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An Overview of Glaciers, Glacier Retreat, and Subsequent Impacts in Nepal, India and China

Regional Overview – Executive Summary

WWF Nepal Program

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Coordinated by:
Sandeep Chamling Rai
Climate Change Officer
WWF Nepal Program.

Editorial support:
Trishna Gurung
Communications Officer
AREAS and Tiger Programmes
WWF International

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This report was compiled by Joe Thomas K and Sandeep Chamling Rai based on the following country reports:

Nepal
'Nepalese Glaciers, Glacier Retreat and its Impact to the Broader Perspective of Nepal'
Dr. Arun. B. Shrestha**,** Hydrologist-Engineers, Snow and Glaciers Hydrology Unit, Department of Hydrology and Meteorology (DHM)/Ministry of Science and Technology, Kathmandu Nepal.

India
'Status review of possible Impacts of Climate Change on Himalayan Glaciers, Glaciers retreat and its subsequent impacts on fresh water regime'
Dr. Rajesh Kumar, HIGHICE-India Glacier Research group, SES, JNU, New Delhi

China
'An Overview of Glaciers, Retreating Glaciers, and Their Impact in the Tibetan Plateau'
Yongping Shen, Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI), Chinese Academy of Sciences (CAS), Lanzhou 730000, China

FOREWORD

Climate change is real and happening now.

The planet is already experiencing its impacts on biodiversity, freshwater resources and local livelihoods. Using current climate change trends, by 2100, the average global temperature may rise by 1.4 – 5.8^{0}C according to the Third Assessment Report from the Intergovernmental Panel on Climate Change (IPCC, 2001). This is certain disaster for fragile ecosystems like glaciers.

Seventy percent of the worlds freshwater is frozen in glaciers. Glacier melt buffers other ecosystems against climate variability. Very often it provides the only source of water for humans and biodiversity during dry seasons. Freshwater is already a limited resource for much of the planet, and in the next three decades, the population growth is likely to far exceed any potential increase in available water.

The Himalayas have the largest concentration of glaciers outside the polar caps. With glacier coverage of 33,000 km^2, the region is aptly called the "Water Tower of Asia" as it provides around 8.6 X 10^6 m^3 of water annually (Dyurgerov and Maier, 1997). These Himalayan glaciers feed seven of Asia's great rivers: the Ganga, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang Ho. It ensures a year round water supply to millions of people.

Climate change has impacted the glacial ecosystem tremendously. Sixty-seven percent of glaciers are retreating at a startling rate in the Himalayas and the major causal factor has been identified as climate change (Ageta and Kadota, 1992; Yamada et al., 1996; Fushinmi, 2000). Glacial melt will affect freshwater flows with dramatic adverse effects on biodiversity, and people and livelihoods, with a possible long-term implication on regional food security.

WWF sees the impacts of climate change on glaciers and its subsequent impact on freshwater as a major issue, not just in the national context but also at a regional, transboundary level. The WWF offices in Nepal, India and China are taking the initiative to develop a regional collaboration to tackle climate change impacts in the glacial ecosystem and address adaptation measures. This report is the outcome of a regional collaboration of the three countries, providing an overview of climate impacts on glaciers with a focus on key areas that needs future intervention.

We hope this will highlight the issue of climate change and galvanize policy makers to take action to ensure a living planet for future generations.

Dr Chandra Prasad Gurung	Ravi Singh	Jim Harkness
Country Representative	Secretary General and CEO	Country Representative
WWF Nepal Program	WWF India	WWF China Program

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Introduction

Climatic changes and its impacts on the fluctuation of glaciers are a natural phenomenon that has been occurring in the Earth's five billion-year-old history. In the past few decades, global climate change has had a significant impact on the high mountain environment: snow, glaciers and permafrost are especially sensitive to changes in atmospheric conditions because of their proximity to melting conditions. In fact, changes in ice occurrences and corresponding impacts on physical high-mountain systems could be among the most directly visible signals of global warming. This is also one of the primary reasons why glacier observations have been used for climate system monitoring for many years (Haeberli 1990; Wood 1990).

A historical overview

There have been at least 17 major glacial advances (glaciations) in the last 1.6 million years alone (Goudie 1983). The most recent, the Last Glacial, reached its peak some 20,000 to 18,000 years ago and came to an end about 10,000 years ago (Goudie 1983). Glaciations are followed by 'interglacial' periods, during which the glacier ice retreats as a result of global warming. The interglacial typically continues for about 10,000 years before the cooling or the next glaciation begins. This cyclical activity, which recurs at intervals of approximately 100,000 years, is generally accepted to be caused by gradual changes in the earth's rotation, tilt and orbit around the sun, which affects the amount of solar radiation the earth receives (Milankovitch 1941 in Bradley 1985).

