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## Climate change in Himalayas: Impacts on lives and livelihoods

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### Abstract

Climate change is emerged as an issue of great concern for the nations around the world. It affects virtually all physical, biological and human systems on this planet. However, the impacts are particularly severe for highly climate sensitive environments like Himalayas. The impacts of climate change are well observed in the Himalayas in the form of increasing temperature, melting glaciers, formation of glacial lakes, glacial lakes outburst floods (GLOFs) event and changing biodiversity and the ecosystems. Often referred as the 'Third Pole' or the 'Water Tower of Asia', Himalayas host largest concentration of glaciers outside the polar region which feed 10 of giant Asian rivers. Himalayas provide lifeline for half a billion people in the mountains and more than 1.3 billion people in the river basins who depend directly or indirectly on mountain resources for food, water, hydroelectricity, timber, biodiversity, and niche products. Climate change is a critical issue in the Himalayas not only because it adversely affects ecosystem of the region but also because it could have serious repercussions for mountain people. Due to fragile ecology and inaccessibility and poor economic development, people in the mountains have limited livelihood options. They depend heavily on agriculture, livestock rearing, forest products and tourism which are highly sensitive to climate change. Thus, any adverse impact on mountain resources will eventually have adverse effects on the life and livelihoods of mountain people. Although data about human well being in the Himalayas is scant, the climate change effects are likely to be experienced by them, among other things, on their livelihoods, health, and natural resource security. Thus, in this paper an attempt has been made to review the available literature on the climate change trends in the Himalayas and their subsequent impacts on mountain people.

**Key Words:** Climate Change; Himalayas; Mountain People; Livelihoods; Health.

### 1. Introduction

Climate change is emerged as an issue of great concern for the nations around the world. It affects virtually all physical, biological and human systems on this planet (UNEP, 2013). Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007a). According IPCC's Synthesis Report (2001), the earth's climate system has demonstrably changed on both global and regional scales since the pre industrial era (Sathaye, et al. 2006). In its fourth Assessment Report issued in 2007, IPCC dispelled many uncertainties about climate change. It confirmed that over the past 100 years, global average temperature rose by 0.74 °C largely due to human induced greenhouse gas emissions (IPCC, 2007; UNFCCC, 2007). However, an increasing rate of warming (0.55°C) has occurred over the past 30 years (Mertz, et al. 2009) and ten of the warmest years on record have occurred since 1990, leading to more frequent and extreme storm events and higher rates of glacial melting on the world's mountains and polar icecaps (Khoday, 2007). IPCC's reports projects that under a business as usual scenario, by 2030, green house gas emissions could increase by 25 - 90 per cent relative to 2000 level and that by the end of the 21st century earth could warm by 3°C (UNFCCC, 2007). It is also projected that even if countries reduce their greenhouse gas emissions, the climate system will continue to change mainly due to the large heat capacity of oceans and long life time of greenhouse gases in the atmosphere (Matthews and Caldeira, 2008).

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Climate change has several implications for natural ecosystem, food production, water availability, health etc (Sathaye, et al. 2006). However, the implications are mainly severe for highly climate sensitive environments like the Himalayas, where climatic conditions typically coincide with poverty, subsistence agriculture, and poor economic development (Pandey and Bardsley, 2013). The impacts of climate change in the Himalayas are well observed in the form of increasing temperature, melting glaciers, formation of glacial lakes, Glacial lake outburst floods (GLOFs) events and changing biodiversity and the ecosystems all of which are expected to have adverse impact on the lives and livelihoods of people living in mountains and downstream who depend directly or indirectly on Himalayan resources for food, water security and livelihood options. Against this backdrop, this paper attempts to review relevant literature on evidences of climate change in Himalayas and its impact on mountain people.

### 1.1. Himalayas

The Himalayas, with their immense natural beauty and rich cultural diversity, are the biggest and tallest mountain range on the Earth (Hasnain 2009). They are rich in biological and environmental resources. They are home to some of the world's most threatened and endemic species (Kollmair, et al. 2005). They possess ecological, aesthetic, and socioeconomic implications, not only for mountain people who derive their day-to-day subsistence from mountain resources but also for the downstream population who relies indirectly on mountain resources for water, hydroelectricity, timber, biodiversity, and niche products (Schild 2008; Schild and Sharma 2011).

