected nearby roads and village settlements, exacerbating the damage.

Data Collection

This research employs a combination of qualitative and quantitative research methods, commonly referred to as a mixed-method approach. The qualitative aspect includes observation and interviews, while the quantitative aspect involves the use of questionnaires. Primary data was gathered firsthand by the researcher directly from the field through observation. This data is divided into two categories: qualitative and quantitative. For this research, qualitative data was obtained through semi-structured, in-depth interviews and participant observations in the field. Four face-to-face, in-depth, semi-structured interviews were conducted with local residents directly impacted by the GLOF event. An interview guide was used to conduct interviews which included questions related to identifying the stakeholders involved in recovery efforts, understanding community perceptions of the recovery process, and gathering information about those who relocated due to the GLOF event.

During field observations, the ongoing impact of the GLOF event was evident, with visible damages still present in the area. Recovery projects were observed, many of which were initiated by the government, while others were supported by NGOs or managed by the local community. Some projects had been completed, while others were still in progress.

Quantitative data, on the other hand, was collected through questionnaire survey. A total of 200 questionnaires were filled with the help of random sampling techniques and questions were asked about the causes, impacts, recovery measures and participants' experience of the recovery process after the 2019 GLOF even. For this research, secondary data was sourced from books, journals, the District Census Report (DCR), and online resources. Relevant literature and research reports available on the internet were also consulted.

Various techniques were applied to analyze the collected data, including cartographic and statistical methods.Statistical analysis involved summarizing the data using averages and percentages, with tables and graphs created using software such as Mapinfo, PowerPoint, and MS Excel. The qualitative data collected through focus group discussions and interview were transcribed and analyzed using coding. Themes were identified after coding the data and the results were presented in the form of text and models. In cartographic analysis, ideas were represented visually through maps and diagrams.

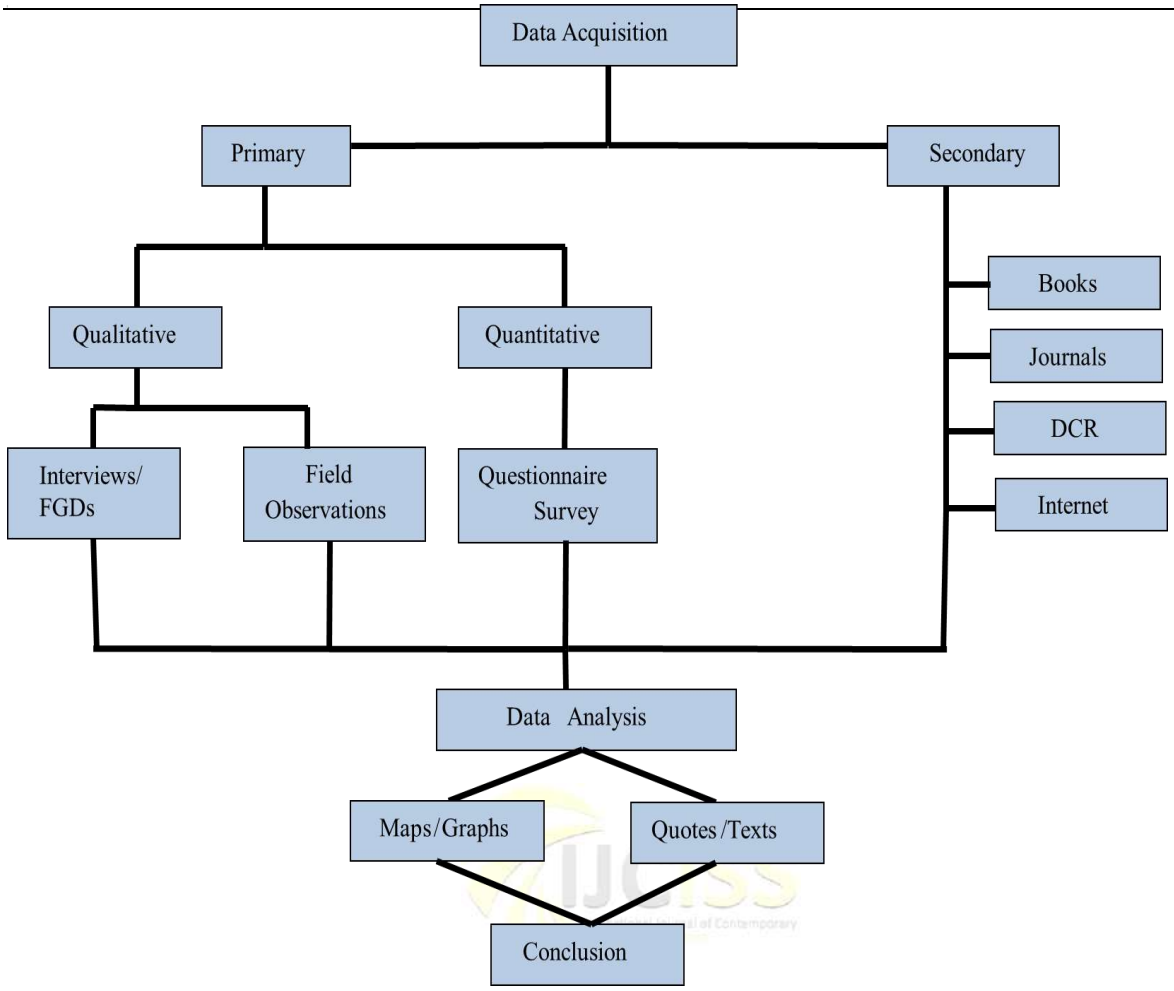


Figure 2: Flowchart elaborating the research methodology

Results

Table 2 shows the characteristics of the respondents.

