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# Local knowledge based perceptions on climate change and its impacts in the Rakaposhi valley of Gilgit-Baltistan, Pakistan

Laxmi Dutt Bhatta, Erica Udas, Babar Khan, Anila Ajmal, Roheela Amir and Sunita Ranabhat
*(Author affiliations can be found at the end of the article)*

## Abstract

**Purpose** – The purpose of this paper is to understand local perceptions on climate change and its impacts on biodiversity, rangeland, agriculture and human health.

**Design/methodology/approach** – A household survey with 300 interviewees and focus group discussions with key stakeholders were conducted and validated at two steps, using the climate data from the nearest weather stations and reviewing literatures, to correlate the local perceptions on climate change and its impacts.

**Findings** – Majority of the respondents reported an increase in temperature and change in the precipitation pattern with increased hazardous incidences such as floods, avalanches and landslides. Climate change directly impacted plant distribution, species composition, disease and pest infestation, forage availability, agricultural productivity and human health risks related to infectious vector-borne diseases.

**Research limitations/implications** – Because of the remoteness and difficult terrain, there are insufficient local weather stations in the mountains providing inadequate scientific data, thus requiring extrapolation from nearest stations for long-term climate data monitoring.

**Practical implications** – The research findings recommend taking immediate actions to develop local climate change adaptation strategies through a participatory approach that would enable local communities to strengthen their adaptive capacity and resilience.

**Social implications** – Local knowledge-based perceptions on climate change and its impacts on social, ecological and economic sectors could help scientists, practitioners and policymakers to understand the



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ground reality and respond accordingly through effective planning and implementing adaptive measures including policy formulation.

**Originality/value** – This research focuses on combining local knowledge-based perceptions and climate science to elaborate the impacts of climate change in a localised context in Rakaposhi Valley in Karakoram Mountains of Pakistan.

**Keywords** Agriculture, Biodiversity, Climate change, Human-health, Karakoram mountains, Vulnerability

**Paper type** Research paper

## 1. Introduction

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013) indicated that the global mean surface temperature has increased by 0.84°C since 1880. This has led to a global threat, i.e. climate change, resulting in substantial socio-economic and ecological impacts, especially in the mountain region. The world's mountains are hotspots of biodiversity and provide climatically different life zones across short elevation distances (Körner, 2004; Fort, 2015). About 10 per cent of the world's population directly depends on mountain resources for their livelihood and well-being (Schild, 2008). The mountainous regions have considerably warmed during the past century, and the temperature rise is expected to continue, whereas precipitation projections show a differential pattern – where some regions are expected to get more rainfall and others less (Kohler *et al.*, 2014). In the changing climate scenario, the future of mountain biodiversity, whether be wild or cultivated, may become site-specific to different ecosystems, and it is likely that there will be increased exposure to multiple hazards because of frequently occurring extreme events such as floods, avalanches and landslides, which will threaten both livelihoods and infrastructure (Kohler *et al.*, 2014).