Often referred as the 'Third Pole' or the 'Water Tower of Asia', Himalayas host largest concentration of glaciers outside the two polar ice caps (WWF, 2005). A significant proportion of the annual precipitation falls as snow particularly at high altitudes which feed Himalayan glaciers (Eriksson, et al. 2009). The glaciers provide approximately  $8.6 \times 10^6$  cubic metres of water annually (Hasnain, 2009) and feed 10 of giant Asian rivers like Ganga, Amu Darya, Indus, Brahmaputra, Irrawaddy, Salween, Mekong, Yangtze, Yellow, and Tarim (Jianchu et al. 2007). Himalayas provides a lifeline for half a billion people in the Himalayas and more than 1.3 billion people in the river basins (Liu and Rasul, 2007) who depend directly or indirectly on Himalayan water resources for their food and water security (Hua, 2009). The two biggest rivers of India (Brahmaputra and Ganga) flow from Himalaya forming rich deltas and provide livelihood to nearly 400 million people (Ray, et al. 2011).

Himalayas also play an important part in supporting the economies of countries like Nepal and Bhutan and Himalayan states of India and Xizang Province of China all of which rely heavily on the Himalayas for hydropower, water supply, agriculture and tourism (Gautam, et al. 2013). In spite of home to all such enormously valuable resources, Himalayas are one of the most tectonically unstable, ecologically fragile, economically underdeveloped, and densely populated mountain systems on the earth (Hasnain, 2009; Tiwari and Joshi, 2014). It is these natural and human characteristics which makes Himalayan region excessively vulnerable to climate change impacts especially to those of melting glaciers and changes in precipitation patterns (Hasnain, 2009).

### 1.2. Climate change in Himalayas

Like many other places on the earth, Himalayas are also experiencing rapid climate change with significant impact on local ecosystems, biodiversity, agriculture and human well-being (Chaudhary *et al.* 2011). Over the past 100 years, Himalayan region has revealed consistent trends in overall warming (Yao, et al. 2006). A number of studies revealed that during the last century warming in the Himalayas have been much higher than global average of  $0.74^\circ\text{C}$  (IPCC, 2007a). It has been between  $0.15^\circ\text{C}$  and  $0.60^\circ\text{C}$  per decade in the past three decades (Shrestha, et al. 2010). However, warming is more pronounced in the high altitude regions as is observed in Nepal and on the Tibetan Plateau (Liu, et al. 2002). Further, in most parts of Himalayas such as Chinese, northwest Indian, and Nepalese Himalaya, rate of warming is consistently higher in winter than in summer (Bhutiyani, et al. 2007; 2010; Shrestha and Devkota, 2010). All this indicate that being elevated regions of the world, Himalayas and the Tibetan Plateau are susceptible to and affected by changes in climate (Gautam, et al. 2007). Projections on the basis of Global Climate Model (GCM) predict a warmer Himalayan region in future with warming likely to be above world average (Gautam, et al. 2013).

### 1.3. Impact of climate change on Himalayan glaciers

One of the most noticeable impacts of climate change in the Himalayas is the rapid retreat of glaciers. In fact glaciers are sensitive and 'high-confident' indicators of climate change (Armstrong, 2010). Evidences suggest that many Himalayan glaciers are receding faster than the world average (Dyurgerov and Meier 2005) and are retreating by 0.3 to 1 m per year (Jianchu, et al. 2007). But the patterns of melting and their impacts differ regionally. A remarkable exception has been seen in the Karakorum region where some glaciers have exhibited advancement (Hewitt, 2005). In the western China, 82% of the glaciers have retreated during the last half of the 20th Century, (Liu, et al. 2006). Most of the glaciers studied in Nepal are receding fast (Fujita, et al. 2001) with reduction in overall glacier area (21%) and ice reserve (28%)

have been observed between 2001 and 2010 (Bajracharya, et al. 2011). Selected glaciers of Indian Himalayas studied also indicated discontinuous retreat since post-glacial time (Bajracharya et al. 2008). The rate of retreat of Gangotri glacier, the principal source of the Ganges (Strategic Foresight Group, 2010) during the last three decades has been more than three times the rate during the past 200 years (Srivastava 2003).

