Project Report

Climate induced disasters: community-based response to Glacial Lake Outburst Flood Systems (GLOFS)

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1. INTRODUCTION

1.1 Issues relating to glacier lakes in Pakistan

Northern areas of Pakistan glaciers form the largest body of ice outside the polar caps and are the main source of water for the numerous rivers that flow from upper Indus basin Hindu Kush-Karakoram-Himalayan (HKH) glacial. These glaciers feed rivers that account for about 75 percent of the stored-water supply in the country of at least 180 million. These HKH glaciers form a unique reservoir which supports perennial rivers such as Indus, Chenab, Ravi, Sutlej, Swat and Chitral River which, in turn, are the lifeline of millions of people in Pakistan (IPCC WGII AR4). Like many other parts of the world, Pakistan glaciers are receding, in the HKH mountain range in north Pakistan. Under the climate change scenarios glaciers are highly sensitive, and resultantly glacier advancement and warming leads to glacier retreat. Therefore, recent glacier retreat and associated glacial lake formations and expansions in mountain areas severe as an example and infallible evidence of global warming. The rapid accumulation of water in there lakes can lead to a sudden outburst of the moraine dam. The consequence rapid discharge of huge amount of water and debris is known as glacier lake outburst flooding (GLOF) (Cruz et al., 2007). These GLOF actions may result into disastrous destruction to the downstream areas. In the 2007 (IPCC) report stated that the HKH glaciers are retreating earlier than in other parts of the world.

Mountain climates are extremely diverse and be determined by on both extensive global circulation arrangements and local topographic effects. GLOFs happen comparatively irregularly, but are a severe flood risk in the High Mountains. ICIMOD has identified numerous glacial lakes in HKH region (ICIMOD 2011). Most of these have been formed in response to warming temperatures during the second half of the 20th century, as a result of rapid glacier melting. Various studies indicate that the warming trend in the Himalaya region has been greater than the global average (ICIMOD, 2007). Pakistan is one of the important countries located in South Asia which includes of five provinces namely Khyber Pakhtunkhwa, Sindh, Punjab, Gilgit Baltistan, Baluchistan and FATA (Federally administered Tribal area). The country has diverse climatic and unstable geological topographies comprising tallest mountain ranges (Himalaya, Karakoram and Hindu Kush), longest rivers and massive plains.

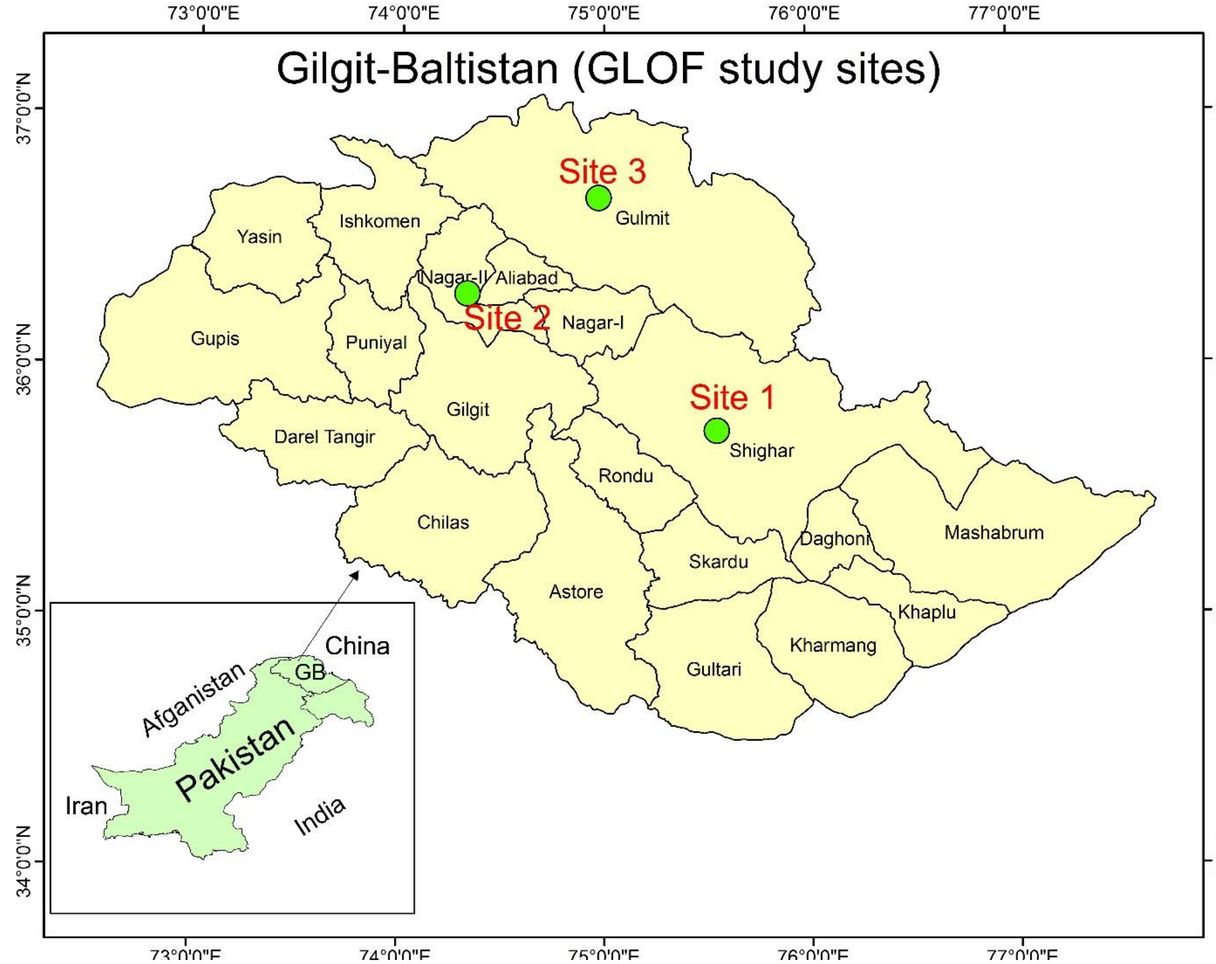


Figure 1. Location map of study area

1.2 Risk of Glacier lakes and Lake Outburst flooding in Gilgit-Baltistan

Pakistan is situated in South Asia between 24°-37°N latitude and 66°-77°E. Three world famous mountain rages Himalayas, Karakoram and Hindu Kush in its north and there are more than 5000 glaciers feeding the Indus from 10 sub-basins through different tributaries. According to glacier inventory established by ICIMOD in 2005 with the help of RS/GIS techniques, there are about 2500 glacial lakes formed due to glacier melt waters and 52 of them were declared potentially dangerous for Glacial Lake Outburst Flood (GLOF). For mountain inhabitants, GLOF is the utmost threat which is being reinforced by climate change in terms of frequency and vulnerability. Due to steep slope downstream, the conceded loads of mud, debris comprising substantial boulders gain impetus and cause heavy losses to land, settlements and infrastructure as well as life losses.

