Climate Change–related Health Impacts in the Hindu Kush–Himalayas

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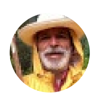

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Review

Climate Change-related Health Impacts in the Hindu Kush–Himalayas

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Abstract: Our goal was to identify the climate change-related health risks and vulnerable populations specific to the mountainous regions of the Hindu Kush–Himalayas. We reviewed published information of the likely health consequences of climate change in mountain regions, especially the findings of a workshop for countries in the Hindu Kush–Himalaya region, organized by the World Health Organization, World Meteorological Organization, United Nations Environment Programme, and United Nations Development Programme. The main climate-related risks in the Hindu Kush–Himalaya region include the expansion of vector-borne diseases as pathogens take advantage of new habitats in altitudes that were formerly unsuitable. Diarrheal diseases could become more prevalent with changes in freshwater quality and availability. More extreme rainfall events are likely to increase the number of floods and landslides with consequent death and injuries. A unique risk is sudden floods from high glacier lakes, which cause substantial destruction and loss of life. Because glaciers are the main source of freshwater for upland regions and downstream countries, the long-term reduction in annual glacier snowmelt is expected to heighten existing water insecurity in these areas. Climate change also is bringing some benefits to mountain populations, including milder winters and longer growing seasons. Populations in mountain regions have unique combinations of vulnerabilities to climate change. The extent of the health impacts experienced will depend on the effectiveness of public health efforts to identify and implement low-cost preparedness and response measures, and on the speed at which emissions of greenhouse gas emissions can be reduced.

Keywords: climate change, Hindu Kush–Himalayas, human health, mountains

INTRODUCTION

Mountains occur on all continents, in all latitude zones, and within all the world's principal biome types. The global mountain area is almost 40 million km^2 (approximately 27% of Earth's surface) (UNEP, 2001). By continent, the Eurasian landmass has the greatest mountainous area. The Tibet (Qing Zang) Plateau and adjacent ranges have the most extensive inhabited land area above 2500 m. All of the world's mountains taller than 7000 m are in Asia, and all 14 peaks above 8000 m are in the Greater Himalaya range.

In 2000, the number of people living in mountainous regions was more than 1.1 billion (Huddleston et al., 2003).

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Table 1. Global Mountain Populations and Percent That Is Urban

Mountain area class by elevation	Population ('000s)	Urban (%)
≥4500 m	5405	4.6
3500–4500 m	20,541	18.8
2500–3500 m	63,373	27.7
1500–2500 m	222,700	26.8
1000–1500 m	226,292	30.3
300–1000 m	574,797	31.4
Total	1,113,108	29.7

Source: Huddleston et al., 2003.

Table 1 shows global mountain populations by elevation. As shown in Table 2, 90% of global mountain populations live in developing and transition countries; of these, one-third are in China and two-thirds in the rest of Asia and the Pacific. Of those living above 2500 m, almost all are highly vulnerable to food insecurity. In addition, a combination of poverty and remoteness results in poor medical support and education systems in many mountainous regions.

Developing countries where a large proportion of the population lives in mountains, such as Bhutan and Nepal, typically have young populations and shorter life expectancies. For example, in 2002, life expectancy at birth was 60 years for males and 62 years for females in Bhutan (compared with 78 years for Japanese males and 85 years for Japanese females) (WHO, 2002).

Agenda 21 (Chapter 13: Managing Fragile Ecosystems: Sustainable Mountain Development) established programs of action to ensure the ecological health and the economic and social improvement of mountain areas for the sake of both mountain inhabitants, whose livelihood opportunities and overall well-being are at stake, and for people living in lowland areas (United Nations 58th General Assembly). The 2002 World Summit on Sustainable Development noted that, despite achievements, populations in mountain regions continue to face significant challenges to development (United Nations 58th General Assembly).

Little attention has focused on the ecological changes in mountainous regions and subsequent health risks faced by mountain dwellers and neighboring countries as a result of global climate change. For example, snowmelt from high mountainous regions is an important source of water to downstream lowland countries. To address the knowledge gap, we review the literature on climate and climate change in mountain regions and summarize the results of an inter-regional workshop on the health impacts of climate change in the Hindu Kush–Himalaya region, held in 2005 (WHO, 2006). The workshop was organized by the World Health Organization, the World Meteorological Organization, the United Nations Environment Programme, and the United Nations Development Programme. Participants represented Afghanistan, Bangladesh (included because changes in run-of from the Hindu Kush–Himalaya region can affect water availability), Bhutan, India, Nepal, Pakistan, and the People's Republic of China, as well as international organizations.