Table 2: Characteristics of the study participants

Age Group of Respondents						
Age group	15-20	21-25	26-30	31 & above	Total	
Frequency	30	100	10	60	200	
Percentage	15%	50%	5%	30%	100%	
Qualification of Respondents						
Respondents	Middle	Matric	Intermediate	Bachelor	Masters	Total
Frequency	10	100	60	10	20	200
Percentage	5%	50%	30%	5%	10%	100%

Occupation of Respondents						
Respondents	Students	Driver	Farmer	Labor	Mechanic	Total
Frequency	90	30	10	30	40	200
Percentage	45%	15%	5%	15%	20%	100%

Figure 3 shows the presence of the respondents at the time of GLOF event. Majority of the participants (90%) said that they were present at the time of the 2019 GLOF event.

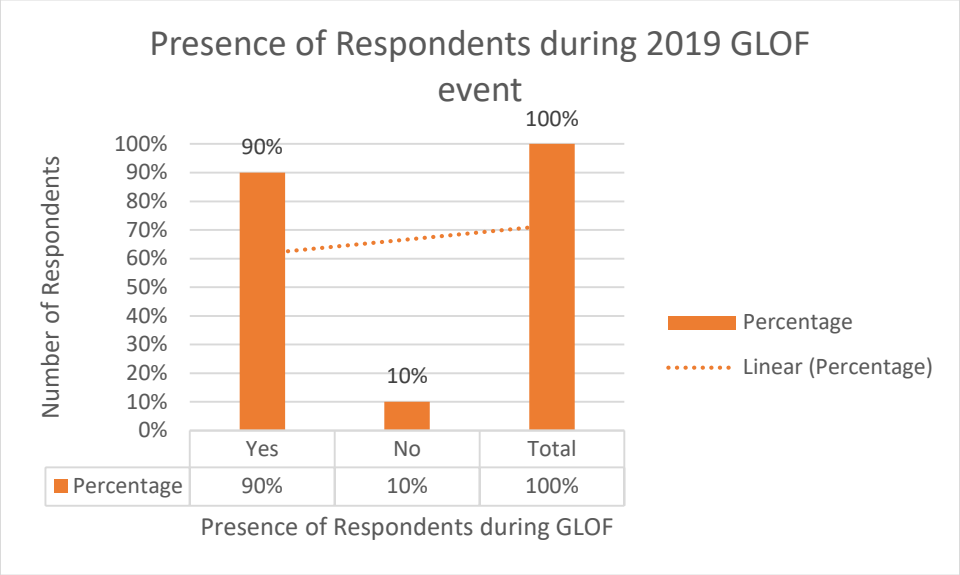


Figure 3: Presence of Respondents during 2019 GLOF event

Figure 4 shows the causes of the GLOF event. Most of the respondents (80%) said that it is because of glacier bursting, while 15% respondents said it is because of high temperature and 1 of them (5%) said it is because of heavy rainfall. One interview participants said:

> The GLOF event is because of the increase in temperature. Whenever it is hot, GLOF occurs (Participant 01)

While the other two who we interviewed thought GLOF is caused by bursting of glaciers:

> The GLOF event is because of the bursting of glaciers. For some reasons. The Glaciers burst and a huge flood comes which washes away everything (Participant 03).