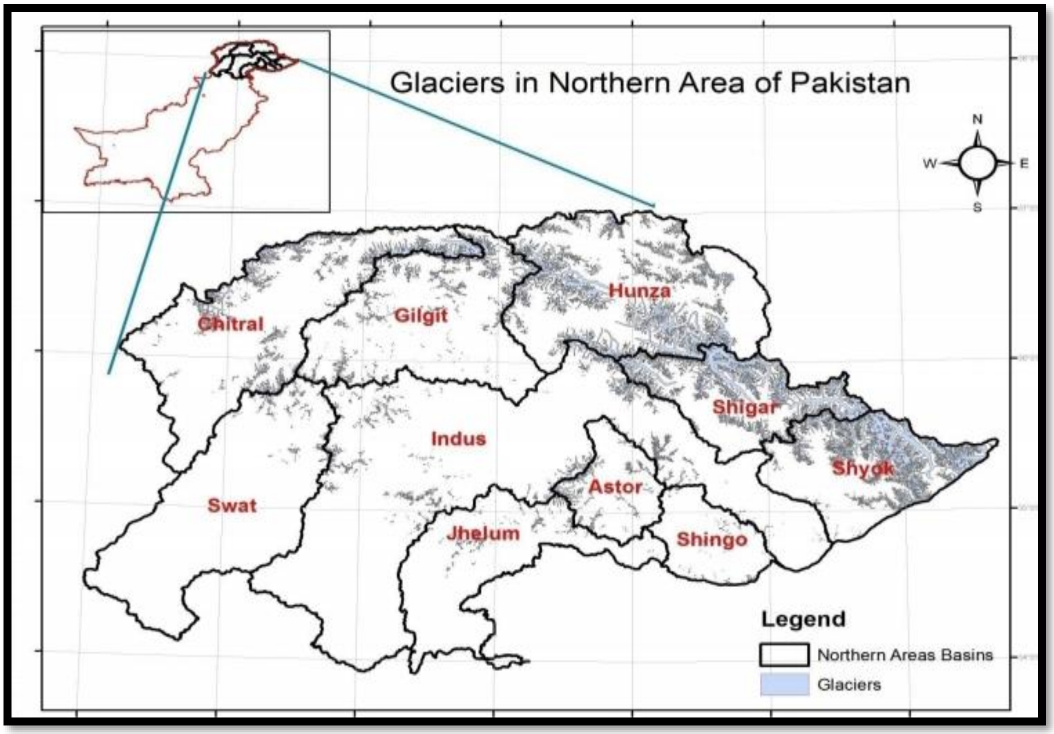


Figure 2. Distribution of Glaciers in Northern areas of Pakistan (source. PMD, Pakistan)

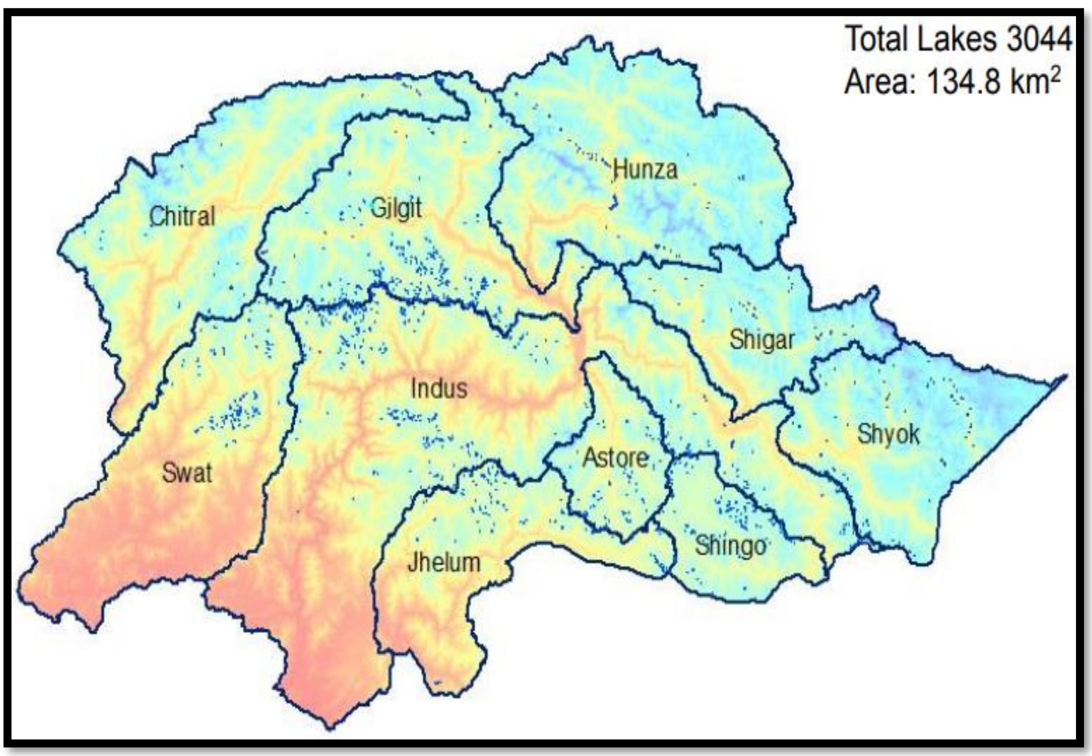


Figure 3. Distribution of Glaciers lakes in Northern areas of Pakistan (source. PMD, Pakistan)

Site 1: Shigar valley

The Shigar Valley is a valley in Gilgit Baltistan in northern Pakistan that is watered by the Shigar River, and centred on the town of Shigar. The valley stretches about 170 km from Skardu to Askole and is the gateway to the high mountains of the Karakoram. The town of Shigar is the largest settlement in valley. Even though the Shigar Valley is a remote and largely inaccessible place, there are several villages in the valley (Figure 1 and 4). Askole is the last settlement in the Shigar Valley, which is still far from the high mountains. Shigar was an administrative sub-division of Skardu District that is now a newly established district. Shigar Town is the main and utmost significant settlement in Shigar valley, situated close to the district headquarter, Skardu. The economy of Shigar is mainly natural resource reliant and is conventionally agro-pastoral in nature. The primary agricultural yield contains of wheat and barley. Apricot is the most plentiful tree crop in the area. Shigar valley is located in Skardu district, Baltistan. It constitutes 59 villages, divided into 10 UCs, with a population of about 45,000 persons. The primary livelihood of its inhabitants is agriculture. Livestock rearing also forms an integral part of every household (IUCN, 2010).

Site 2: Bagrot valley

Bagrot Valley situated between 74°43′E, 36°5′N and covers an area of about 452 km^2. It is categorized by extreme relief, from 1500 m up to 7788 m altitude. Local agriculture be governed by on irrigation for growing crops. Livestock is grazed on the higher reaches, while downstream of the main villages the valley is only thinly vegetated due to low precipitation (Ehlers and Kreutzmann 2000). During the summer, meltwater first from snow and later from glaciers is the main source for irrigation and plays a dominant role in the cultivation of land (Reineke 2001).

Bagrot Valley, the main valley glaciers are Hinarche, Burche, Gutumi, and Yune, while numerous smaller cirque glaciers exist in the higher reaches. Hinarche Glacier is divided into 2 distinct regions: the rather flat lower tongue (from 2500 m to 3350 m over a distance of 9 km) and the steep icefall elongating from 7788 m down to 3350 m within only 8.5 km. The glacier area is about 42.3 km^2 and the major part of the lower tongue is enclosed by supraglacial debris, similar to the other glacier tongues in the valley (Mayer, 2010).

