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Glacial lake outburst flooding in Bagrot Valley - new threat due to climate change

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Abstract

The receding glaciers in northern part of Pakistan are one of the most reliable evidences of the changing global climate. The melting of glaciers in this high mountainous terrain can caused to increase the risk of glacier related hazards. One of these risks is Glacial Lake Outburst Floods (GLOFs). As glaciers retreat, glacial lakes form behind moraine or ice dams. These dams are comparatively weak and can break suddenly as a result, discharge huge volume of water which carried mud, debris and boulders. Such outbursts become catastrophic to downstream infrastructure and community as millions of cubic water release in sudden. Glacier thinning and retreat in the Bagrot valley has resulted in the formation of new glacial lakes and the enlargement of existing ones due to the accumulation of glacier melt water. A study has been conducted on the Bagrot valley regarding the impact of climate change on GLOF potential. Furthermore GLOF inventory for this region have been developed by using RS/GIS technology. Some lake which are potential dangerous are keep under consideration. The result shows that some of the lakes have grown in size and vulnerable to GLOF. Increase in temperature and precipitation may also triggered the GLOF event in this valley. Linear Trend Model for temperature and precipitation have been developed for the valley to analysis the temperature and precipitation impact on the GLOF event.

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Introduction

Pakistan has some of the world's highest and most spectacular mountains. The three world famous mountain ranges; Himalayas, Karakoram and Hindukush are existed in Gilgit-Baltistan with the greatest concentration peaks over 8000m high anywhere in the world. A total of 30 tallest peaks are located in HKH Region including K2, the second highest peak in the world (John F.Shroder, 1980). The mountains in Gilgit-Baltistan (GB) are an extension of what is generally called the "Great Himalayas " continuing along western Nepal through Jammu and Kashmir in north-west India and northern Pakistan, and then south west along the mountain in the border region between Afghanistan and Pakistan. These ranges lies between 33.55° and 37.5° North latitude 71° and 77.5° longitude covering an area of 72,496 km² are the home of mountain glaciers and highest peaks of the world. Karakorum Mountain has greater snow and ice cover as compared to other mountains in the world (Roohi, 2007). The glaciered area in northern Pakistan is estimated to cover 15,000km2 and almost 37% of the Karakoram region is covered by glaciers. This large mountain system provides water for human consumption, agriculture and electricity production. The economy of this region relies on agriculture and it is highly dependent upon water availability and irrigation. More than 50% of water in the Indus River originating from Karakoram comes from snow and glacier melts.

The frequency of GLOF events is increasing in the Hindu Kush Himalayan (HKH) region since the second half of the 20th century due to the combined effects of climate change and deforestation. Satellite observation of the mountain top lakes in the region have revealed a steady increase in the size and volume of many of these glacial lakes at high altitudes, enhancing the possibility of a devastating outburst flood affecting sizeable populations, damaging precious socio-economic infrastructure and development assets in the Himalayan belt (UNDP 2010). The Bagrot valley which lies in Karakoram range is also considered vulnerable to the GLOF events due to fluctuation of glaciers. Many GLOF events has been reported in this valley which has serious impact on infrastructure, crop land, property and human life downstream.

The aim of this study was to developed glacial lake inventory and identify the potential dangerous lakes which can be outburst due to climate change. The climate variability (temperature and precipitation) was also analysed which are the key factor to GLOF events to occurred and accessed its impact on downstream community and infrastructure.

Materials and methods

Study Area

Bagrot valley is located at a distance of 35 km in North East of Gilgit city. It covers an area of 452 km2 with 1100 households and approximate population of 10,000 people. The villages of Hamaran, Sinaker, Datuchi, Bulchi, Farfu, Hoppy and Chirah in the valley are interconnected by un-metalled roads. The Bagrot River with the length of 26.8km supplies water for irrigation to all the villages inside the Bagrot valley and the other villages Jalalabad and Oshikhandass. This valley is considered at high risk of GLOF from the mountain glaciers receding and advancing at different rates. Some of the glaciers are heavily debris covers while others are relatively clean. The main glaciers in this valley are Hinarche, Gargo, Gutumi, and Yune while several smaller cirque glaciers exist in the higher reaches.