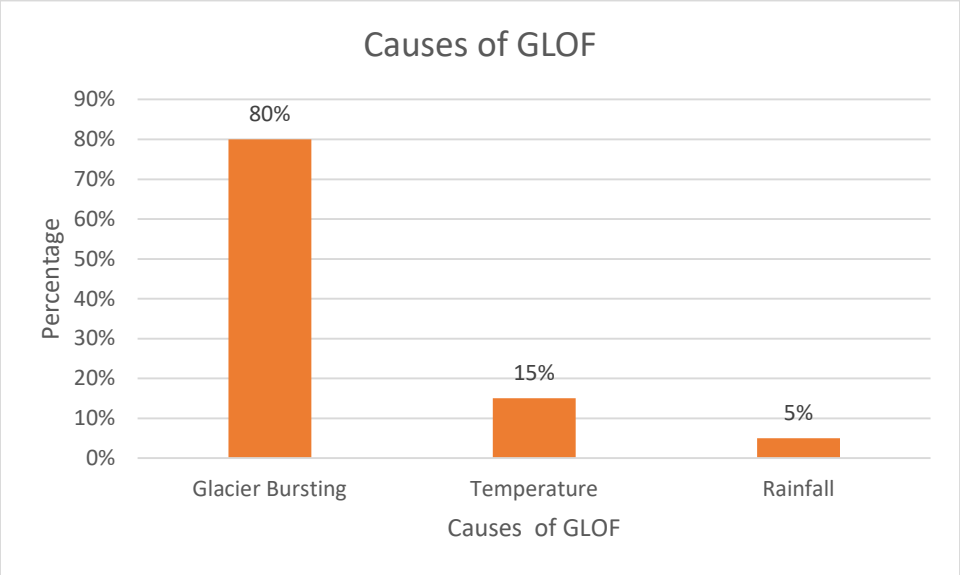


Figure 4: Causes of GLOF

All of the respondents told us that there was no loss of human life occurred because of the flood, but 4 to 5 people got injured. It is important to mention that there was a severe danger to human lives but due to the blessings of almighty Allah they came to know about the flood and fled to the safer places. One of the respondents said:

> We had come to know about the downstream movement of the flood approximately 30 minutes before and we fled to the safer places to save our lives (Participant 01).

Another respondent said that:

> We had been informed one day before the GLOF event that is how we could manage to save our lives (Participant 03).

The affected people could only manage to save their own lives but a catastrophic loss to properties occurred because of the GLOF event. Damages to houses, livestock agricultural lands, shops, and two to three cars have been destroyed. One of the respondents said:

> In the village of Isghoor three cars have been damaged due to the severe flood (Participant 04).

Figure 5 presents the extent of damage to various types of infrastructure, categorized into two groups: "Totally Damaged" and "Partially Damaged," expressed as percentages. For houses, the data shows that 10% were completely destroyed, while the majority, 90%, sustained partial damage. Roads and utility poles, on the other hand, suffered the most severe damage, with 100% of both being totally destroyed and none experiencing partial damage.

Bridges experienced a mix of damage, with 60% being completely destroyed and 40% partially damaged. Irrigation channels were also heavily impacted, with 85% totally destroyed and 15% partially damaged. Similarly, water supply pipelines were significantly affected, with 80% completely destroyed and 20% sustaining partial damage.

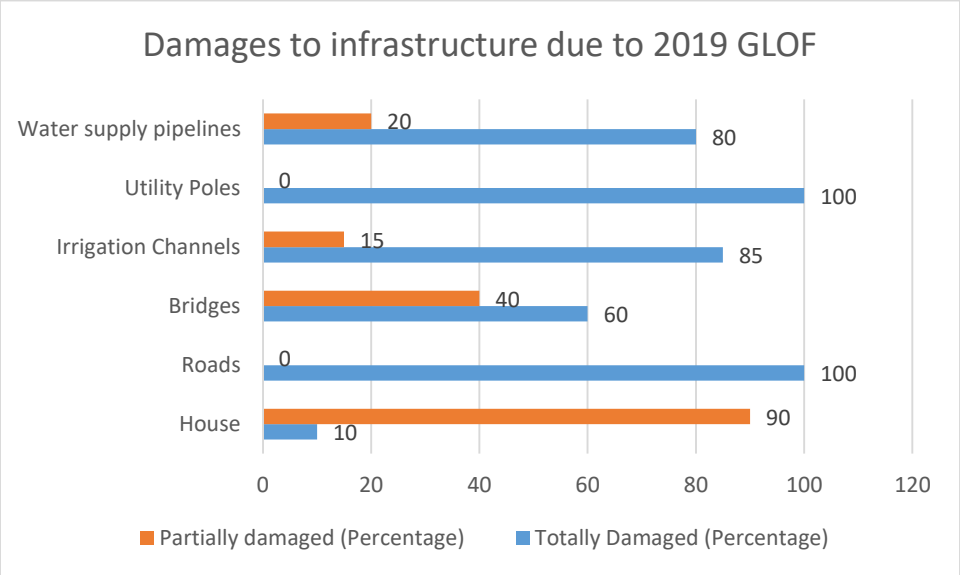


Figure 5: Infrastructure Damage due to 2019 GLOF

Figure 6 illustrates the extent of livestock damage, categorized by the number of animals lost or injured. The majority of losses occurred in smaller groups, with 65% of incidents involving fewer than 10 animals lost, while 20% of incidents involved the loss of 31 or more animals. Similarly, 65% of livestock injuries also occurred in groups of less than 10, and only 10% involved 31 or more animals. Smaller-scale losses and injuries were the most common, with a significant portion of incidents affecting fewer than 10 animals.