Karakoram, avalanche nourishment and the extent of rock walls in the amassing zone are critical factors in the amount of supragacial debris on the lower glacier area. The debris on the glacier reflects the local geology, dominated by basalt and andesite (Petterson and Treloar 2004). In the greater Rakaposhi/Diran group, Hinarche Glacier can be considered illustrative of the valley glaciers, with a strong vertical gradient in the accumulation zone, an wide debris cover on its tongue, and a medium-sized area (Mayer, 20110)

Site 3: Passu Valley

Passu valley is located in the Gilgit Baltistan region of northern Pakistan. Situated along the Karakoram Highway in Upper Hunza, Passu is a popular tourist destination because of its easily accessible sweeping landscapes, and highest elevation is 7,478 m (24,534 ft) tall Passu Sar Mountain, the Passu Glacier, and Passu Cones. Passu is along the Hunza River, some 15 kilometers from Gulmit, the Tehsil headquarters of Gojal, in the Gilgit-Baltistan region of Pakistan, and about 150 km upriver from Gilgit. Passu is located in Upper Hunza, also known as the Gojal Valley. It lies very near the tongue of the Passu Glacier, and just south of the tongue of the Batura Glacier. The latter is the seventh longest non-polar glacier in the world at 56 km, and reaches very near to the highway. Lake Borit is a large water feature below the Hussaini village in the area. Tupopdan, 6,106 metres (20,033 ft), also known as "Passu Cones" or "Passu Cathedral", lies to the north of the village; it is the most photographed peak of the region. Also nearby are the high peaks of Pasu Sar, Shispare Sar, and Batura. Passu Glacier is situated in the south side of Passu village. Passu Peak is situated in the back side of the glacier. This glacier is linked with Batura Glacier and many other glaciers of the region

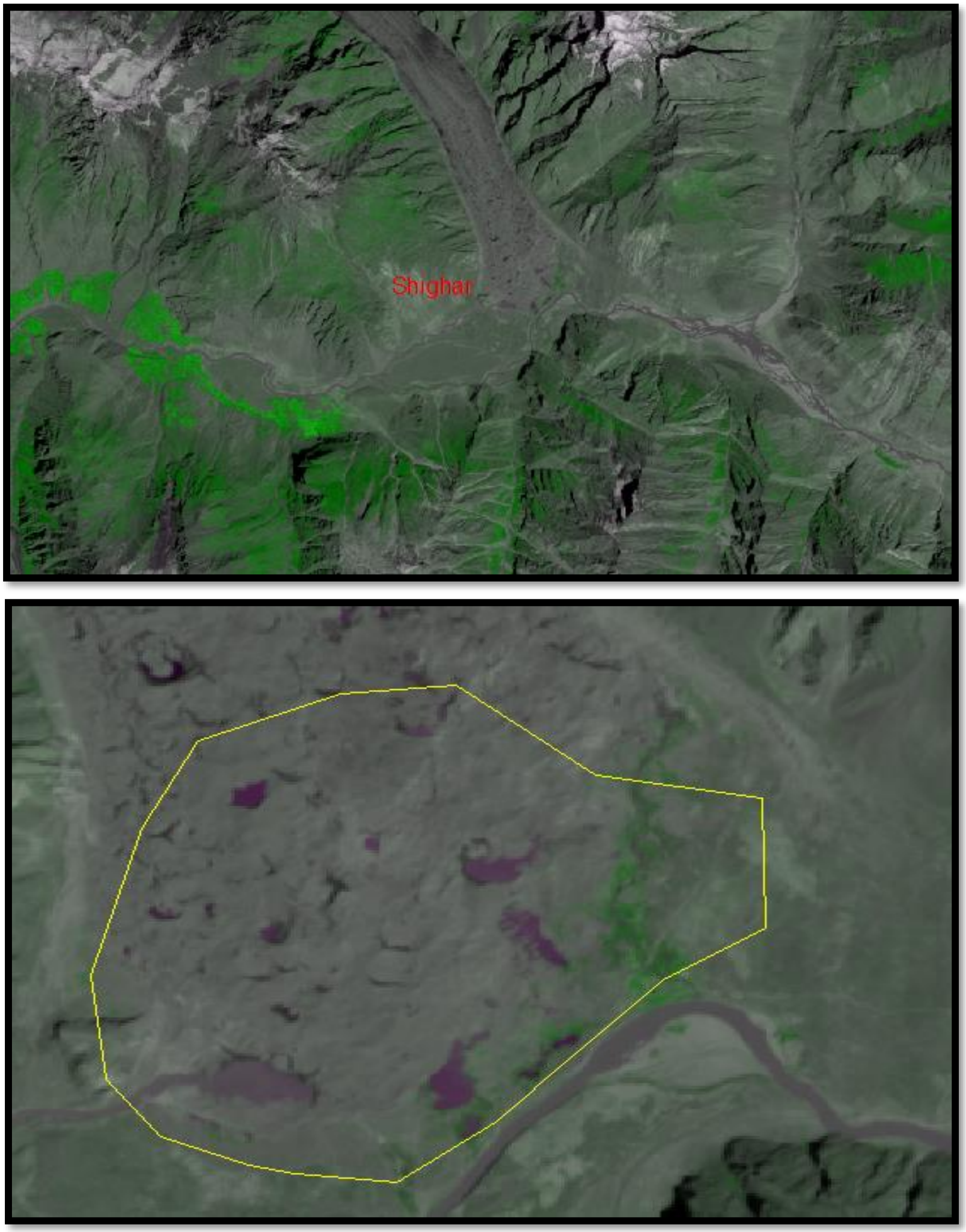


Figure 4. (a) Satellite view of Shigar valley (b) Glacier lakes on Shigar glacier