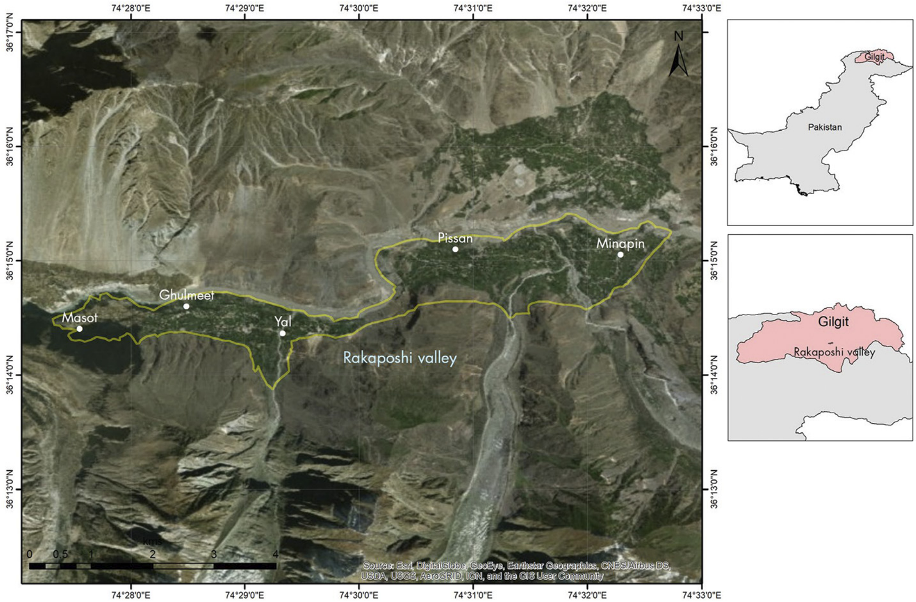
The mountains in Karakoram–Hindu Kush Himalaya (HKH) are also sensitive to the impacts of climate change. Over a century, the mean temperature in the HKH region has changed at a rate of 0.10°C per decade (Ren *et al.*, 2017). Climate projections suggest that the temperature will increase 1-2°C by 2050, and the precipitation patterns will change with longer and erratic monsoon and less frequent but more intense rainfall (Lutz *et al.*, 2014; Shrestha *et al.*, 2015). Because the HKH region is considered an important storehouse of freshwater, the impacts of climate change will, however, not only limit to freshwater availability to 240 million people upstream and 1.9 billion living downstream (Sharma *et al.*, 2018) but will also affect the livelihoods, agricultural productivity, biodiversity including plant phenology (physiology, reproductive and metabolic changes), population and their habitats (Körner, 2004; Xu *et al.*, 2009; Ahmad *et al.*, 2012; Ali *et al.*, 2017). Visible effects of climate change in the HKH region has been observed through changes in phenology and reduced agriculture production of some major crops in some regions of HKH (Webb and Stokes, 2012; Hart *et al.*, 2014). Wangda and Ohsawa (2010) reported that due to climate change there is probability of shifting of evergreen broad-leaf species from upper limit of 2900 m (current) to higher altitudes in future. Similarly, climate change has affected the daily activities and livelihoods of local communities. According to Suberi *et al.* (2018), local people of the mountain reported low crop production and encroachment of invasive species that hamper agricultural production. However, generalising climate projection findings and the possible impacts of climate change particularly in the mountains brings a larger uncertainty because of its orographic nature that provides micro-climatic conditions along the elevation gradient. In addition, except for a few areas in the HKH, there is still huge data gap on historical climate, which prevents an in-depth understanding of climate variability and its feedback mechanism, further limiting the validation of climate models and projection of future scenarios (Ren and Shrestha, 2017). Thus, local knowledge and perceptions of local communities are very crucial to understand the changing climate in many remote areas of the HKH mountain region (Khan *et al.*, 2011). Local knowledge-based perceptions on climate change are essential to develop enabling policies, effective communication strategies and socially accepted technologies to minimise risks and reduce climate vulnerability (Whitmarsh and Capstick, 2018).

In Gilgit-Baltistan, formerly known as Northern West Frontier province of Pakistan, there are only nine observatories for weather reporting (Pakistan Meteorological Department, 2018), which means that the climate data is scanty and the impacts of climate change may vary in the fragile mountainous areas due to a sharp altitudinal gradient, mostly being site-specific. Rakaposhi Valley, located in Nagar District of Gilgit-Baltistan, is reported as especially vulnerable to climate change and its associated hazards include glacier lake outburst floods (GLOFs), flash floods, avalanches, landslides, droughts, erosion, cloud burst and extreme weather spells (WWF, 2010, 2015a). Extreme climatic events in the area have repeatedly affected major agricultural crops, pastures, infrastructure and livelihoods of the local communities over the past 30 years (WWF, 2015a). There are no any local weather stations in the valley, except the one recently installed by the Water and Power Development Authority (WAPDA) at Hoper, and given the rugged terrain with steep geography, the spatio-temporal climate may vary from the nearest weather observatory. In this context, understanding local community's perceptions on climate change and its impacts on livelihoods including effects on different ecosystems is very important to generate baseline information and develop adaptation strategies. Such local knowledge-based perceptions provide opportunities for policymakers, social development organisations and private sectors to effectively plan, design and implement adaptation programs by minimising risks and hazards. This study, therefore, attempts to provide a systematic analysis of the perceptions of local communities in Rakaposhi Valley to generate a baseline information on changing climate patterns and their direct impact on biodiversity, rangelands, agriculture, including risks to human health. A qualitative research approach was adopted to document the community perceptions on climate change and its impacts. However, the climate data from nearest locations was retrieved because of the absence of local weather stations in the valley and relevant literatures were reviewed to validate the perception findings.

## 2. Methodology

### *2.1 Study area*

Rakaposhi Valley is located in Nagar District of Gilgit-Baltistan, approximately 80 km north of Gilgit town in Pakistan (Nafees *et al.*, 2014). The valley comprises five villages including Pisan, Yal, Massot, Ghulmet and Minapin with population of 8,500 people living in 906 households (WWF, 2015b). Most of them are agro-pastoralists, highly dependent on mountain farming and livestock herding to earn bread and butter for their families (Khan, 2012). The valley has diverse ecosystems including alpine and sub-alpine pastures, alluvial plains, glaciers, peaks and high-altitude wetlands. Rakaposhi Peak, 7,788 m asl, is a jewel in the crown of the valley. Major species recorded in the area include snow leopard, Siberian ibex, Indian grey wolf, red fox, snow partridge and raptors (Figure 1).