Climate And Climate Change In Mountain Regions

Mountains influence climate through their altitude, continental position, latitude, and topography (Barry, 1997). In general, air pressure, temperature, and humidity decrease with increasing altitude, and solar radiation (especially UV) and wind speeds increase. At 1500 m, the partial pressure of oxygen is about 84% of the value at sea level, falling to 75% at 2500 m, and 63% at 3500 m. Air temperature decreases about 5.5°C for every 1000 m increase in altitude (but this varies diurnally, seasonally, latitudinally, and from region to region).

Latitude and continental location together influence climate and local weather patterns. Latitude influences day length and the seasonal distribution of solar radiation. In mid-latitudes, the dry and dust-free air at higher altitudes retains little heat energy, leading to marked extremes of temperature between day and night. Some mountains are almost permanently dry, others are wet, and others are highly seasonal in climatic pattern. Extensive mountain ranges create barriers to air motion and generate their own climates.

Beyond the general, knowledge of climatic processes in specific mountain regions is usually limited because of a paucity of data. Relatively dense meteorological networks exist for the Alps and parts of North America. Elsewhere, problems of access and financial resources have limited the number of weather stations. A 1992, 19 of the 30 principal observatories in mountain regions were in Europe; none were in the Himalayas (Barry, 1992).

Global average surface temperatures increased in recent decades (IPCC, 2007). Temperatures are increasing at a greater rate in the uplands regions of Nepal (Shrestha et al., 1999). Over the period 1977–1994, mean annual maximum temperatures in the northern part of that country increased

Table 2. Number of Vulnerable Rural People (Millions of People) Living in Different Classes of Mountain Regions, by Developing and Transition Countries[a]

	Mountain Area Class (Meters above Sea Level)						
Region	300–1000	1000–1500	1500–2500	2500–3500	3500–4500	>4500	Total
Total rural mountain population	242	98	105	32	10	4	490
Vulnerable people living in rural mountain areas							
Asia and the Pacific	78	29	20	7	4	3	140
Latin America and Caribbean	10	5	9	5	4	0.2	33
Near East and North Africa	11	7	8	4	0.3	0.03	30
Sub-Saharan Africa	11	11	7	2	0.09	0	31
Transition countries	8	2	1	0.4	0.2	0.02	12
Total	118	54	45	18	9	3	245
Percentage of vulnerable people in the total rural mountain population	48%	55%	43%	57%	87%	82%	

[a]"Vulnerable rural mountain people" were defined as those living in rural areas where rainfed cereal production was less than 200 kg per person per year and the bovine density index was medium-to-low. "Rural mountain people" included those living in closed forests or protected areas. Source: Huddleston et al., 2003.

by more than 0.06°C per year above the long-term mean, with some regions recording increases of up to 0.12°C per year. This contrasts with the Siwalik and Terai regions in the lowlands that warmed less than 0.03°C per year. Glacier retreat is the main explanation for this higher rate of warming. The reduction in snow and glacier cover from a small amount of climate change reduces the albedo effect and increases the surface temperature, causing a positive warming feedback in the local environment (Meehl, 1994).

These upward trends are expected to accelerate over the coming decades. By 2100, global atmospheric concentrations of carbon dioxide are projected to be between 490 and 1260 ppm (75%–350% above the concentration of 280 ppm in the year 1750) (Albritton et al., 2001) and the global mean temperature is projected to increase by between 1.1° and 6.4°C as a result, with a best estimate range of 1.8°–4.0°C (IPCC, 2007). Future scenarios of climate change in mountain regions are highly uncertain due to the low spatial resolution of climate models, but the physical principles of the albedo effect support projections of continued greater warming in mountainous areas and high northern latitudes.