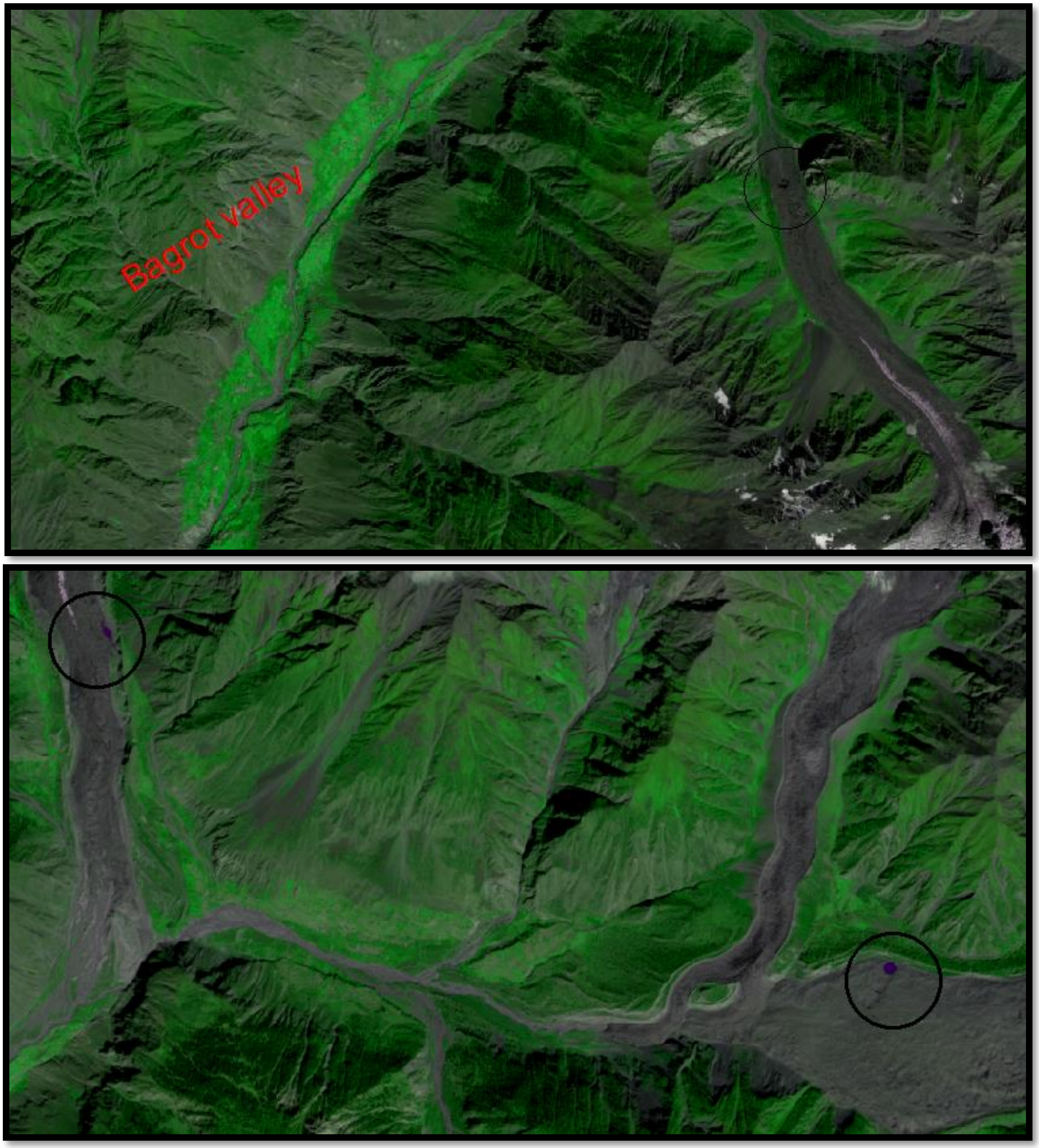
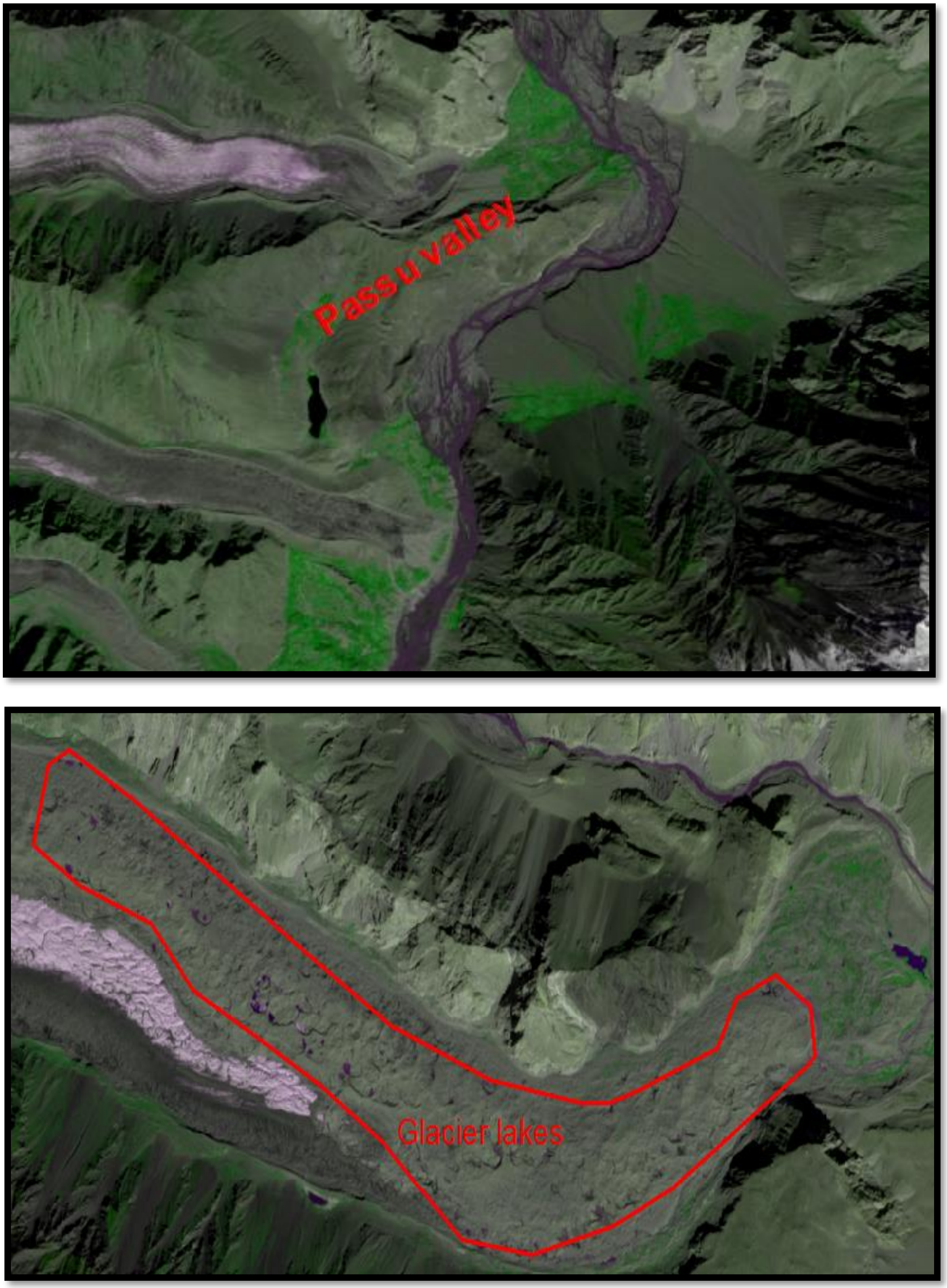


Figure 5 (a) Satellite view of Bagrot valley (b) Glacier lakes on Bagrot glacier

Figure 6 (a) Satellite view of Passu valley (b) Glacier lakes Passu glacier



2. Research methodology

Purposive selection of the study areas is based on the potential risk of GLOF which indicates that all the locations are highly susceptible to GLOF hazard and also affected by a number of natural hazards such as flash flooding, river flooding, debris flow, landsliding and rock fall. The study has conducted in Shigar, Bagrot and Passu village of Gilgit-Baltistan (Figure 1). The climatic conditions of the area shows cold winters and warmer summers. Hunza, Gilgit, Skardu and Shigar are the main rivers in the study areas which is part of Indus River in Upper Indus Basin. The snow and glacier melting on the Karakoram and Hindu Kush mountains and torrential rainfalls causes flash flooding in the areas, and also become highly hazardous for Glacier Lake and glacier lake outburst flooding under changing climate. The Glacier lakes and Lake Outburst become more common in the study area. Therefore, rural households were surveyed for this study. The population of the sample size was based on 20% of the selected each site as total number of household (HH) (Shigar 30, Bagrot 36 and Passu 34 HH).

The random sampling techniques was then employed for the selection of the respondents form the three sites. The research is based on both secondary and primary data collected through a household questionnaire survey. The questionnaire for the households included questions about the socioeconomic and demographic characteristics of the respondents, knowledge about natural hazards, GLOF awareness, GLOF related mitigation measures and climate change perception. The questionnaire survey of 70 households was completed, and completion of a single questionnaire took at least 40 to 45 minutes on average. SPSS 22 version and Excel were used for data analysis. The primary data was entered in to the SPSS software Version 22 for analysis.