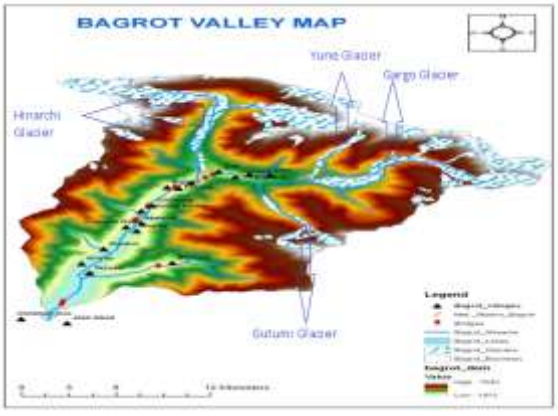

Fig. 1. Bagrot valley.

Data Source and Methodology

Glacial lake inventory was developed for Bagrot valley by using RS/GIS Technology. Google earth was used to identify the lakes on the glaciers. Large number of lakes were identified on the Hinarchi and Gargo glacier but we choose the lakes which are potentially dangerous to outburst having large volume of water. Identified lakes were mapped on the Digital Elevation Model (DEM). Ground verification was performed by visiting the identified lakes on the glacier and snap shots of the observed lakes were taken on different time series for change detection.

To assess the impact of temperature and precipitation on glacial lake formation and its outburst phenomena, monthly data of temperature and precipitation from the period 1993-2009 was interpreted by using regression analysis. The precipitation and temperature data was collected from the Automatic weather station installed by Prof. Dr. Matthias Winiger in the valley.

Results and discussion

Glacial lake inventory for Bagrot valley was developed by using RS/GIS technology in which ten lakes were identified out of which three lakes, glacial lake 3 from Hinerachi glacier and glacial lakes 2 and 5 from Gargo glaciers were considered dangerous and keep under observation as shown in Fig: 2. During the filed visit we observed that, the dame of these three lakes are moraine/ice dame which are likely to be outburst when the volume of water increases certain limit.

According to IPCC,2007 the average global temperature has increased by 0.75 C^o since the industrial revolution and the future change in global average temperature is expected to increase 2.4 C^o-6.4 C^o over the 21st century . World Metrological Organization (WMO, 2011) stated that, the first decade (2001-2010) is the warmest decade over the world and the 2010 is ranked warmest year 0.53 C^o followed by 2005(0.52 C^o) and 1998 (0.52 C^o). In last two decades, sixteen warmest years of the globe occurred.

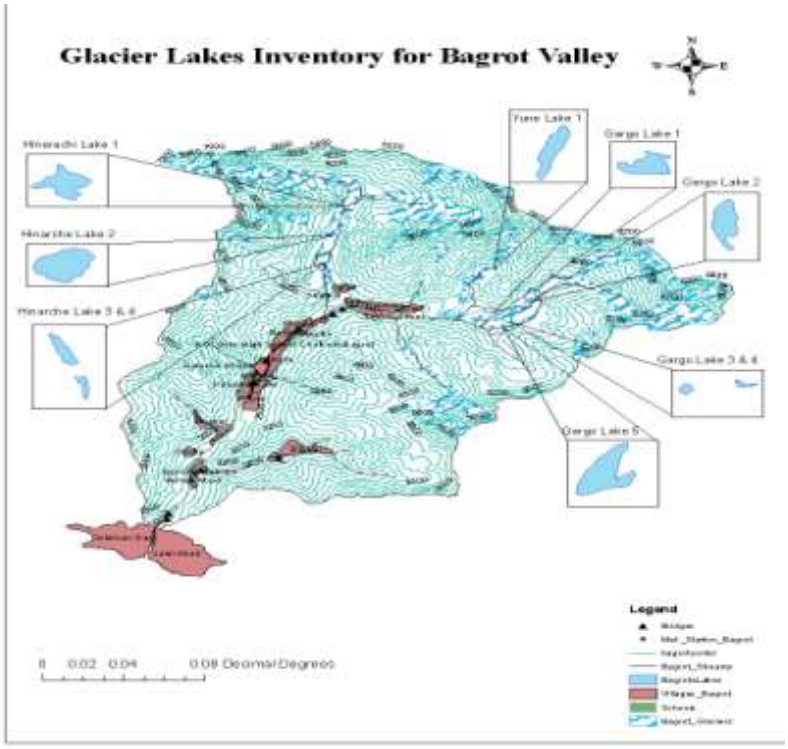

Fig. 2. Glacial Lake Inventory for Bagrot valley.

dangerous for outburst. Similarly, sudden heave precipitation will also cause the GLOF events to occur and effect downstream community and its infrastructure.

Fig. 3. Variations of Annual Mean Temperature in Bagrot valley.

The Linear Trend Model of temperature for the Bagrot valley was developed based on the meteorological data, which shows an increasing trend 0.18 C° from the period of 1993-2009 as shown in the Fig: 3. Due to rising trend of temperature in this region, leave alarming signals of glacial lake formation, their expansion and the outburst flooding.