**Source:** ICIMOD, 2019

**Figure 1.**
Map of Rakaposhi Valley in Hunza-Nagar District, Gilgit-Baltistan, Pakistan

*2.2 Data collection and analysis*

A qualitative research method was adopted to document the community perceptions on climate change and its impacts in Rakaposhi Valley (WWF, 2010). Social survey methods such as structured and semi-structured interviews and focus group discussions (FDGs) were used during field visits in the year 2015 to collect primary data. A similar method has been used for recording climate change perception of local communities in many studies (Chaudhary *et al.*, 2011; Sujkahu *et al.*, 2016; Egbe *et al.*, 2014; Joshi *et al.*, 2013). Face-to-face interviews were held with 300 respondents, randomly sampled covering 33 per cent of the total households. The respondents in the interviews and FGDs were key stakeholders such as herders, village elderly people, school teachers and youth including both women and men. About 30 min to maximum 1 h time was allocated for each interview depending on the knowledge of the respondents. Different qualitative questions were asked to better understand the impact of climate change on biodiversity, agriculture, rangelands and health of the communities in Rakaposhi Valley, including their perceptions on the changing climate.

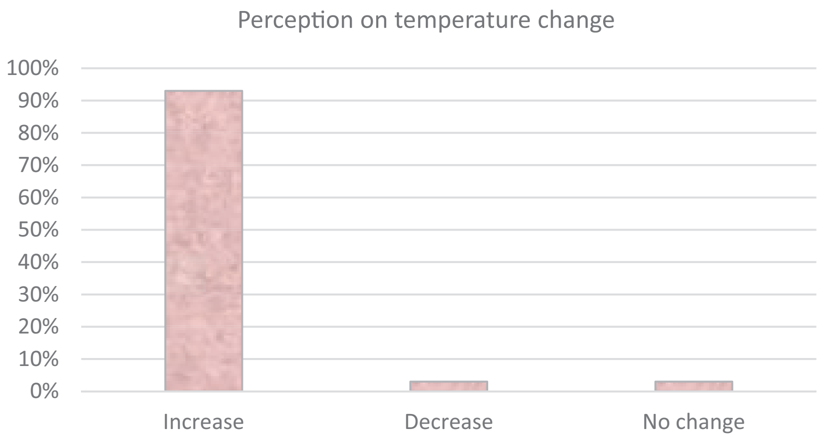
On the other hand, the climate change perceptions of the communities were validated with the daily total sum of precipitation and average temperature data from the study area. The data was retrieved from the ICIMOD's Regional Database System using a $10 \times 10\ km^2$ spatial resolution for a period of 30 years from 1981 to 2010 (Lutz and Immerzeel, 2016). A linear regression trend analysis was performed for both precipitation and temperature data, where $y = a + bX$ was defined by a (the intercept) and trend b (the slope). The slope of this linear regression provides the rate of change in the given climatic parameters.

Additionally, a thorough literature review was conducted to further validate the community perceptions on the impacts of climate change on biodiversity, rangelands, agriculture and human health. Finally, Microsoft Excel 2013 was used for climate change perception data analysis and developing the output tables and graphs.

## 3. Results and discussion

### 3.1 Temperature trend

About 93 per cent of the respondents argued that they witnessed an increase in mean annual temperature over the past 25 years, perhaps due to climate change (Figure 2). To validate this perception from a majority of the respondents, a historical average temperature trend from 1981 to 2010 was analysed in the study area. A linear regression trend analysis showed that both winter and summer are getting warmer at the rate of 0.05°C and 0.02°C, respectively, over the past 30 years (Figure 3). In Gilgit-Baltistan, the mean winter temperature increased at the rate of 0.044°C, which showed a similar trend to that in Rakaposhi Valley; however, in contrast, the summer temperature in Gilgit-Baltistan showed a declining rate of 0.026°C (WWF, 2008). On the other hand, several other studies reported a warming trend in the high mountains and in the Himalaya, with minimum temperatures increasing faster than the maximum, and such increases are greater in the higher elevation (Shrestha *et al.*, 1999; Bhutiyani *et al.*, 2007; Fan *et al.*, 2010). Additionally, it should be noted that the differences on elevation and spatial variation in high mountains, including the effect of seasonality at the temporal scale, could have greater impacts on surface warming, mostly at higher altitudes (Rangwala and Miller, 2012). For example, a significant seasonal variability was observed in Tibetan plateau where the winter warming rate is almost double