3. Socioeconomic profile of the respondents

Variables like gender, age, marital status, occupation, education, source of water, primary fuel for cooking, number of years living in the area and source of income use were used to determine the socioeconomic conditions of the communities to GLOF disasters. The average age of the respondents is 48 years and 82.3% of the respondent's duration of the stay in the same village is more than 30 years. The findings of this study showed that majority the respondents 88% were married. Results indicate that 40% of households were illiterate, 15% were primary, 9% primary and 15% matriculation passed. Most studies indicate that there is a positive relationship between education and knowledge and practices of people. The low levels of education could be attributed to high poverty levels and lack of motivation to pursue higher education. The dependency ratio of each household was 8.75 while the percentage of family types was 41% singly and 58% joint. Results show that almost all members of the household (98.6%) used wood as a main source of fuel for cook and heating in winter. The employment category showed that 13% governmental, 9% private 14% farmers and 15% are housewife. However, the percentage of households with multi livelihood sources for all three sites such as farming, laboring, business and services. The 29% of households were kacha houses while 69% household have semi Pakka houses whereas 97% of the respondents have own houses.

The result revealed that 51% of household source of drinking water is piped water from public tank, 7% have unprotected water directly from streams and rivers whereas 36% have improved water in their yard provided by Aga Khan Development Network, north Pakistan. Result show that 97% of the household source of water for their agriculture land. Potato and wheat are staple food in three villages. The percentage of households with multiple crops such as potato, wheat, maize and animal fodder, whereas 60% of the respondents indicated that potato is their main cash crop. Similarly, a large majority of the respondents (97%) have kept animals for milk and meat. Communities living in mountain areas are mostly vulnerable to food insecurity. Slopes with steep and differing altitudes often make the soil shallow, poor in micronutrients, restricted and difficult to cultivate and inappropriate for mass agricultural production. Distance from roads, poor infrastructure and marginalization render access to markets more difficult. Further, the occurrence and magnitude of extreme climatic events are traditionally higher in mountains than in lowlands, a situation that is increasing due to climate change (FAOUN, 2015).