A particular concern in tropical Asia is whether climate change will affect the monsoon season. The climate of tropical Asia is dominated by two monsoons: the summer southwest monsoon influences the regional climate from May to September, and the winter northeast monsoon influences the climate from November to February. The monsoons bring most of the region's precipitation and are critical for providing drinking water and water for rainfed and irrigated agriculture (Lal et al., 2001). Increases in rainfall during the northeast monsoon, as well as increases in the magnitude of extreme rainfall events, both of which have been projected with climate change, are expected to increase the frequency and intensity of flooding in the region (Lal et al., 2001). If the southwest monsoon arrives later or withdraws earlier, then soil moisture deficits would worsen in some areas.

Another concern is that climate change will alter the depth of mountain snow packs and glaciers and their seasonal melting, with subsequent negative impacts on the communities, agriculture, and power generating stations that rely on their freshwater runoff. Glaciers and glacial lakes are the sources of headwaters of many large rivers in areas such as the Hindu Kush–Himalaya regions of Nepal, India, Pakistan, Bhutan, and China (Tibet). For example, meltwater from Himalayan glaciers contribute a sizeable portion of river flows to the Ganga, Brahmaputra, Indus, and other river systems in south Asia (Smith et al., 2001). About 70% of the summer flow in the Ganga comes from melting glaciers. In China, 23% of the population lives in the western regions where glacial melt provides the principal dry season water source (Barnett et al., 2005). Glaciers also act to regulate water runoff from the mountains to the plains between dry and wet periods, thus glaciers are instrumental in securing agricultural productivity and livelihoods for millions of people.

Rising temperatures may cause snow to melt earlier and faster in the spring, shifting the timing and distribution of runoff. Projections are for a regression of the maximum spring stream-flow period in the annual cycle of about 30 days and an increase in glacier melt runoff of 33%–38% (Barnett et al., 2005). These changes could affect the availability of freshwater for natural systems and human use. Excessive melt water could cause flash floods. If freshwater runoff is reduced in the summer months because of earlier melting, soils and vegetation may become drier and the risk of wildfires may increase. Changes in stream flow and higher water temperatures also could affect insects and other invertebrates that live in streams and rivers, with repercussions up the food chain.

Glacier Lake Floods

A unique risk in mountainous areas is glacial lake outburst floods. Glacial lakes form on the lower altitude end of a glacier as it retreats. Unstable mounds of rock that were deposited during the glaciations of the Little Ice Age provide a natural dam at the downstream edge of the majority of glaciers. Sudden floods occur when these moraine dams break and discharge large volumes of water and debris. Such events have caused catastrophic downstream flooding and loss of life. Human well-being, as well as mortality, is greatly affected by glacial lake floods, which wash out agricultural land and bridges, and sever communication for substantial periods between people living on either side of rivers or ravines. For example, in the Lunana region of northwestern Bhutan, glacial lake floods occurred in 1957, 1969, and 1994, causing extensive damage to the Punakha Dzong (a religious and administrative center) (Iyngararasan et al., 2002). The outburst in 1994 resulted in 17 deaths and 91 households affected. Agriculture also was affected. In August 1985, a flood from the Dig Tsho (Langmoche) glacial lake in Nepal destroyed 14 bridges and caused about US$1.5 million in damage to the Namche small hydropower plant.

The frequency of glacial lake floods in the Himalayan region increased during the second half of the 20th century (UNEP, 2000). A 1999 study identified 3252 glaciers and 2323 glacial lakes in Nepal, and 677 glaciers and 2674 glacial lakes in Bhutan (Iyngararasan et al., 2002). Potentially dangerous glacial lakes were identified on the basis of actively retreating glaciers and other criteria. In Bhutan, 24 are considered to be potentially dangerous. Some glaciers in Bhutan are retreating at about 20–30 meters per year, creating many small glacier lakes that can merge over time to form larger lakes. The Thorthormi and Raphstreng glaciers and their lakes are highly dangerous and are moving at the rate of 40 meters per year. The developing Thorthormi lake is 50–60 meters above the Raphstreng lake. This glacier complex is in imminent danger of bursting, which could release 50 million cubic meters of water and cause a flood reaching to northern India 150 miles downstream. A major glacial lake flood in this complex is predicted by 2010 (RAO, 2006).