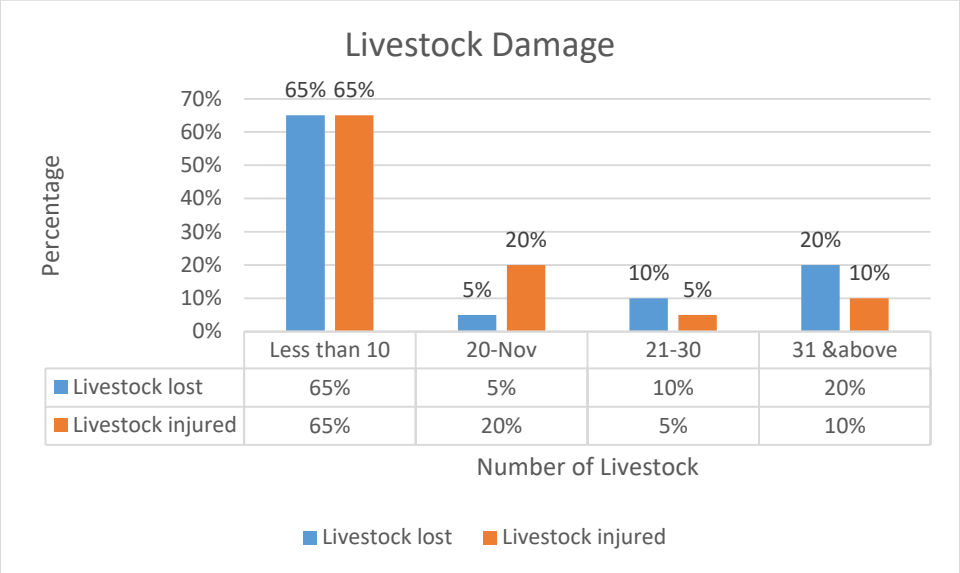


Figure 6: Livestock damage due to 2019 GLOF

Figure 7 illustrates the percentage of field damage incidents during the 2019 GLOF event in Golain Valley, Chitral, categorized by the size of the affected fields. The majority of damage, 55%, occurred in fields larger than 51 acres, indicating that larger fields were most affected by the event. Fields ranging from 20 to 30 acres accounted for 30% of the incidents, while 10% of the damage

occurred in fields between 31 to 40 acres. The smallest percentage, 5%, was associated with fields between 41 to 50 acres. This suggests that the GLOF event had a significant impact on larger fields.

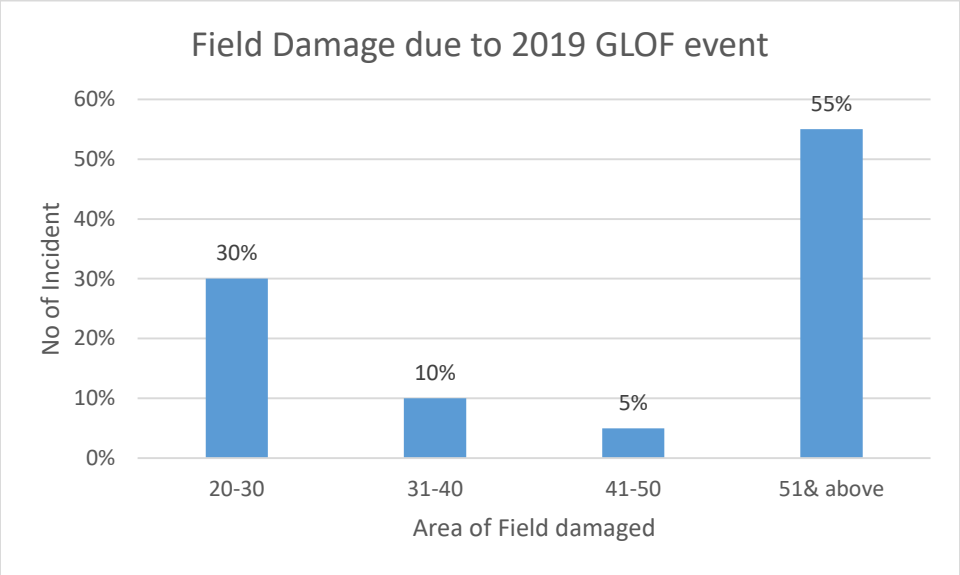


Figure 7: Fields damage due to 2019 GLOF event

Rescue teams visited the affected area after one week of the GLOF event. After that, the government officials visited the site about 13 to 14 days later and they made embankments, temporary bridges, irrigation channels, etc. According to one of the respondents:

> The temporary recovery projects started suddenly after the event but the proper recovery projects started after two months of the event like the reconstruction of roads, bridges, irrigation channels, utility poles (Participant 02).

Figure 8 shows the involvement of different stakeholders in the recovery process after the 2019 GLOF event in Golain Valley, Chitral, based on respondents' feedback. A significant majority, 75%, identified the government as the primary actor in the recovery efforts. NGOs were mentioned by 20% of respondents as contributing to the recovery process, while only 5% of respondents indicated that the local community played a role in these efforts. This suggests that the government took the lead in recovery, with some support from NGOs and minimal involvement from the local community. In the words of one interview participant:

> Most of the recovery projects have been done by the government like the construction of roads, irrigation channels, embankments but NGO has a great role as well in the construction of temporary bridges, utility poles, repairing of roads (Participant 04).