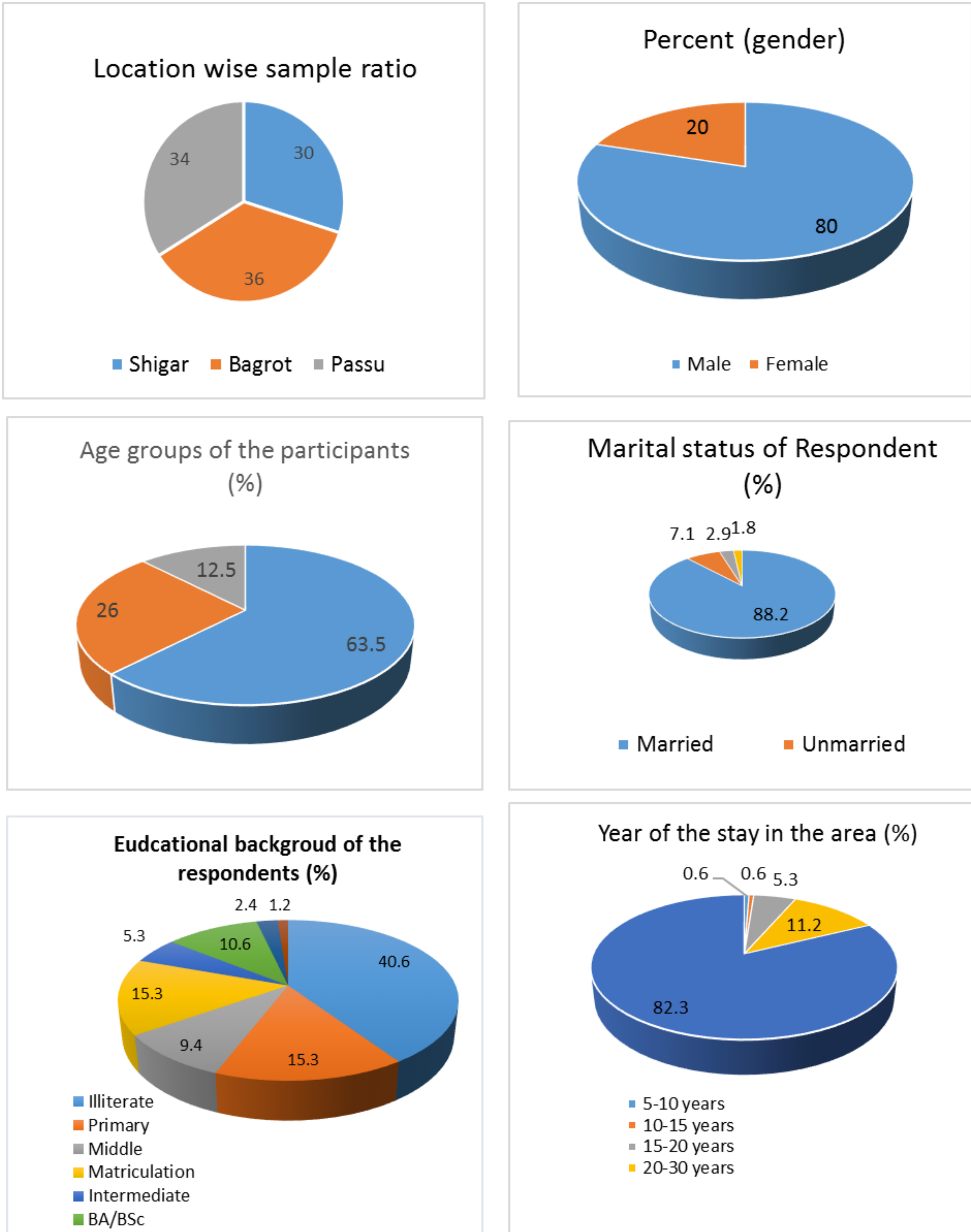


Figure 7. Socioeconomic profile of the respondents

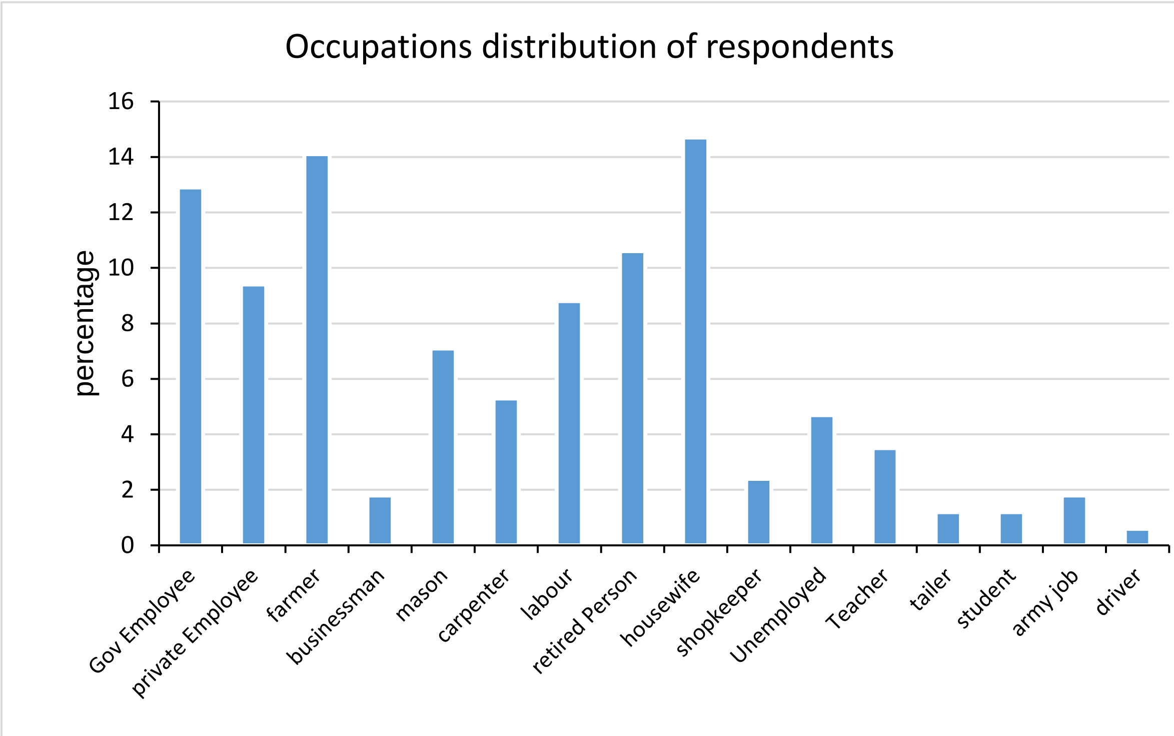


Figure 8. Occupations of the respondents

4. People perception of glacial lake hazard and risk of outburst flooding

4.1 Local community perceptions on Climate Change patterns

Communities in the studied village do not keep a careful account of climatic variations, but they can recognized and identified few types of extreme events related to climate variability or climatic patterns in the last 20 years such as, floods, droughts, strong winds, snow storms, hot and cold waves and precipitation intensities. These climatic patterns have differing impacts on different villages. The communities perceived changes in temperature patterns shown in Figure 9. Our analysis indicated that almost 98% of households from Shigar, Bagrot and Passu have experienced change in temperature and precipitation patterns during the last 20 years. Results showed that 47.2% of people believe that there was a significant increase in temperature, while, 34.6 percent believe that slight increase in temperature. The analysis also showed that 51.9 percent of households believe the hot season has become hotter, whereas, 24.9 percent of households believe that cold season has become colder. The findings also revealed that 55.4 percent household believe that cold season has become warmer. The results revealed that 61.9 percent of households believed that the frost is less common in their area as compared to the past 20 years (Figure 9).

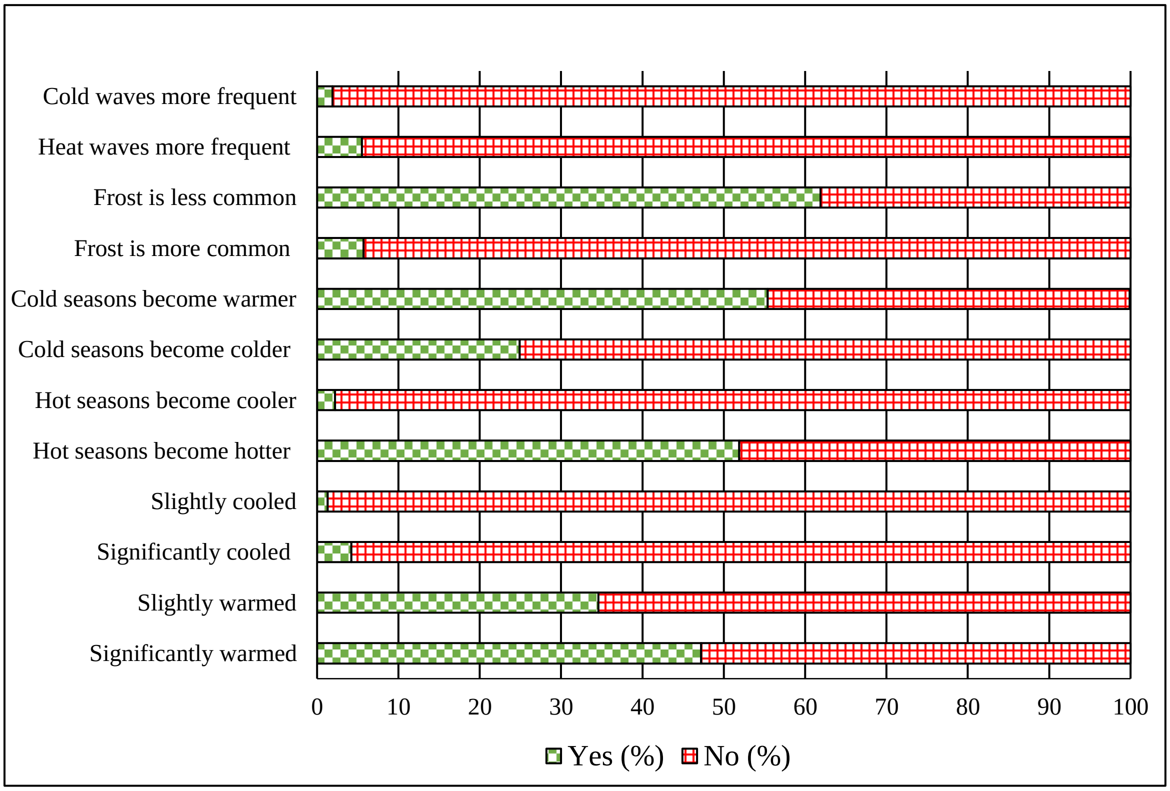


Figure 9. Households experienced changes in temperature patterns in the last 20 years

About 97.5% of the respondents in Shigar, 98.4%, Bagrot, 97.6% and Passu 97.8% households have experienced changes in precipitation during the last 20 years (Figure 10). Our analysis shown that 47.3 percent of households believe that annual amount of rainfall increased during the last 20 years, while 52.7% believed that their no change in annual rainfall. About 32.4 percent of the respondents perceived that summer rainfall increased while, 67.5% believed that summer rainfall decreased. A majority of the people (95.1%) believed that there was no increase or decrease in winter rainfall during the last 20 years. Only 10.2 percent of the respondents perceived that timing of rainfall has advanced while, only 2% believed that timing of rainfall has delayed. Out of the total respondents, about 18.4 percent believed that number of rainy day has increased while 81.6 percent mentioned that number rainy days has decreased. Majority of the respondents (96.4%) perceived that number of snowfall days has decreased while, only

3.6% of the respondents mentioned that snowfall days has increased. When asked about change in precipitation intensity, about 71.3 percent believed that precipitation intensity has increased, whereas, 72.4 percent of respondents observed that more erratic precipitation during the last 20 year (Figure 10).