Fig. 4. Hinarchi Glacier Lake (Babari Lake).Snapshots taken during the field visit.

During the filed visit to Bagrot Valley in 2008, a snapshot of Babari Lake on Hinerchi glacier was taken. It was a small pond of water (100 m²) which was expanded in to a big lake (1100 m²) within three years of time period (2008-2011).

On 7th may, 2014, there was main head line in the front page of National/local newspaper (www.dailyk2.com) that, GLOF event occurred in Babari lake as a result it washout the River Bridge which was the only access way to the upper area of the valley(Khama village, Gargo pasture, Barchi pasture) along the water channel of Chira village. A filed visit was conducted to access the damages and to analysis outburst mechanism of the lake. It was observed that the outburst occurred due to huge pressure of water. The lakes was totally debris covered and Lake water makes its ways by making hole in the glacier as can be seen in Image c of the Fig: 4. During the interview with the elders of the community it is revealed that it took them one week to build new bridge and to the repair the damaged channel. Since this Lake was already under observation and the glacial lake watch group informed the local community well in time about the dangerous level of water as a result no human life loses were reported.

Due to changing climate, the precipitation pattern also has been changed. Usually snow fall was started during the month of December and January in the last decades but now there is generally tendency of snow fall occurrence in the end of winter. Snow fall that starts in the end of February or March will not stay long and melt immediately when warming start in March-April. Reduce residence period does not allow the metamorphic process to complete for conversion of snow in to ice.

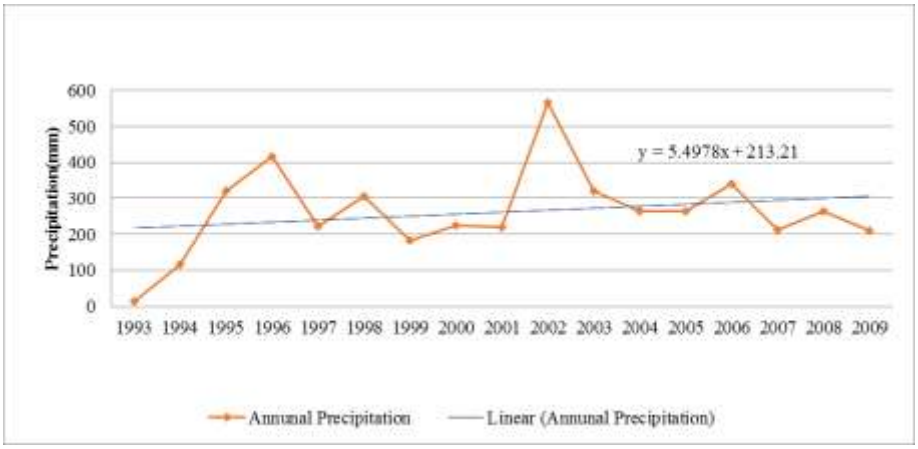

Fig. 5. Variations of total Annual Precipitation in Bagrot valley.

Rain fall at the higher elevation up to 4000masl is common phenomenon in the mountain terrain where it was rear in the past and now the snowfall is seldom occurred at these elevations (Winiger *et al.*, 2005). The changing pattern of precipitation may cause the shifting of snow line.

According to the study conducted by Rasul, *et al.*, 2006 indicate that snowline has risen up slope by about 1 km during the last 25 years. This upward shift of snowline caused massive migration of biodiversity. The increasing trend of temperature from lower elevation to higher elevation has not only affected the biodiversity but also melt the lower elevation glaciers speedy as a result formation of glacial lakes and their outburst effect to downstream community.

Conclusion and recommendation

- There are relatively unstable lakes along Hinarche Glacier compared to the lakes on other Gargo and Yune glaciers.

- The outburst of Hinarchi lake damage the Water channel for Chira valley and river bridge that is used by local community to carries their livestock to the pasture.

- There is probability of Land erosion/cutting along the flow of river due to flash flooding.

- There are signs of advance of Yune Glacier which may block the track to the Barchay and Gargo pastures directly affecting their livestock activity.

- The lead time is minimum for the villages (Chira and Bulche) situated in the Northeastern part of the valley.

- The expected land degradation in the flood plain area imposes serious socio-economic threats to the local community and may result in their displacement.

- Accelerated Melting and Rainfall addition may trigger GLOF events.

- An early warning system capable of providing alerts in case there is a threat of GLOF is essential for the Valley

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