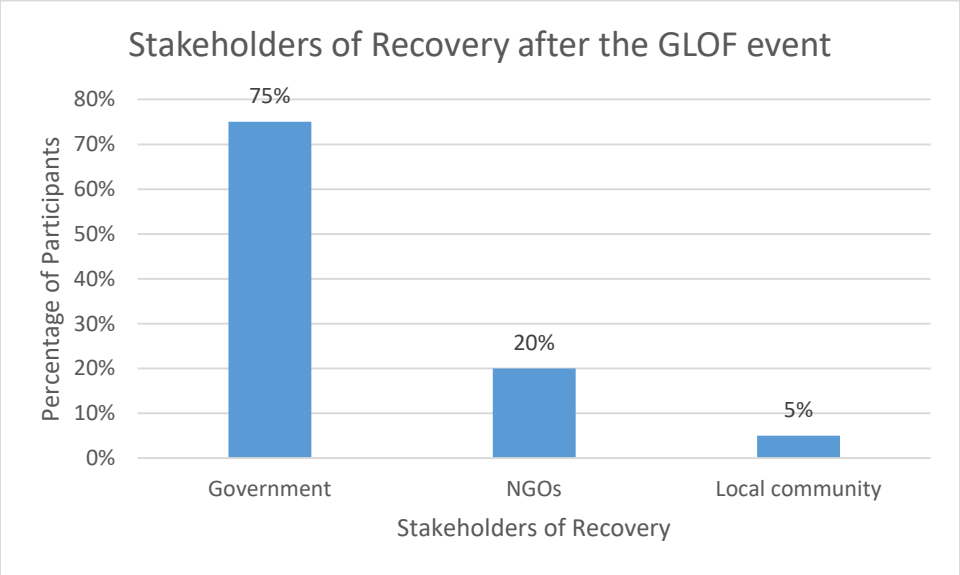


Figure 8: Stakeholders participating in Disaster recovery after 2019 GLOF

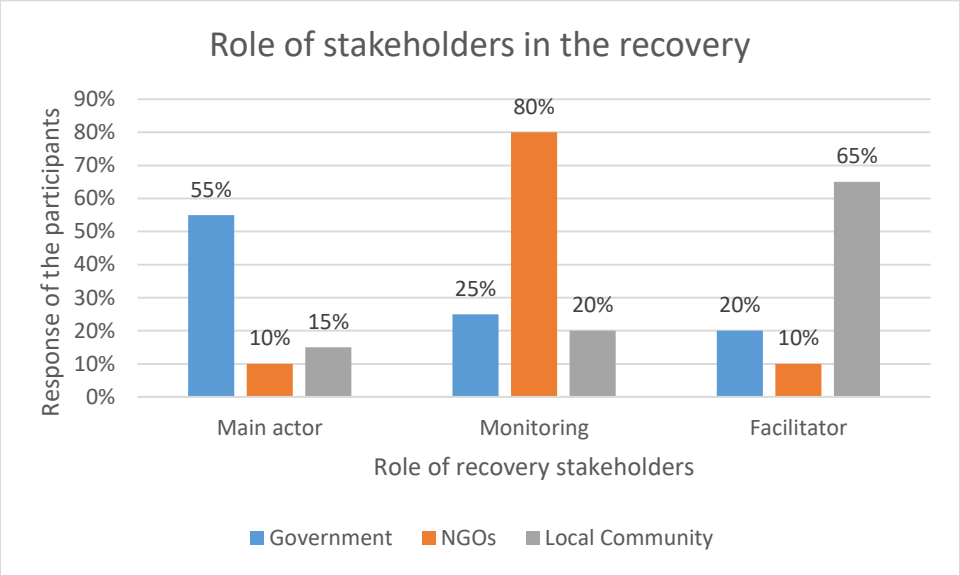


Figure 9: Role of different stakeholders in the recovery

The figure 9 highlights participants' views on the roles of various stakeholders in the recovery process after the 2019 GLOF event in Golain Valley, Chitral. The government was seen as the main actor by 55% of respondents, with 25% viewing its role as monitoring and 20% as facilitating recovery. All of the respondents were quite satisfied with the work of the government because most of the recovery projects have been done by the government. Like the recovery of roads, bridges, irrigation channels, and the construction of embankments for safety measures, etc. One of the interviewees said:

> The government played a major role in the recovery process after the catastrophic GLOF event like the construction of roads, bridges, embankements, irrigation channels (Participant 02).

NGOs were primarily recognized as monitors, with 80% identifying them in this role, while only 10% saw them as main actors or facilitators. As one interview participant said:

> The temporary bridges and utility poles have been constructed by the NGO immediately after the flood (Participant 02).

The local community was mostly seen as a facilitator, with 65% of respondents assigning them this role, while 15% viewed them as the main actor and 20% as monitors. This suggests that the government led the recovery, NGOs focused on oversight, and the local community played a significant role in facilitating the process. As explained by one participant:

> "The role of the local community was outstanding in the recovery process like the clearance of debris from the affected houses, saving of the livestocks and other properties and last but not the least for the construction of temporary bridges (Participant 03).