#### **1.4. Impact on biodiversity**

Biodiversity is exposed to climate change impacts (ICIMOD, 2012). It is predicted by several studies that warming will result in major decline in biodiversity across a wide variety of alpine habitats in the Greater Himalayas, including tundra and rangelands (Klein, et al. 2004; Walker, et al. 2006). Himalayas are also important storehouses of agrobiodiversity (Rassul, 2012). There are many plant species in the Himalayas which may not be able to respond successfully to projected changes in rates and scale of climate (Mutke and Barthlott, 2005). Moreover, natural vegetation may respond to climate change in complex ways; some species may increase, some decrease, and some new ones are likely to appear due to climate change (Chen, et al. 2003; Williams, et al. 2007). Biodiversity benefits people in a number of ways. It supplies people with basic subsistence needs (Zomer, 2009) such as food, water, fibre, implements, medicines, energy and housing (Sharma, 2004). Loss of biodiversity due to climate change will have significant consequences for the poor and marginalised people who depend almost exclusively on natural resources for survival (Sharma, et al. 2009).

#### **1.5. Impact on fresh water availability**

Climate change is likely to have profound effects on the availability of, and access to water. In Asia, access to freshwater, particularly in large basins is expected to decline by 2050 (Eriksson, et al. 2009). As Himalayan glaciers are the largest freshwater reserves, rapid loss of glaciers may significantly reduce the availability of freshwater in the region (ICIMOD, 2008). The seasonal melting of glaciers supplies freshwater resources for downstream populations and ecosystems, particularly in arid areas of the Himalayas and during the critical dry seasons (Eriksson, et al. 2008). However, continued deglaciation associated with climate change and global warming is expected to adversely affect the hydrological regimes of river basins originating in the Himalayas (Hua, 2009). Due to accelerated melting of glaciers, river discharges are expected to increase initially, but as the water storage capacity of glaciers is reduced, the flow is likely to decline. According to IPCC's Fourth Assessment Report (2007), if the present trend of glacial shrinkage continued some Himalayan catchments would run out of water during the dry seasons (Singh, et al. 2011). All this is likely to have adverse effects on drinking water, biodiversity, hydropower, industry, agriculture, with widespread implications for the people of the region and environment of the earth (Bajracharya, et al. 2007). It is projected that due to climate change induced glacial melt, half a billion people in the Himalayan region in general and quarter a billion in China particularly could be seriously affected (Stern, 2007).

#### **1.6. Impact on lives of mountain people**

Climate changes in the Himalayas and their subsequent impacts on Himalayan ecosystem particularly on water resources are likely to have dramatic impacts on mountain people. Living in the mountain region is already a challenge. Mountain people face a number of hardships in their day to day life due to fragility of ecosystems, remoteness, poor accessibility and marginalisation from the mainstream, lack of access to basic facilities such as health care, education, and physical infrastructure, markets, lack of employment opportunities and proneness to natural hazard of the mountain regions (ICIMOD 2010). In such circumstances, climate change acts as an additional stressor which can restrict mountain people's capacity to cope with or adapt to new and often more harsh environmental conditions. Although, mountain people have contributed very little to the global emission of greenhouse gases, they represent the first among communities vulnerable to the adverse impacts of climate change (Macchi, ICIMOD, 2010). Their vulnerability mainly results from poverty, high incidence of food insecurity and poor health, excessive reliance on natural resources, marginalisation, and limited livelihood diversity (Macchi; ICIMOD 2010). Although, there is limited data about human well-being in Himalayas (Negi, et al. 2012), it is evident that climate change effects are likely to be experienced by them, among other things, on their livelihoods, health, and natural resource security (Sharma, et al. 2009).