**Source:** Survey (2015)

**Figure 2.** Community perception on climate change impacts on the temperature pattern

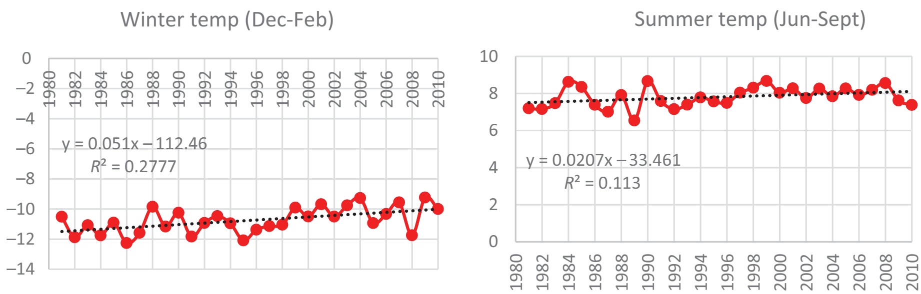


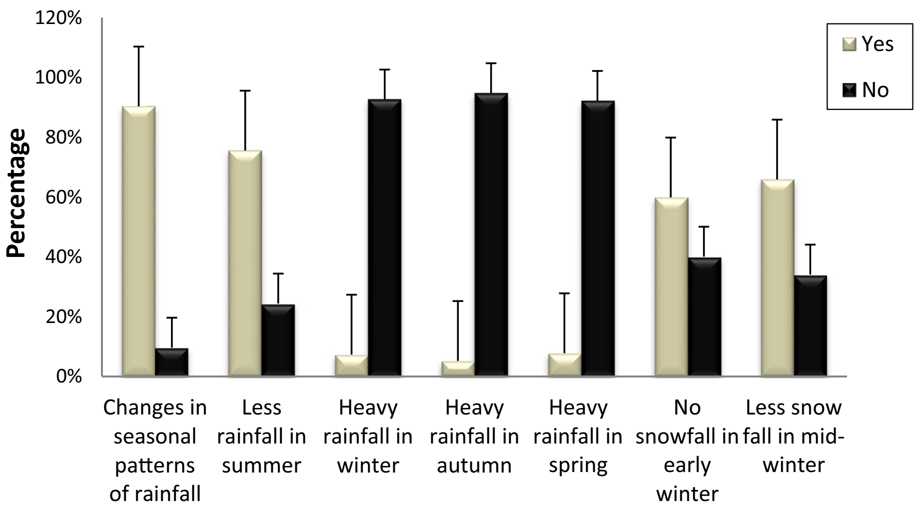

**Figure 3.** Average winter and summer temperature trends over 30 years

the annual mean warming rate (Liu and Chen, 2000). Likewise, the western Himalayan region in India also showed higher winter warming between 1971 and 2007 compared to the rest of India (Kothawale *et al.*, 2010). These findings are similar to the current study, where the winter warming rate is higher than the summer, and this also matches with the perception from majority of the respondents.

### *3.2 Precipitation trend*

About 90 per cent of respondents stated that the precipitation pattern has changed in Rakaposhi Valley over the past 25 years (Figure 4). Majority of the respondents indicated that they have witnessed an increase in rainfall during winter and spring, whereas a decrease in summer rainfall. On the other hand, 59 per cent respondents indicated that there has been no snowfall during early winter and 65 per cent believed that there is only less snowfall during the mid-winter season.

In Pakistan, there had been strong drought spells in terms of length and intensity throughout the country from 1998 to 2002 because of the El Nino effect (Ahmed and Schmitz, 2011; Naheed and Rasul, 2011). A study in the Karakoram mountain range found that the winter rainfall increased from 1961 to 1999, whereas the summer rainfall decreased (Archer and Fowler, 2004). Naheed and Rasul (2011) found that the percentage of the rainfall variability coefficient in northern Pakistan gradually increased from 1960 to 1999 but, decreased during 2000-2009. Another study from the northern part of Pakistan showed an increase in the rainfall pattern both in summer and winter seasons (Hashmi *et al.*, 2012). This is similar to the findings of the precipitation trend analysis done from 1981 to 2010 in Rakaposhi Valley, where both summer monsoon and winter rainfall trends showed increase over 30 years; however, the amount of rainfall received during the summer was less than that of the winter rainfall (Figure 5). This could be the reason that although the summer rainfall trend was slightly increasing, the community perceived that they witnessed less rainfall in summer compared to that in the winter season.




**Source:** Survey (2015)

**Figure 4.** Community perception on climate change impacts on the rainfall pattern

*3.3 Hazard risks*

Pakistan is one of the natural disaster prone countries, falling on sixth place in the world (Ahmad *et al.*, 2011). All of the provinces in Pakistan, including Gilgit–Baltistan, are vulnerable to geological and hydro-metrological hazards (Ahmad *et al.*, 2011). The mountainous geography and fragile environment of Gilgit-Baltistan further increase the vulnerability to different hazard risks (WWF, 2010). In terms of hazard risks in Rakaposhi Valley, majority of respondents reported that the frequencies of avalanches, landslides and floods have increased, whereas droughts, flash floods and glacier lake outburst flood (GLOF) events decreased over the past 25 years (Figure 6). Although GLOFs are common in Gilgit-Baltistan with more than 35 GLOFs observed in past two centuries with an increasing frequency in the recent years, such natural hazards have not been reported in Rakaposhi Valley from 1990 to 2012 (Din *et al.*, 2014), perhaps due to local micro-climatic conditions resulting in less glacial lake formation in the valley. Hence, the community perception also reported a decrease in the occurrence of GLOF events. Concurrently, high temperature and high frequency of floods due to heavy rainfall are permanent features of Hunza-Nagar District and Rakaposhi Valley (WWF, 2015a). Severe floods have been reported in the