Glacial cycles are punctuated by relatively short periods of localized cooling and warming, during which glaciers advance and retreat. The most recent cooling episode of the present interglacial commonly referred to as the 'Little Ice Age' (LIA), affected parts of North America (Curry 1969), Asia (Chu Ko-Chan 1973) and Europe from about 1300 AD through to the latter half of the 19th century. During the LIA (1550-1850 AD) glaciers were much longer than today (Yamada *et al.* 1998). It may have been the result of volcanic eruptions and the presence of volcanic ash in the atmosphere that caused cooling by reducing the amount of solar radiation reaching the earth's surface (Lamb 1970). Changes to ocean currents have also been suggested, as has tectonic activity, concentration of carbon dioxide in the atmosphere, and sunspot activity (Goudie 1983).

The present scenario

The 20th century has been a watershed vis-à-vis glacial fluctuations on a global scale. This has been a period of dramatic glacier retreat in almost all alpine regions of the globe, with accelerated glacier and ice-fields melt in the last two decades. The first phase of this glacier retreat was associated with emergence from the Little Ice Age that ended in the 19th century. It corresponded with a warming of 0.3ºC in the first half of the 20th century in the northern hemisphere (24^{o} to 40°N). In the last 25 years, a second 0.3ºC warming pulse has caused northern hemisphere temperatures to rise to unprecedented levels compared to the last 1,000 years. The 1990s were the warmest decade of the millennium and 1998 the hottest year of the millennium. In all, there was a temperature rise of close to 1ºC across the continents.

Research shows that the glacier cover of mountain regions worldwide has decreased significantly in recent years as a result of warming trends. A recent comparison of historical glacier data with images from the ASTER (Advance Spaceborne Thermal Emission and Reflection Radiometer) instrument on NASA's TERRA satellite by the United States' Geological Survey revealed a significant shrinkage of mountain glaciers in the Andes, the Himalayas, the Alps and the Pyrenees over the past decade (Wessels *et al.* 2001). These observations are consistent with published results from many other glacier studies around the world that also recorded rapid glacier retreat in recent years. A study by Dyurgerov and Meier (1997), who considered the mass balance changes of over 200 mountain glaciers globally, concluded that the reduction in global glacier area amounted to between 6,000 and 8,000 km^2 over a 30 year period between 1961 and 1990.

According to Haeberli and Hoelzle (2001) of the World Glacier Monitoring Service (WGMS), the measurements taken over the last century "clearly reveal a general shrinkage of mountain glaciers on a global scale". They observed that the trend was most pronounced during the first half of the 20th century and that glaciers had started to grow again after about 1950. However, they claim that mountain glacier retreat has been accelerating again since the 1980s at a "rate beyond the range of pre-industrial variability". Based upon a number of scientific investigations (e.g. Kuhn 1993a, Oerlemans 1994) and the IPCC (1996b) there are forecasts that up to a quarter of the global mountain glacier mass could disappear by 2050 and up to half could be lost by 2100.

Closer to the present focus of our areas of study, Himalayan glaciers have also been found to be in a state of general retreat since 1850 (Mayewski & Jeschke 1979). The Himalayan glaciers feed seven of Asia's great rivers: Ganga, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang He, and ensure a year-round water supply to billions people.

The Khumbu Glacier, a popular climbing route to the summit of Mt Everest, has retreated over 5 km from where Sir Edmund Hillary and Tenzing Norgay set out to conquer the world's highest mountain in 1953. Since the mid-1970s the average air temperature measured at 49 stations of the Himalayan region rose by 1°C with high elevation sites warming the most (Hasnain 2000). This is twice as fast as the 0.6°C average warming for the mid-latitudinal northern hemisphere over the same time period (IPCC 2001b), and illustrates the high sensitivity of mountain regions to climate change (Oerlemanns *et al*. 2000). The Dokriani Barnak Glaicer in India retreated 20m in 1998, and the Gangotri Glacier some 30m.

Overview of the problem

The *New Scientist* magazine carried the article "Flooded Out – Retreating glaciers spell disaster for valley communities" in their 5 June 1999 issue. It quoted Professor Syed Hasnain, then Chairman of the International Commission for Snow and Ice's (ICSI) Working Group on Himalayan Glaciology, who said most of the glaciers in the Himalayan region "will vanish within 40 years as a result of global warming". The article also predicted that freshwater flow in rivers across South Asia will "eventually diminish, resulting in widespread water shortages".

As apocalyptic as it may sound, it needs to be underlined that glaciers need to be studied for a variety of purposes including hazard assessment, effects on hydrology, sea level rise and to track climatic variations. There are several problems associated with retreating glaciers that need to be understood in order to proceed to the next stage of quantifying research and mitigating disaster. In this context it would be imperative to understand the nature of problems that confront Nepal, India and China. While the following section deals with problems faced by all three countries, country-specific losses and details would be dealt with separately.