#### **1.7. Impact on livelihoods**

Mountain people in the Himalayas have limited livelihood options. The main source of livelihood for mountain people in Himalayas is agriculture (Tiwari and Joshi, 2014) and livestock rearing (Leduc, 2008). However, due to rugged terrain and harsh climate, agriculture in mountainous regions is challenging. Crops are seasonal in nature (ICIMOD, 2012) and the productivity is considerably poor (Tiwari and Joshi, 2014). Moreover, agriculture in Himalayan regions is generally rain-fed and thus vulnerable to changes in timing and frequency of rainfall (Gautam, et al. 2013). Climate change induced hazards such as floods, landslides, and droughts and changes in precipitation patterns directly affect crop yields and livestock and thus have urgent consequence for the livelihoods of mountain people (Macchi ICIMOD, 2010). Moreover,

rising temperatures and drier climates are also expected to degrade rangelands (Dirnbock, et al. 2003) which may adversely affect livestock rearing practices in the Himalayan region. Rangeland degradation leads to scarcity of fodder and causes malnutrition and eventual degradation of livestock which in turn leads to reduction in commercial activities and shortage of food items like yak butter, cheese, meat and wool for the people themselves (NTNC- ACAP, 2012).

Besides agriculture and livestock rearing, tourism is another major source of livelihood for mountain people in the Himalayas. However, like agriculture, tourism is highly climate sensitive economic activity (Simpson, et al. 2008). It may adversely affect the appeal of a destination, disturb infrastructure related to transport and energy, damage the natural resource base, impact tourists' satisfaction, health and safety and influence the general sustainability of facilities and destinations (Becken and Hay, 2007). The same is true in case of tourism in Himalayan region also. Due to increased incidences of natural hazards in mountain region, travelling across high mountain routes may perceive to be dangerous. Tourist attraction may also be reduced if mountain environments lose significant portions of the glacial landscape (Kaltenborn, et al. 2010). Thus, any change in the characteristics of the Himalayan climate may have negative impact on tourism flow in the region by changing the perceived attractiveness of the Himalayan environment (Nyaupane and Chhetri, 2009) and thereby affects mountain people who directly or indirectly depend on tourism for their survival.

### 1.8. Impact on health

Climate change is also likely to affect health of people living in Himalayas. The Third Assessment Report of the IPCC predicts that, climate change is expected to expand the geographical distribution of some vector-borne diseases such as malaria and dengue to higher altitudes and latitudes (Strategic Foresight Group, 2010). Spread of Bartonellosis, tick-borne diseases and infectious diseases linked with the rate of pathogen replication are also likely to increase. Recently, existence of malaria mosquitoes has been reported at high altitudes in the region (Eriksson, et al. 2008). Climate change induced water-borne diseases such as cholera, diarrhoea, salmonellosis, and giardiasis, as well as malnutrition conditions are common in Himalayan countries like Bhutan, India, Myanmar, and Nepal (Sharma, et al. 2009.). It is projected that by 2030, due to elevated temperatures and increased flooding, the risk of contracting such diseases or suffering from malnutrition will increase (Patz, et al. 2005). As mountain people have limited access to primary health-care and sanitation facilities, as well as confront food deficiencies, maternal and infant mortality rates are above average for mountain people (FAO, 2008). Their well being will be further challenged by crop failure due to water shortages and more frequent natural disasters, and the spread of crop and livestock pests and diseases to higher altitudes due to rising temperatures (Macchi ICIMOD, 2010). Climate change may also have some positive benefits for health status of certain populations in the Himalayan region. Due to less cold, living in mountain region will become more comfortable, and the risks linked with cold and respiratory diseases will be reduced as people would use less fuelwood for heating purposes (Eriksson, et al. 2009).

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## 2. Conclusions

Himalayas are experiencing rapid climate change with widespread implications for local environment, water resources, biodiversity, agriculture and human system. Himalayas are warming at a rate more than the world average. Many glaciers are melting at a faster rate. Precipitation patterns are also changing. Accelerated rate of melting glaciers and changing precipitation patterns have adversely affected river regimes and fresh water availability in the region. Likelihood of extreme events with more unpredictability has also increased in the region. Thus, climate change by adversely affecting water availability and precipitation patterns and occurrences of extreme events have adversely affected lives and livelihoods of mountain people. The major sources of livelihoods for mountain people are agriculture, livestock rearing and tourism all of which are highly vulnerable to changes in climatic conditions. In order to assess the impacts of climate change on Himalayan ecosystem and people wellbeing, reliable data from different sectors such as climate, hydrology, agriculture and socio-economic wellbeing is required. Although, there is a good deal of research on the climate change impact on the Himalayan ecosystem, the data on the socio-economic well being of mountain people is scant. Thus, more research is needed to have clearer picture of the impacts of climate change on the lives and livelihoods of mountain people.

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