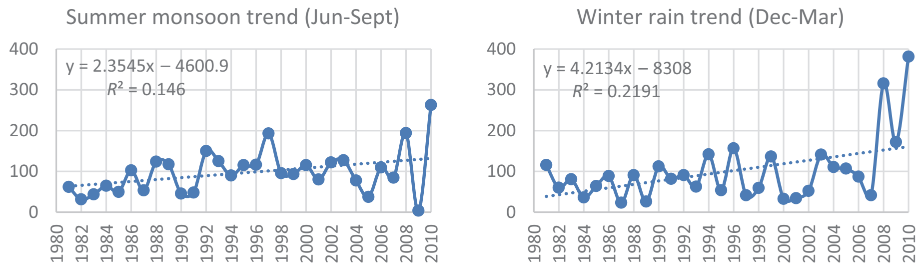
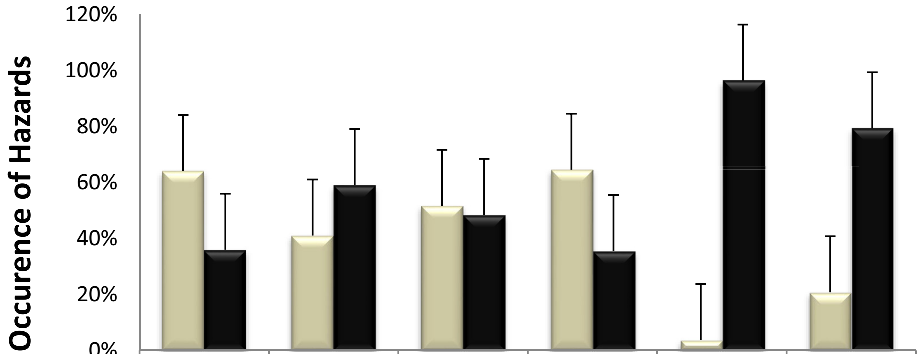



**Figure 5.**
Trend of summer monsoon and winter rain over 30 years




| | Avalanches | FlashFlood | Land sliding | Floods | Droughts | GLOFs |
|---|---|---|---|---|---|---|
| Increase | 64.05% | 41.01% | 51.61% | 64.51% | 3.68% | 20.73% |
| Decrease | 35.95% | 58.99% | 48.39% | 35.49% | 96.32% | 79.27% |

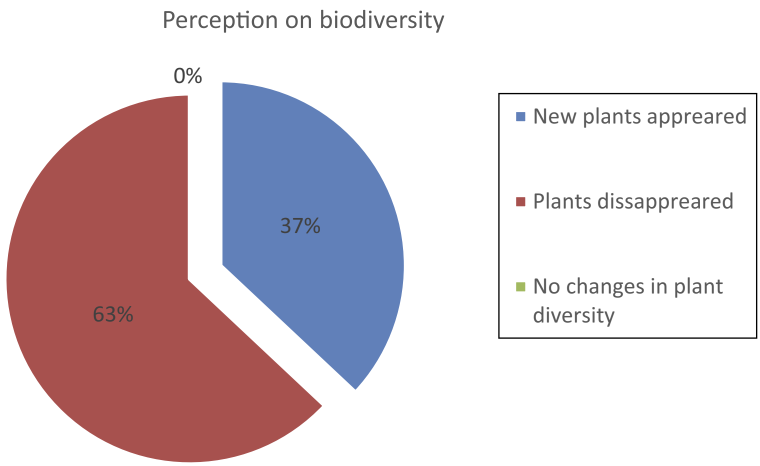
**Source:** Survey (2015)

**Figure 6.**
Climate change and community perception on the hazard risks

country during 1950, 1956, 1957, 1973, 1976, 1978, 1988, 1992, 2006 and 2010 with the latter having greater impacts, resulting in highest number of death tolls, injuries and property damages (Ahmad *et al.*, 2011; Hashmi *et al.*, 2012). The 2010 flood inundated low-lying areas of 347 villages in Gilgit-Baltistan with 183 death toll, damaging 3,157 houses and destroying about 7,900 ha cropped land (Hashmi *et al.*, 2012). The flood is attributed to the heavy rainfall because of changes in the climate and monsoon pattern as well as deforestation and construction of dams (Hashmi *et al.*, 2012).