Potential Climate-Related Health Risks in Mountain Regions

A comprehensive assessment of the health impacts of climate change requires knowledge of the vulnerability of populations and their capacity to respond to new conditions. Only crude estimates of the current burden of climate-sensitive diseases in the Hindu Kush–Himalaya regions are available due to the lack of health surveillance data at the local level. As a first step at generating this information, an inter-regional workshop was conducted to qualitatively estimate the likely health impacts of climate change and the public health adaptations that would be needed (WHO, 2006).

Climate change-related impacts on mountain ecosystems could affect population health by creating favorable conditions for: disease vectors; forest fires; avalanches, heavy snowfalls, major storms, floods, and droughts; altering depth and duration of snow cover and length of snow-free season; and changes in cloud cover and available sunlight. The workshop focused on how these environmental changes could influence future patterns of four health outcomes: (1) morbidity and mortality from extreme weather and climate events, (2) insect- and rodent-borne diseases, (3) water-related diseases, and (4) malnutrition.

Extreme Weather and Climate Events

Four types of floods are common in tropical Asia: riverine floods, flash floods, glacier lake floods, and breached landslide-dam floods. Each of these is associated with morbidity and mortality in, generally, unprepared populations. Flash floods are common in the foothills, mountain borderlands, and steep coastal catchments. Riverine floods occur along the courses of the major rivers, broad river valleys, and alluvial plains.

A major concern for India and Bangladesh is the projected reduction in water availability as a result of reduced snowmelt from glaciers in the Himalayas, particularly from the glaciers in India and Nepal that are the source of the Ganga. Gangotri is the longest Indian glacier (26 km) and is currently retreating at a rate of 20 meters per year, compared to 16 meters per year historically [Dr. Ananthanarayan, 2005, personal communication]. If the present trend continues, the Ganga will initially swell in volume (due to increased snowmelt), then shrink as snow cover reduces in subsequent years. This will endanger the lives of the millions of people in these countries who live on the river's plains and depend upon it for water. Adding to these pressures, massive deforestation in India and Nepal has significantly reduced the capacity of the Himalaya to absorb monsoon rains. This, along with other factors, has increased flooding in Bangladesh and diminished water quality due to the amount of soil carried downstream.

Insect- and Rodent-borne Diseases

The pattern of vector-borne diseases in human populations is inherently sensitive to changes in environmental conditions that influence the life cycle dynamics of the pathogen, its vector, and its host. Even small variations from the mean temperature and precipitation, or in vegetation, can alter the geographic distribution and abundance of vectors and the rate of pathogen replication within vectors. Malaria is already a problem in most countries in the Hindu Kush–Himalayas (although not yet prevalent in the cooler mountainous areas) (Bhattacharya et al., 2006). A number of research groups have used either statistical or biological techniques to model the potential spread of malaria as a consequence of climate change (Martens et al., 1999; Rogers and Randolph, 2000; Tanser et al., 2003; van Lieshout et al., 2004; Ebi et al., 2005). The models project reductions in the geographic range of malaria in certain regions, and increases in the geographic range and incidence in others. Where malaria is projected to increase, the various models are consistent in projecting that most of the future spread of malaria will occur at the margins of the current distribution, where cold climatic conditions have to date constrained transmission.

Water-related Diseases

Water-related infections have four means of transmission: ingested through water supplies (water-borne); through lack of water for personal hygiene (water-washed); via an aquatic host (water-based); and via insect vectors that depend on water (Bradley, 1977). Many diarrheal diseases have more than one means of transmission, and all modes are possible in mountain regions.

Diarrheal diseases are a major cause of morbidity and mortality in developing countries. In 2002, diarrheal diseases caused 1.8 million deaths worldwide (out of a total of 57 million deaths) and 61 million Disability Adjusted Life Years lost (DALYs) (out of 1490 million) (WHO, 2002). In countries in Southeast Asia with high child and adult mortality, 0.5 million people died of diarrheal diseases in 2002 (out of the regional total of 12.4 million deaths) and there were 18.7 million DALYs (out of 363 million).