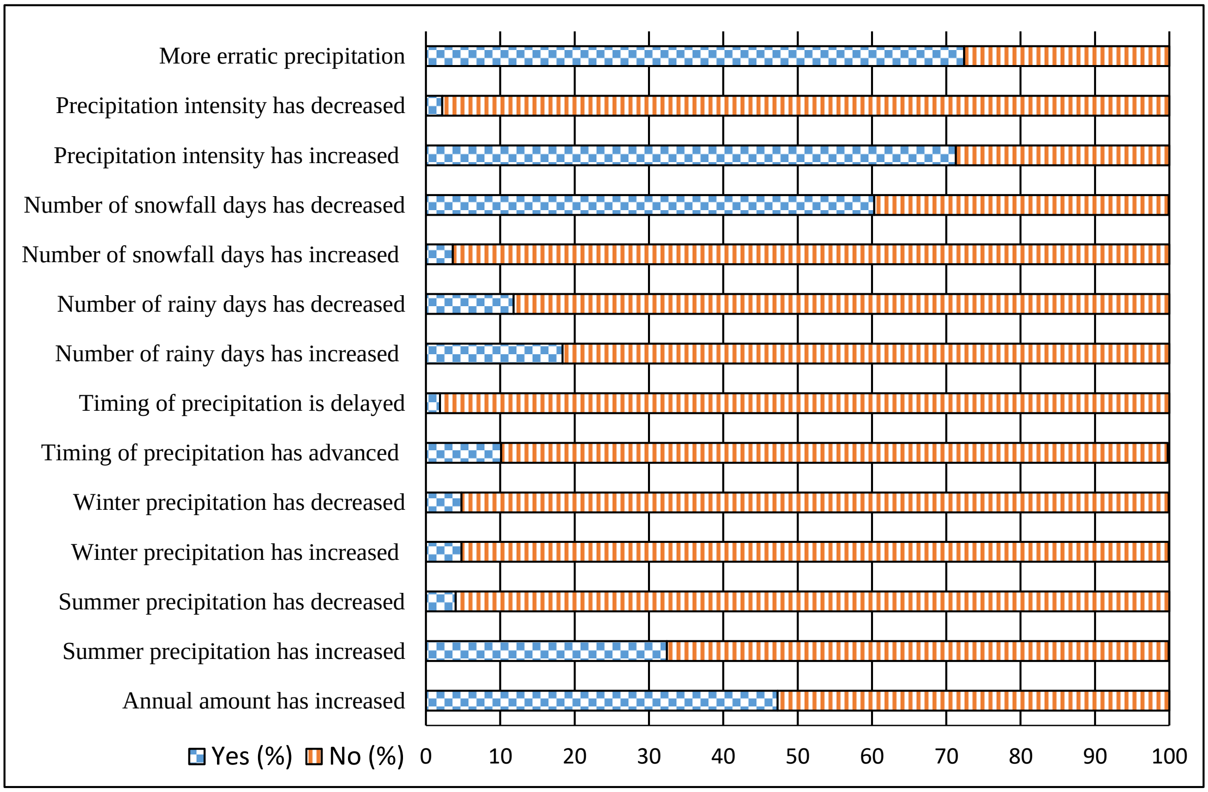


Figure 10. Households perceived changes in precipitation patterns for the last 20 years

4.2 Local people perception of Environmental Changes

Regarding people perception (70%), they perceived environmental changes during the last 20 years. This perception is related to increase in natural hazards such as flash flooding, glacier lake outburst flooding, and landsliding, and also mentioned rapid expansion of buildup area. Regarding the respondent's perception, almost 93% aware about the natural and types of natural hazards (Figure 11). About 74% of the respondents believed that the area where they are living not safe for natural disasters, 60% respondents living in the because of unavailability of land in any safe place, 51% also mentioned the reason of poverty while 5%, 6% and 9% living in the hazardous area because fertile agriculture land, easy access to road or city and ancestor land, respectively.

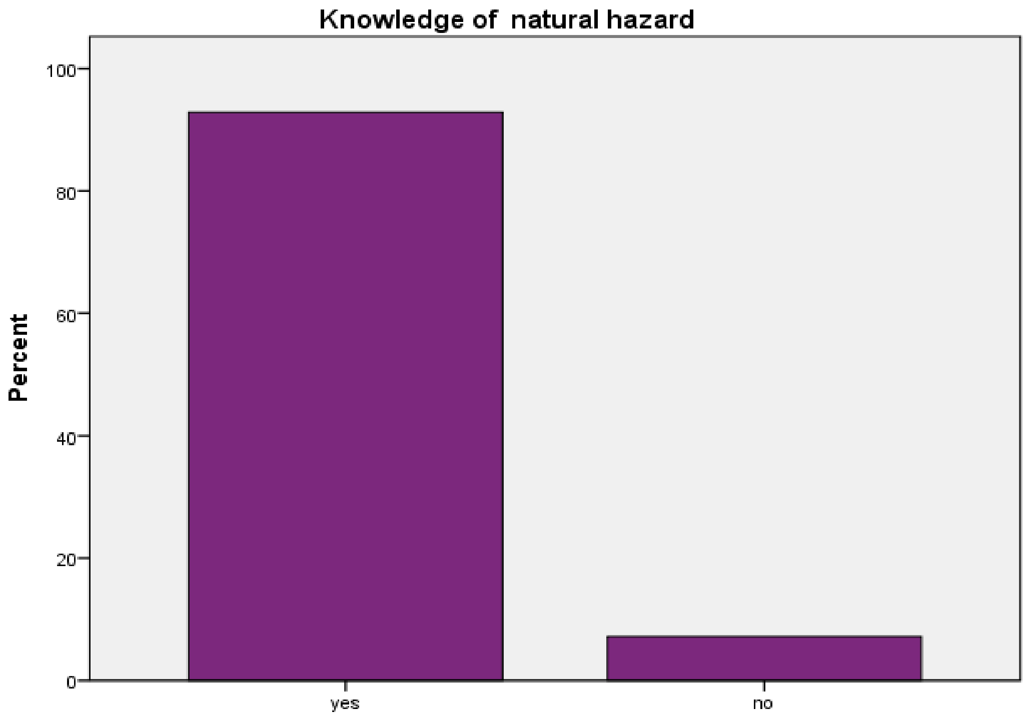


Figure 11. Respondent's knowledge regarding natural hazards

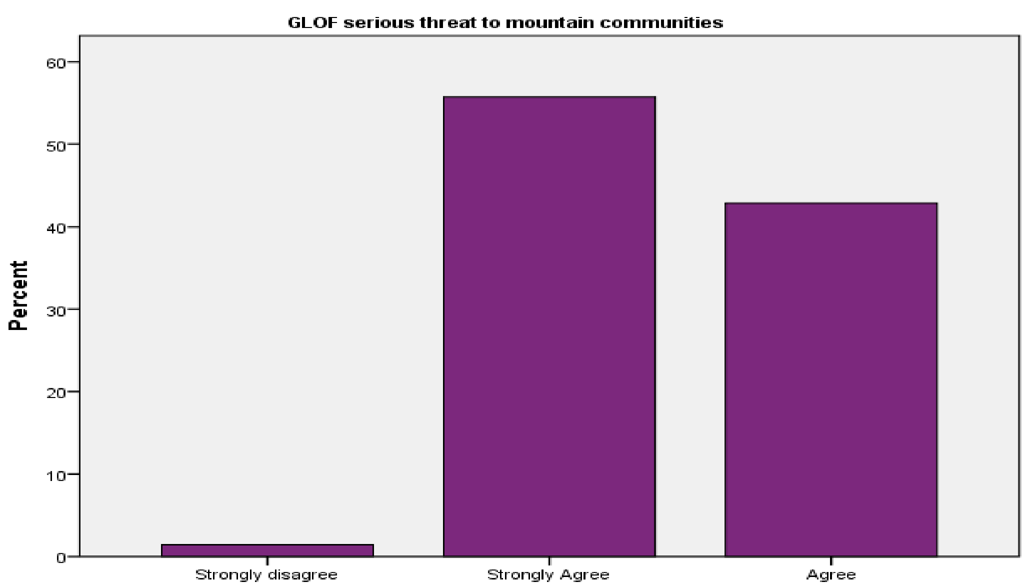


Figure 12. Community perception on GLOF as serious threat

The frequent events such as flash flooding, landsliding and debris flow regularly hit to the mountain communities socioeconomic condition and they face problem in livelihood, communication and loss of infrastructure and even basic necessities of life. According to Figure 12, 56% and 43% of the respondents, strongly agreed and agreed respectively with the increase of vulnerability to life and property, due to the uncertain in Glacier Lake and risk of outburst flooding. More than 80% respondent mentioned that GLOF risk increased due to rapid melting of glaciers, climate change and torrential rainfalls.