Risks and associated impacts of glacier retreat

Freshwater regime

More than half of humanity relies on the freshwater that accumulates in mountains (Mountain Agenda 1998). Glaciers 'mother' several rivers and streams with melt runoff. A significant portion of the low flow contribution of Himalayan rivers during the dry season is from snow and glaciers melt in the Himalayan region. The runoff supplies communities with water for drinking, irrigation and industry, and is also vital for maintaining river and riparian habitat. It is posited that the accelerated melting of glaciers will cause an increase in river levels over the next few decades, initially leading to higher incidence of flooding and land-slides (IPCC, 2001a). But, in the longer-term, as the volume of ice available for melting diminishes, a reduction in glacial runoff and river flows can be expected (IPCC 1996b, Wanchang *et al.* 2000). In the Ganga, the loss of glacier meltwater would reduce July-September flows by two thirds, causing water shortages for 500 million people and 37 percent of India's irrigated land (Jain 2001; Singh *et al.* 1994).

Glacial lake outburst floods (GLOFs)

Glacial lake outburst floods (GLOFs) are catastrophic discharges of water resulting primarily from melting glaciers. An accelerated retreat of the glaciers in recent times has led to an enlargement of several glacial lakes. As the glaciers retreat they leave a large void behind. The ponds occupy the depression earlier occupied by glacier ice. These dams are structurally weak and unstable and undergo constant changes due to slope failures, slumping, etc. and run the risk of causing GLOFs.

Principally, a moraine dam may break by the action of some external trigger or self-destruction. A huge displacement wave generated by rockslide or a snow/ice avalanche from the glacier terminus into the lake may cause the water to top the moraines and create a large breach that eventually causes dam failure (Ives 1986). Earthquakes may also be one of the factors triggering dam break depending upon magnitude, location and characteristics. Self-destruction is a result of the failure of the dam slope and seepage from the natural drainage network of the dam.

Characterized by sudden releases of huge amounts of lake water, which in turn would rush down along the stream channel downstream in the form of dangerous flood waves, GLOF waves comprise water mixed with morainic materials and cause devastation for downstream riparian communities, hydropower stations and other infrastructure. In South Asia, particularly in the Himalayan region, it has been observed that the frequency of the occurrence of GLOF events has increased in the second half of the 20th century. GLOFs have cost lives, property and infrastructure in India, Nepal and China.

Glacial Lake Out-burst Floods (GLOF) are the main natural hazards in the mountain areas of this region. A 1964 GLOF in China destroyed many kilometers of highway and washed 12 timber trucks 71 km from the scene. An outburst of Zhangzangbo Lake in 1981 killed four people and damaged the China-Nepal Friendship Bridge in the northern border, seven other bridges, a hydropower plant, Arniko highway and 51 houses. The damage was estimated to be USD 3 million. The 1985 GLOF at Dig Tsho was triggered by a large avalanche. A hydroelectricity project, 14 bridges, 30 houses and farmlands worth USD 4 million were destroyed. In 1998, the outburst of Tam Pokhari in Nepal killed two people, destroyed more than six bridges and washed away arable land. Losses worth over 150 million rupees have been estimated. A high water level was observed even after 19 hours in the Koshi barrage near the Indo-Nepal border. The river reverted to its original flow only after three days (Dwivedi 2000).

There are about 159 glacier lakes in Koshi basin (Sharma 1998). Nearly 229 glacier lakes were identified in Tibet's Arun basin, out of which 24 are potentially dangerous (Meon & Schwarz 1993). Since 1935 more than 16 GLOFs have been reported which either occurred or extended into Nepal.

National economic costs

For a landlocked country like Nepal, which relies on hydropower generation as a vital source of national income, the prospect of an eventual decrease in the discharge of rivers spells doom. For an energy-constrained economy like India, the prospect of diminishing river flows in the future and the possibility that energy potential from hydropower may not be achieved has serious economic implications. The implications for industry extend beyond the 'energy' argument: chemical, steel, paper and mining industries in the region that rely directly on river/stream water supply would be seriously affected. Reduced irrigation for agriculture would have ramifications not only on crop production but eventually on basic human indices like available food supplies for people and malnutrition.

While the impacts of deglaciation are briefly outlined in the aforementioned categories there are, as mentioned earlier, details specific to each of the countries that will be dealt within the country-specific case study. It would be useful to refer to each country analyses with the thematic support literature covered in the previous sections. The country case-studies are useful in understanding physical and climatological characteristics of the region and serve as useful bases of reference for further research.