*3.4 Climate change impacts on biodiversity*

The respondents from focus group discussions reported that the impact of climate change has altered plant distribution, abundance and flowering periods in Rakaposhi Valley. Likewise, about 63 per cent of the total respondents interviewed reported that due to climate change some domestic as well as wild plants have disappeared from the study area, whereas 37 per cent claimed seeing few species that were never seen before in the study area over the past 25 years (Figure 7). In addition, some new fruit trees such as apples, cherry, grapes, peach and apricot have been introduced in the area, which were not part of the local plant diversity. A detailed forest inventory in Gilgit-Baltistan showed higher tree species diversity with Simpson's index value of 0.813 (Ismail *et al.*, 2018). On the other hand, rapid glacier melt due to climate change has caused habitat loss of many floral and faunal species and also interrupted migratory routes of several migrating species (Khan and Ali, 2011). Climate change has also influenced plant phenology, i.e. physiology, reproduction and metabolism, in the Himalaya and its sister ranges (Burkett *et al.*, 2005). Therefore, climate change has direct impact on the mountainous floral community (Xu *et al.*, 2009) and it has been observed that various mountain vegetation types are shifting from lower to higher altitudes because of a lack of tolerance to higher temperatures (Sanz-elorza *et al.*, 2003). Furthermore, it is difficult to estimate the actual effect of climate change in the mountain because of uncertainties related to climate scenarios and non-linear feedback between the impacts on different sectors (Nogués-Bravo *et al.*, 2007). So, several systematic ecological research studies



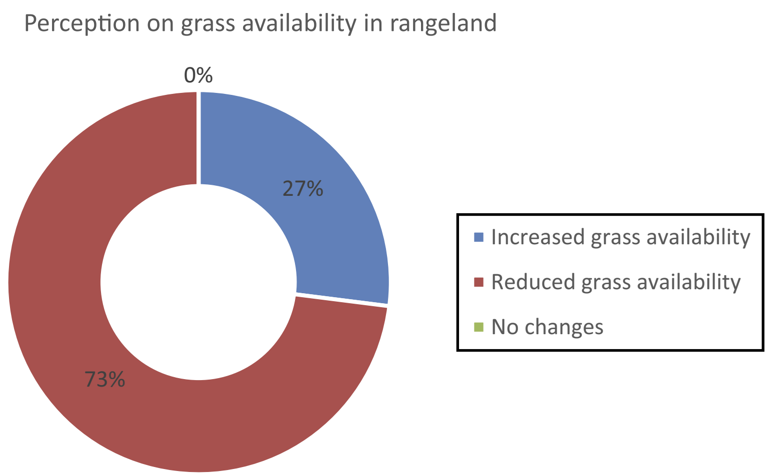

**Source:** Survey (2015)

**Figure 7.**
Perception on climate change impacts on the biodiversity

and joint monitoring programs should be conducted to gather knowledge on the impacts of climate change and mountain biodiversity (Ishaq *et al.*, 2015).

*3.5 Climate change impacts on rangeland*

Gilgit-Baltistan offers 35 per cent rangeland, which is approximately one third of its total area (Khan, 2013). However, there is lack of evidence-based knowledge on the impacts of climate change on rangeland and pastoralism, limiting the effective management for development of the livestock industry. The grazing pressure is very high in these alpine rangelands during the summer season, and this pressure concurrently shifts to dry temperate rangelands during autumn and early spring (Omer *et al.*, 2006). In Rakaposhi Valley, 73 per cent of the respondents reported a decline in forage productivity in the alpine and sub-alpine rangelands over the past 25 years, whereas 27 per cent respondents claimed having well-flourished forage, which might be due to the moist southern aspects or prevailing micro-climatic conditions in these areas. The findings from group discussions revealed that the availability of grasses and fodders in the rangeland was subjected to changing climatic patterns, especially with respect to the precipitation such as snowfall and rainfall. The decline in growth rate of forage has a strong correlation either with droughts or diminishing water resource availability for irrigation, including degradation of rangelands due to overgrazing and excessive removal of natural vegetation for firewood, animal bedding and feeding. In addition, intrusion of invasive and non-palatable species further shrank the grazing land, causing shortage of feed and fodder for the livestock. In Gilgit-Baltistan, the major changes were particularly observed in terms of species composition, distribution and productivity of the rangelands (Khan, 2003; Shaheen *et al.*, 2011; Joshi *et al.*, 2013; Khan, 2013). Less availability of grasses and fodders and diminishing productivity directly affected animal health (Thornton *et al.*, 2009), and the herders have now changed their traditional grazing patterns as an adaptive measure (Joshi *et al.*, 2013), which ultimately resulted in lower household economy and food insecurity (Figure 8).