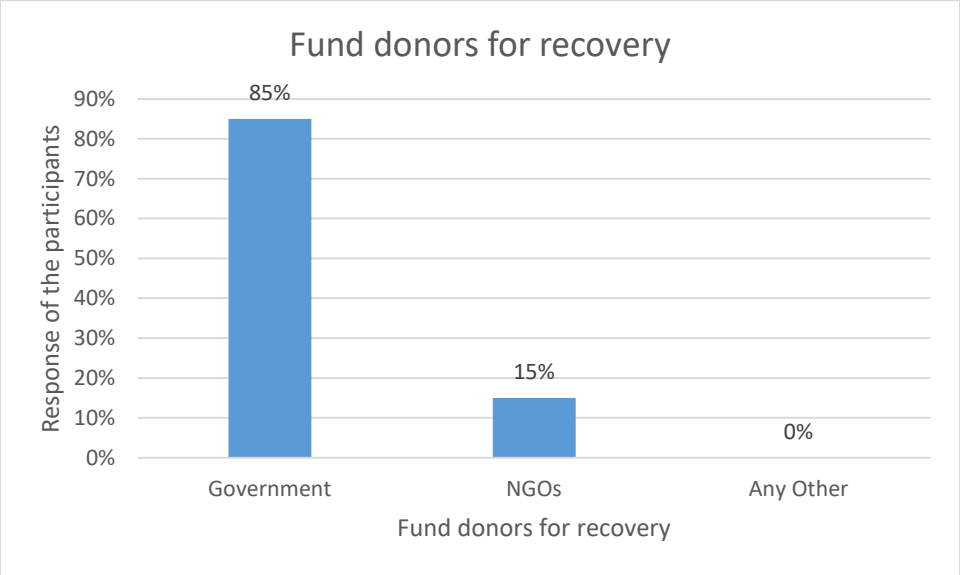


Figure 10: Recovery fund donors

The figure 10 shows participants' responses regarding the sources of recovery funds following the 2019 GLOF event in Golain Valley, Chitral. A significant 85% of respondents indicated that the government was the primary source of recovery funding. NGOs contributed to 15% of the funds, while no respondents identified any other sources of funding. This suggests that the government's role was overwhelmingly dominant in financing the recovery efforts, with some additional support from NGOs. One participant said:

> Almost all the funds for the recovery projects have been given by the government like for the construction of roads, bridges, houses, embankments, and irrigation channels (Participant 04).

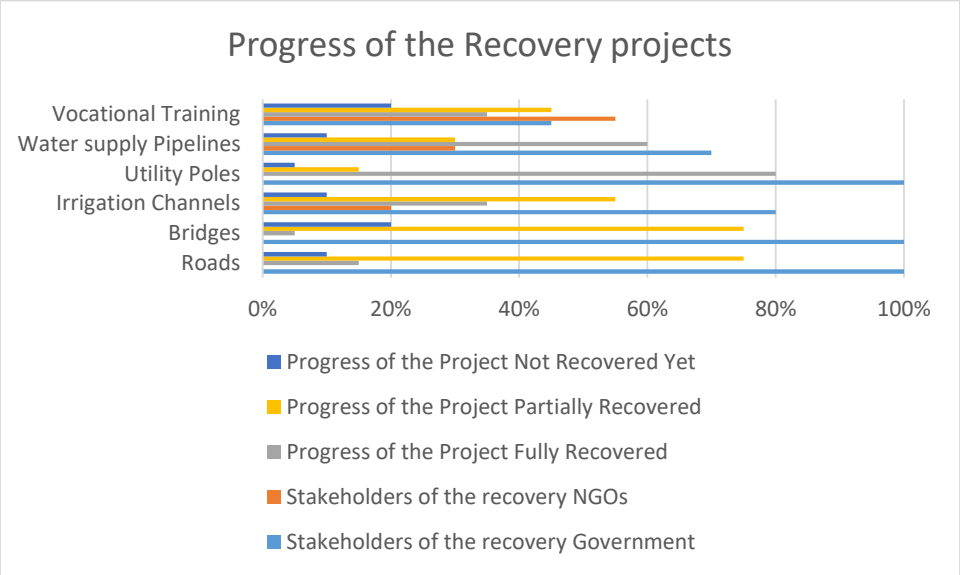


Figure 11: Progress of the recovery projects

The figure 11 provides an overview of the recovery projects following the 2019 GLOF event in Golain Valley, Chitral, highlighting the involvement of stakeholders and the progress made. For roads and bridges, the government was solely responsible, with roads 15% fully recovered, 75% partially recovered, and 10% not recovered yet. Similarly, for bridges, only 5% were fully recovered, 75% partially recovered, and 20% remain unrecovered. Irrigation channels saw 80% of recovery efforts led by the government and 20% by NGOs, with 35% fully recovered, 55% partially recovered, and 10% still unrecovered. Utility poles were entirely managed by the government, with 80% fully recovered, 15% partially recovered, and 5% unrecovered. Water supply pipelines involved 70% government and 30% NGOs, with 60% fully recovered, 30% partially recovered, and 10% not recovered. Vocational training projects was a combined effort, with 45% by the government and 55% by NGOs. In this case, 35% were fully recovered, 45% partially recovered, and 20% not yet recovered. In the words of one participant:

> Most of the projects have been completed but few embankments are in progress and expected to be completed soon (Participant 03).