The burden of diarrheal diseases in mountain regions has been shown in a number of recent studies (i.e., Pokhrel and Viraraghavan, 2004; Moffat, 2003; Bohler and Bergstrom, 1996; Pokhrel and Kubo, 1996). The quantity and timing of runoff from snowmelt and glaciers directly and indirectly influence the incidence and prevalence of water-related diseases. An increasing difference between the wet and dry seasons is projected in future, with wetter wet seasons (and increases in flash floods) and drier dry seasons (with increased stress on water resources,). During the wet season, floods flush feces into water sources; during the dry season, lack of water increases the risk of water-washed diseases. The likely need for water storage will increase the risk of water-borne and water-based infections.

Food Shortages

Undernutrition occurs when food production or distribution are disrupted, and when agricultural land is degraded (e.g., soil erosion following flash floods, or salt poisoning from rising inland water tables or sea level rise). An intensification of droughts, or a shift in the range or intensity of the Asian monsoon (both projected to occur), is projected to alter the distribution of agricultural productivity (Parry et al., 2004) and threaten food security at the local level. Less is known about how climate change will influence domestic animal health and the abundance of plant pests.

Burden Of Climate-Sensitive Health Outcomes: Current And Future

Table 3 is a summary of the workshop discussions about the presence of climate-sensitive health outcomes in the Hindu Kush–Himalayas. Not all the impacts of climate

Table 3. Current Climate-Related Health Determinants and Outcomes in the Hindu Kush–Himalaya Regions: A Synthesis of Country Reports

Country	Afghanistan	Bangladesh	Bhutan	China	Nepal	India
Heat waves	M–P	P	—	P	P	P
Flood deaths/morbidity	—	—	—	—	—	—
Glacial lake floods	M–P	—	M–P	M–P	M–P	M–P
Flash	M–P	P	M–P	M–P	M–P	M–P
Riverine (plain)	P	P	—	P	P	P
Vector-borne disease	P	P	P	P	P	P
Malaria	P	P	P	P	M–P	P
Japanese encephalitis	—	P	—	P	P	P
Kala-azar	P	—	—	—	P	P
Dengue	—	P	P	P	—	P
Water-borne diseases	M–P	P	M–P	M–P	M–P	M–P
Water scarcity, quality	M–P	P	P	M–P	M–P	M–P
Drought-related food insecurity	M–P	P	—	M–P	—	M–P

M–P, the health determinant or outcome that occurs in the mountainous and non-mountainous (i.e., plains) areas; P, the health determinant or outcome that only occurs in the non-mountainous (i.e., plains) areas; —, the health determinant or outcome that is not present in the country.

change on life and livelihood in predominantly cold mountain regions are expected to be negative. Older people in Nepal are already reporting that their homes and villages are more comfortable during warmer winters (Dahal, 2005). Tourism is profiting from longer drought periods in post-monsoon months, and apples may grow larger and more flavorsome in high altitudes historically too cold for apple farming.

Conclusions

Mountains are fragile ecosystems that are globally important as the source of most of Earth's freshwater, repositories of biological diversity, popular destinations for recreation and tourism, and areas of important cultural diversity, knowledge, and heritage. Many mountain environments have been degraded through deforestation, cropping, the excessive mining of other natural resources, and inappropriate infrastructure development. Many of the world's poorest and food-insecure populations live in mountain regions.

Climate change is an additional pressure that will, mostly negatively, influence mountains and the people who depend on the ecosystem services they provide. The impacts of climate change on human health will be direct, indirect, multiple, interacting, and significant. This poses major challenges to governments and resource managers. The remoteness of many mountain regions, and the dearth of published literature on the projected changes to climate and resulting health impacts for populations within them, adds to this complexity.

Based on the current profile of vulnerability, and given projected climate changes, most countries in the Hindu Kush–Himalayas would experience increasing burdens of climate-sensitive health determinants and outcomes. Advances in development would be the most effective strategy for improving future health prospects, while at the same time reducing (in the case of large emitters) or keeping current greenhouse gas emissions low. Public health-specific adaptation measures to increase resilience include improving vector-control, disaster preparedness (such as identifying areas for emergency settlements and appropriate housing), and integration of the environment and health sectors. Land-use decisions (cropping, deforestation, settlement location, dams, scale of mining, etc.) influence the availability and potability of water in these regions and downstream, and decisions made today will aggravate or minimize environmental hazards in the future.

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