**Source:** Survey (2015)

**Figure 8.**
Perception on climate change impact on the availability of grasses in rangelands

*3.6 Climate change impacts on agriculture and crop productivity*

In Pakistan, wheat, rice and maize crops from the agriculture sector contributed positively to the GDP from 1985 to 2015 (Chandio *et al.*, 2016). Agriculture is the second largest sector, accounting for more than 21 per cent of the GDP, and the largest employer, absorbing 45 per cent of labour force (IFAD, 2015). However, the agriculture sector is likely to be most sensitive to climate change because of extreme weather events such as increased temperature, severe droughts or floods, and increased attack of disease pests and soil degradation (Smit and Skinner, 2002; Farooqi *et al.*, 2005), causing threats to agricultural productivity and ultimately leading to food insecurity. Climate change directly impacts the productivity of agricultural crops through shortening of the growing period, losses in yield due to extreme climatic events, changes in river flows and land degradation (Iqbal *et al.*, 2009). Because there is high variability in rainfall, particularly during pre- and post-monsoon seasons, it poses challenges to farmers, mainly in the rain-fed areas, resulting in crop failure or loss in yield (Naheed and Rasul, 2011).

In Rakaposhi Valley, 54 per cent of respondents in the interview reported that the agricultural productivity had decreased over the past 25 years, whereas 46 per cent stated increase in the productivity. Focus group discussions further revealed that a variety of new crops and vegetables such as beans, cabbage, Canadian wheat, carrot, garlic, red beans, maize, potato, pulses and turnips were introduced by the state and other development actors during the late eighties and early nineties. The introduction of new crops has consequently increased diseases and pest attack that seriously damaged apples and apricots, which provide major income to the local communities. Abbas *et al.* (2018) highlighted that replacement of traditional crops by high-yielding varieties in Gilgit-Baltistan has increased disease pest infestation, for example, late blight, early blight, nematodes and leaf roll virus affecting potatoes; gummosis disease affecting apricots, almonds, plums and peaches; and crown gall disease affecting cherries. In addition, some studies showed that the warming trend in high mountains in northern Pakistan has positive impacts on the yield of wheat and other winter crops such as barley because of prolonged growing degree days and shortened growing season length (Hussain *et al.*, 2005; Hussain and Mudasser, 2007). Alternatively, in the wheat-growing regions of southern Pakistan such as Punjab and Sind, a model simulation showed that one degree increase in temperature reduced the yield by 44 kg per hectare (Ahmed and Schmitz, 2011). A recent study on climate change impacts on agricultural productivity of major crops in Pakistan showed negative influence of rainfall, whereas both positive and negative influences of temperature (Ali *et al.*, 2017). Climate change, therefore, may have differential impacts on crop yields, depending on different agro-ecological zones, crop cultivars and varieties.

Furthermore, the respondents in the focus group discussions reported loss in soil fertility owing to the excessive use of inorganic fertilisers such as urea, nitrate and diammonium phosphate (DAP), causing soil desertification. The use of such inorganic fertilisers and pesticides started to increase over the past three decades in the study area; first, it aimed to improve the crop yields, but later, its inefficient use eventually resulted in loss of soil fertility.

*3.7 Climate change and risks to human health*

Outbreaks of seasonal and water-borne diseases such as diarrhoea, malaria and dengue were frequently found in the valley, whereas an increase in flu and typhoid were also witnessed during the study years, perhaps due to changing climatic conditions, water contamination and air pollution (Figure 9). Although 37.17 per cent respondents stated that climate change was the major cause of such diseases, whereas 29.35 per cent of the respondents believed that lack of facilities was the major reason. The warmer temperature

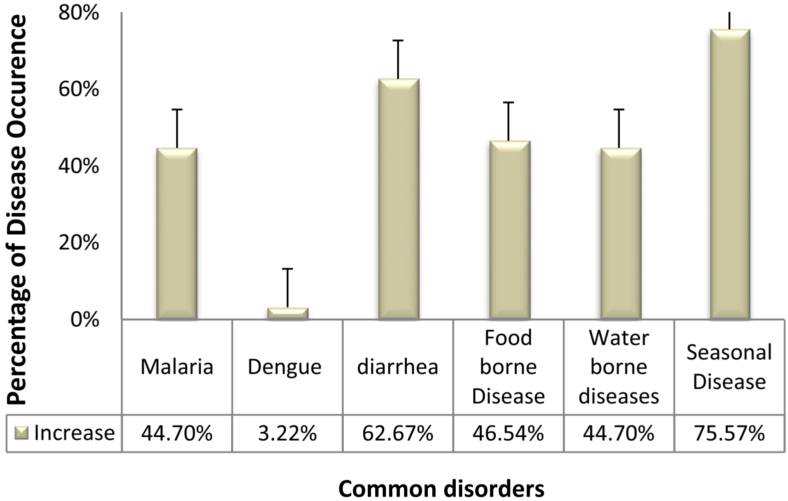



**Figure 9.**
Trend of climate-change-induced water-borne diseases

**Source:** Survey (2015)

could increase higher incidences of heat-related cardiovascular and respiratory diseases, whereas wetter conditions could increase infectious vector-borne diseases such as malaria, dengue, yellow fever and encephalitis (Farooqi *et al.*, 2005; Malik *et al.*, 2012). Moreover, infants, children and elderly people are amongst the major sufferers in the study area (Figure 10), which could be due to their low immunity, physical weakness, low adaptation to