4.3 Structural and non-structural measures

To some extent community actions can considerably lessen the probable effects of potential natural and anthropogenic hazards. Natural hazards are progressively increased due to the Global warming and human development, which have further enhanced the possible effects into the environmental components. The unevenness circumstance in natural environmental leads to diverse types of environmental crisis not only at the regional scale but also to the global one. Structural and non-structural mitigation measures act as a main aspect to settle down the future environmental crisis (Rakib et al., 2017). Almost 80% percent of the respondents are living in along the streams which is between close to -500m from the stream. More than 90% of the respondents not experienced any disastrous GLOF event in the last 20 years but majority strongly agreed GLOF is a serious hazard in future under changing climate patterns. Similarly, 89% of the respondents mentioned that yet community not initiated any structural measure in order to reduce GLOF risk. However, 11% mentioned that they personally initiated plantation of trees along the stream in their area (Figure, 13). More 40% respondents agreed that some mitigation measure have been taken by government and NGOs such as embankments, safety walls and plantations but majority of the respondents (38%) not satisfied from quality of these structural measures. Glacial lakes in KHK face a huge risk of Glacial Lake Outburst Flood (GLOF) due to the continuing effects of global climate change leading to substantial amount of snow and glacier melt thus weakening the natural barriers holding these high altitude glacial lakes. HKH region is at an ever growing risk every year and always waiting for an unavoidable natural disaster. Subsequently GLOF can cause threatening to human life and physical properties, it has now become very significant to design an appropriate mechanism which supports in reducing hazards from such events.

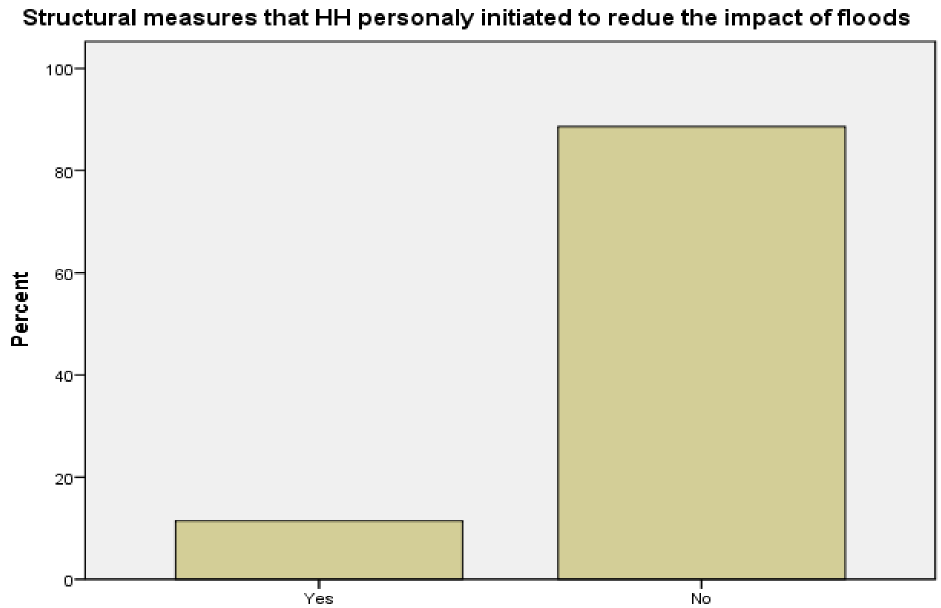


Figure 13. Household level structural measure to reduce GLOF impacts

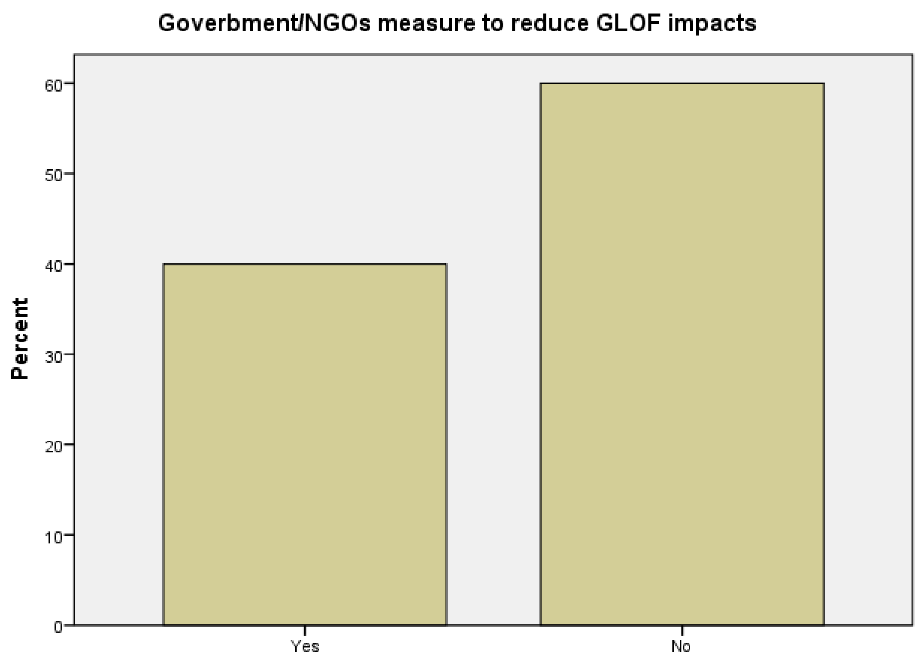


Figure 14. Government or NGO level structural measure to reduce GLOF impacts

4.4.1 Community perception of GLOF risk reduction

With an emphasis on community-based risk reduction and including much-needed non-structural risk reduction measures such as awareness-raising, coordinated preparedness, land use planning, and early warning systems. More than 90% respondents mentioned that government is not ready or not interested to tackle glacier related hazards such as GLOF. And also communities commented that pre and post disasters preparedness and response phase not adequate. Majority of the respondents (90%) indicated that no any kind of early warning system in their area but 20% respondents mentioned that traditionally people inform each other if any kind of natural hazard likely to happen (Table.1)

Table 1. Community awareness, preparedness and early warning methods

Traditional method for early warning system		
Methods	Frequency	Percent
Call one another	3	4.3
Upper people call to lower	2	2.9
Someone call from high altitude	1	1.4
Neighbor inform	3	4.3
Monitoring by local voluntaries	11	15.7
Stream monitoring	1	1.4
Total	21	30
Disaster preparedness related activities or discussion in HH family		
	Frequency	Percent
Yes	57	81.4
No	13	18.6
Total	70	100
HH family is relatively well prepared for any type of GLOF event		
Yes	0	0
No	70	100
Total	70	100
HH have 72 hours minimum disaster supplies on hand		
Yes	20	28.6
No	50	71.4
Total	70	100.0
Household identified and discussed with family regarding safe place, in case of GLOF event occur		
No	41	58.6
Yes	10	14.3
Not sure	19	27.1

Recommendations

- Train local people on GLOF risk management and prepared to act on GLOF during any disaster
- Developed GLOF related manual for GLOF hazard and risk awareness
- Equipped GLOF team a villages level in the light of Search and Rescue, first aid and community-based early warning system
- Construct structural mitigation such as embankment with gabion revetment and bioengineering in along the rivers and streams to reduce risk of flood and minimizing damage in the event of flooding.
- Synchronization among local communities and line agencies and stakeholders on GLOF risk management
- Installed an automated and community-based early warning system