Still, some of the recovery projects have not been completed due carelessness and slow work of the contractors. Some of the roads, water supply channels, and bridges have not been completed. One of the respondents said:

> In some parts of the study area, roads and irrigation channels have not been completed due to the incompetency and carelessness of the contractors (Participant 04).

Table 3: Reconstruction of Houses

Response of the Participants	Stakeholder of the projects			Compensation Received		Amount of Compensation	
	Government	NGOs	Self-help	Yes	No	Fully damaged(100,000	Partially damaged(50,000)
	100%	0%	0%	60%	40%	65%	45%

The Table 3 summarizes participants' responses regarding the compensation received for recovery projects. The government was the sole stakeholder involved, with 100% of the projects attributed to them, while NGOs and self-help initiatives played no role. Regarding compensation, 60% of participants reported receiving compensation, while 40% did not. Of those who received compensation, 65% received the full amount of 100,000 for fully damaged assets, and 45% received 50,000 for partially damaged assets.

Almost 4 to 5 families have migrated due to the GLOF event. These families have migrated from the affected area because their houses have completely been destroyed and the area had been much more vulnerable to the GLOF event again. On asking about the migration one of the respondents said that:

> Almost 4 to 5 families have migrated from the affected area because their houses have been destroyed and secondly the affected area had become much vulnerable to the GLOF event, that is why they have migrated from the area to downtown (Participant 02).

The government gave 1 lac for fully damaged houses and 50 thousand for the partially damaged ones as per our results which is very less amount for fully damaged houses and the partially damaged as well. The affected people are not satisfied with this amount because it is too less to reconstruct a fully damaged and partially damaged house. One of the respondents said:

> 1 lac is not going to do anything for a fully damaged house (Participant 03).

Discussion

The findings of this study reveal a complex landscape of recovery efforts and vulnerabilities in the aftermath of the 2019 GLOF event in Golain Valley, Chitral, which align with and expand upon the existing literature on GLOF impacts and community responses. Shahid (2024) highlights the severe impact of GLOFs on the Hassanabad settlement in Hunza, where areas close to the nullah have suffered significant land erosion and remain vulnerable to future events. Similarly, the results of the present study show that the infrastructure in Golain Valley, including roads, bridges, and irrigation channels, remains largely only partially recovered, with only a small percentage fully restored. This ongoing vulnerability underscores the findings of Shahid (2024), particularly regarding the persistent risks faced by communities in close proximity to glacial bodies.

The role of community-led initiatives in mitigating the impacts of GLOFs, as highlighted by Shahid (2024), also finds resonance in the present study. However, in Golain Valley, the involvement of the local community in recovery efforts appears to be limited compared to the prominent role played by the government. For instance, the study reveals that 75% of the recovery efforts are attributed to government initiatives, with the local community playing a minor role as a facilitator, contributing only 15% as a main actor in recovery activities. This contrasts with Shahid's (2024) findings, where community-led disaster risk management was pivotal in protecting local residents. This difference might be attributed to the varying levels of organizational capacity and resources available to communities in Hunza compared to those in Golain Valley.

Haider et al. (2024) also emphasize the economic challenges faced by communities repeatedly affected by GLOFs, particularly in Sosot Village, where recurring events have hindered economic resilience. The present study similarly finds that compensation provided by the government to the affected residents of Golain Valley has been inadequate, with only 60% of respondents confirming receipt of compensation. Even among those compensated, only 65% received the full amount for fully damaged properties. This limited financial support may contribute to the prolonged recovery process and the ongoing vulnerability of the region, echoing the economic struggles observed by Haider et al. (2024).

The study by Rinzin et al. (2023) on the susceptibility and risk associated with potentially dangerous glacial lakes in Bhutan emphasizes the importance of comprehensive risk assessments to manage GLOF hazards. The current study complements this by demonstrating that,

although there is some progress in recovery, a significant portion of infrastructure in Golain Valley remains only partially recovered or not recovered at all, highlighting gaps in the risk management process. For instance, roads and bridges—critical components of infrastructure—are reported as only 15% and 5% fully recovered, respectively, with large portions still partially or not recovered. This suggests that, like the lakes studied by Rinzin et al. (2023), Golain Valley's infrastructure remains at risk and requires ongoing attention and resources for complete restoration.

Furthermore, the findings related to gendered vulnerabilities as presented by Khalid et al. (2021) are relevant when considering the broader implications of the recovery efforts in Golain Valley. While the present study does not explicitly focus on gender, the limited involvement of the local community in recovery activities could suggest that certain groups within the community, potentially including women, might be underrepresented or face barriers to participating fully in these processes. This aligns with Khalid et al.'s (2021) observation that vulnerabilities are often experienced differently across gender lines, particularly in rural, disaster-prone areas.