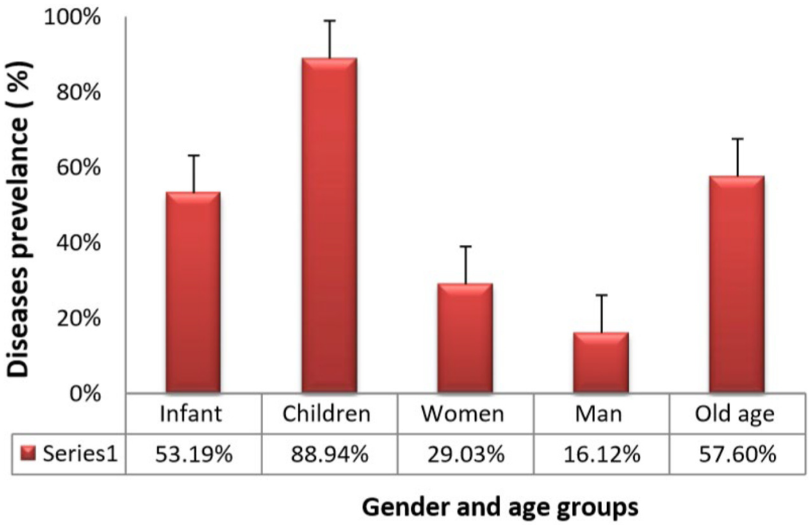



**Figure 10.**
Occurrence of infectious diseases in different age groups and gender

**Source:** Survey (2015)

extreme weather conditions and lack of medical facilities. Malik *et al.* (2012) also reported that elderly people and urban poor in Pakistan are highly vulnerable to the risk of heat-wave-related morbidity and mortality as a result of increasing temperature. In Gilgit-Baltistan and other parts of Pakistan, climate change has significantly increased water-borne diseases because of the erratic floods contaminating drinking water from the streams and rivers (WWF, 2010). A study on climate change vulnerability analysis by agro-ecological zonation in Pakistan showed that health risks in the northern part of the country were mainly related to diarrhoea and gastroenteritis, skin and eye infections, acute respiratory infections and malaria (Malik *et al.*, 2012).

## 4. Conclusion

Climate change has been greatly affecting people's life and life-supporting systems in Rakhaposhi Valley, increasing vulnerability by manifolds. Uncertain weather patterns and extreme events with the increasing frequency and intensity have adversely affected human health, livelihoods, biodiversity and ecosystems in the Karakoram Mountains. It is very important to understand multidimensional nature of the drivers of change, responses and feedback mechanisms to be able to reduce the vulnerability, which is induced due to not only climate change impacts but also socio-political and economic changes in the region. Because the local communities hold immense traditional knowledge, and they are the ones directly affected by the impacts of the changes including climate change, their participation is very crucial in planning, designing and implementing adaptive measures as well as contributing to policy making. Furthermore, the climate change perception study provides researchers, practitioners and decision makers a clear insight into the local emerging issues, risks and vulnerabilities. To respond to such uncertain risks and vulnerabilities, it is recommended to strengthen the capacity of local communities and encourage them to use customised technologies that use combined science and traditional knowledge so that they can enhance their adaptive capacity and build resilience against existing as well as emerging climate risks. Additionally, it is highly recommended to develop area-specific climate change adaptation strategies for tackling emerging environmental concerns and building local capacities so that communities could manage risks and diversify livelihood options through preparedness and recovery, for example, by adopting climate smart agriculture, soil conservation, irrigation water management, livestock and pasture management, high-value horticulture, product diversification and promoting renewable energy.

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**Author affiliations**

Laxmi Dutt Bhatta, International Centre for Integrated Mountain Development, Kathmandu, Nepal

Erica Udas, International Centre for Integrated Mountain Development, Kathmandu, Nepal

Babar Khan, WWF Pakistan, Lahore, Pakistan

Anila Ajmal, Deutsche WeltHungerHilfe, Islamabad, Pakistan

Roheela Amir, Universiti Kebangsaan Malaysia, Bangi, Malaysia, and

Sunita Ranabhat, International Centre for Integrated Mountain Development, Kathmandu, Nepal

**Corresponding author**

Laxmi Dutt Bhatta can be contacted at: Laxmi.Bhatta@icimod.org