In conclusion, the study results indicate a challenging recovery environment in Golain Valley, marked by limited community involvement and incomplete infrastructure restoration, despite significant government intervention. These findings corroborate and extend existing research on GLOF impacts and community vulnerabilities, highlighting the need for more inclusive and comprehensive recovery strategies that address the persistent risks and socioeconomic challenges faced by affected communities.

Recommendations and Conclusion

Based on the findings of this study, several recommendations are essential to improve the effectiveness of the recovery efforts and enhance the resilience of the community in Golain Valley, Chitral. While the government has played a major role in the recovery process, it is crucial that the funding allocated for recovery efforts, particularly for fully and partially damaged houses, is increased significantly. The current compensation of 100,000 PKR for fully damaged houses is inadequate. More substantial financial assistance from both the government and NGOs is needed to ensure that affected families can rebuild their homes and lives with dignity. Additionally, there should be a streamlined process for disbursing these funds to avoid delays. The slow progress in completing certain recovery projects, such as roads in the upper parts of the study area, needs urgent attention. The government and involved stakeholders should prioritize the completion of these critical infrastructure projects to restore normalcy in the affected areas. Regular monitoring and accountability mechanisms should be implemented to ensure that projects are completed on time.

It is vital that the local community is kept informed and engaged in disaster preparedness efforts. Regular communication between the administration and the community will help ensure that residents are aware of potential risks and can take necessary precautions. Community-led disaster preparedness programs should be encouraged, with training sessions and drills to enhance local capacities for emergency response. The establishment of a reliable early warning system is essential to protect lives and property in the event of future GLOFs. This system should be integrated with local communication networks and should involve the community in its operation. Early warnings can provide critical lead time for evacuations and other protective measures, significantly reducing the impact of disasters.

Pre-positioning of food, water, and other relief items in strategic locations within the valley is necessary to ensure that these resources are readily available in the event of a disaster. This proactive approach will help prevent shortages and ensure timely distribution of aid during emergencies. Afforestation should be promoted, and deforestation must be strictly controlled to reduce the environmental vulnerability of the region. Trees play a crucial role in stabilizing soil and preventing landslides, which can exacerbate the effects of GLOFs. Reforestation programs should be initiated with community involvement, ensuring that local residents understand the long-term benefits of these efforts. The Golain Valley's natural beauty offers significant potential for

tourism, which could contribute to the local economy. The government should consider developing safe and sustainable tourism infrastructure in the region, which could also support recovery efforts by providing alternative livelihoods for residents. Promoting tourism would require ensuring that the area is safe and that necessary facilities are in place for visitors.

The construction of safe shelters or designated safe zones within the valley can provide much-needed security to residents during emergencies. These shelters should be equipped with basic amenities and should be accessible to all community members. This would help reduce the fear and uncertainty that currently plagues the community. A comprehensive emergency response plan should be developed, detailing the roles and responsibilities of all stakeholders, including government agencies, NGOs, and local communities. This plan should outline procedures for rescue operations, relief distribution, and post-disaster recovery. Regular training and simulations should be conducted to ensure that all parties are prepared to act efficiently during a disaster.

This study, based on primary data collection through questionnaires and interviews, highlights the critical need for comprehensive post-disaster recovery efforts in GLOF-prone areas like Golain Valley, Chitral. The research underscores the importance of not only addressing the immediate recovery needs but also preparing for future disasters through improved infrastructure, enhanced community engagement, and robust early warning systems. Post-disaster recovery is not merely about rebuilding what was lost but also about strengthening the community's resilience to future hazards. The findings indicate that, while significant progress has been made in some areas, there are still substantial gaps that need to be addressed. The slow recovery of infrastructure and inadequate compensation for fully damaged houses are major concerns that require immediate action.

Moreover, this study highlights the importance of involving the local community in disaster preparedness and recovery processes. Community-led initiatives, coupled with stronger support from the government and NGOs, can significantly enhance the effectiveness of recovery efforts. Finally, the study emphasizes the need for similar research in other GLOF-prone areas of Pakistan. Understanding the unique vulnerabilities and recovery challenges of different regions is essential for developing tailored strategies that can mitigate the impact of future disasters. The insights gained from this research can serve as a valuable foundation for future studies and policy-making aimed at improving disaster management in Pakistan.

The findings from this study have significant policy implications, emphasizing the urgent need for a more coordinated and well-funded approach to disaster recovery in GLOF-prone areas. Policymakers should prioritize the allocation of adequate resources for recovery efforts, ensuring that compensation for affected households is commensurate with the extent of damage. There is also a critical need for the development of a comprehensive disaster management framework that integrates early warning systems, community preparedness, and sustainable environmental practices. Future research should focus on refining vulnerability assessment tools, such as the Flood Vulnerability Index (FVI), and exploring innovative adaptation strategies that can be tailored to the unique socio-economic and environmental conditions of different regions. Additionally, long-term monitoring and evaluation of recovery projects are essential to ensure their effectiveness and to guide policy adjustments as new challenges emerge. By addressing these policy gaps and investing in forward-looking research, the resilience of communities facing GLOF threats can be significantly enhanced.

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