Climate Change: A Himalayan Odyssey

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CLIMATE ACTION NETWORK
South Asia

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Acknowledgments

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This report **"Climate Change: A Himalayan Odyssey"** has been produced by Climate Action Network South Asia (CANSA) with support from **AirClim.**

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1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6)'s Cross-Chapter Paper on 'Mountains', climate change impacts in mountains and their attribution to human influence have increased in recent decades with observable and serious consequences for people and ecosystems in many mountain regions.[1] Climate-related hazards, such as flash floods and landslides, have contributed to an increase in disasters affecting a growing number of people in mountain regions and areas further downstream. Climate change is largely negatively impacting food, fibre, and other ecosystem products, including agriculture and ecosystem services across many different mountainous regions. Climate and cryosphere change have negatively impacted the water cycle in mountains, including variable timing of glacier melt and snowmelt stream discharge. Rising temperatures, seasonal shifts in glacier and snowmelt induced runoff, and increased frequency of extreme events are threatening the lives and livelihoods of people living in the mountain regions. The changes in the hydrological cycle significantly change the precipitation patterns that is leading to changes in river runoff and ultimately affecting agricultural productivity and human wellbeing.[2,3] Observed changes in seasonality (timing and extent) are negatively affecting mountain winter tourism and recreation.[4]

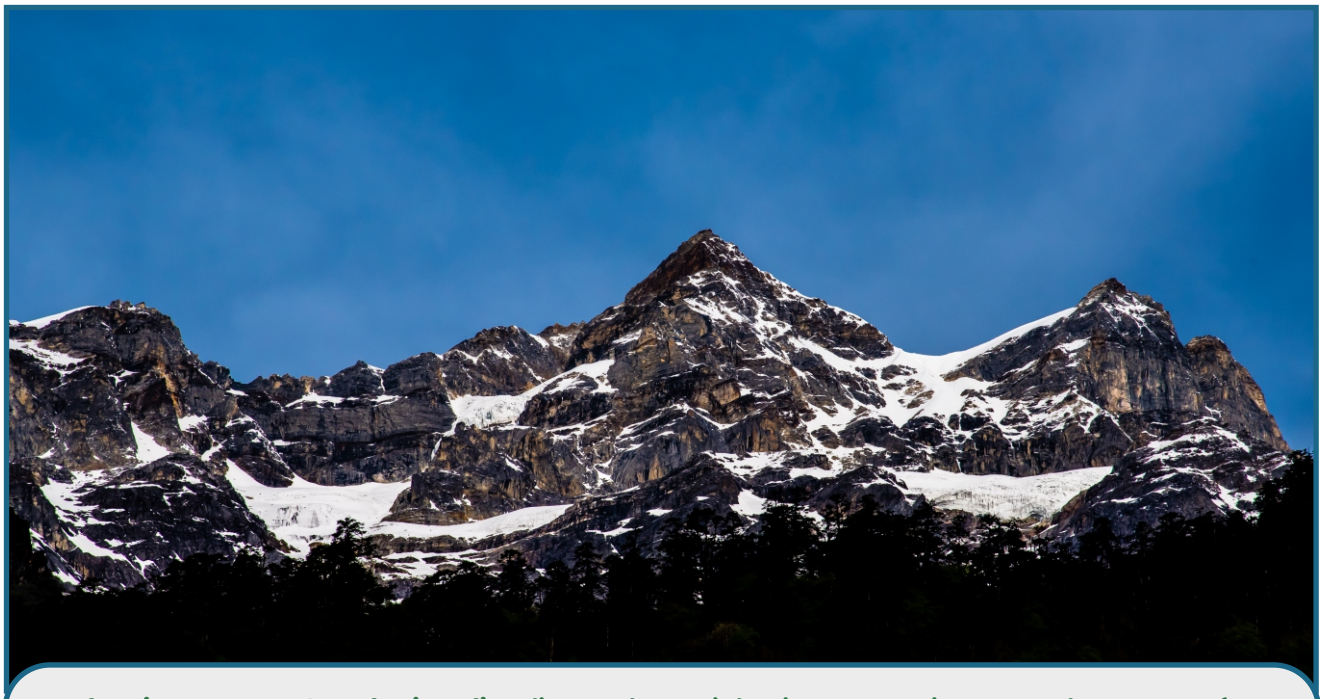
The Himalayas are inherently vulnerable to heavy rains, flash floods, landslides etc., as these are new mountains which are still growing and are seismically very active.[5] Climate change has added another layer of vulnerability. It is acting as a force multiplier and making landslides, flash floods and cloudbursts more disastrous. The most widely reported impact is the rapid reduction in glaciers, which has profound future implications for downstream water resources. The impacts of climate change are superimposed on a variety of other environmental and social stresses, many already recognized as severe.[6] The Himalayan region is the source of ten of the largest rivers in Asia. The basins of these rivers are inhabited by 1.3 billion people and contain seven megacities. Natural resources in these basins provide the basis for a substantial part of the region's total GDP and important environmental services, which are also of importance beyond the region.[7,8] Due ill-thought human interven-tions dams, hydropower projects, highways, mining, deforestation, buildings, unregulated tourism, and pilgrimage, the fragility of the mountains has increased.

Climate change and mountain social-ecological systems (Source: IPCC AR6 CCP, 2022)

The Himalayas, sometimes called 'the roof of the world', are the most extensive and rugged high altitude areas on Earth with over a hundred mountains exceeding 7,200 metres in elevation and the largest areas covered by glaciers and permafrost outside the polar regions. Himalayan glaciers are also referred to as Earth's 'third pole" and Asia's 'water towers' because they supply fresh water to communities throughout South Asia. Roughly 210 million people live in the region, and another 1.3 billion people who live downstream depend on rivers fed in part by glaciers and mountain snowpacks. **Photo:** Shailendra Yashwant for CANSA

Various studies suggest that mountain temperatures are increasing at a faster rate than the global average.[9,10] The annual mean temperature time series analysis over HKH and Indian land mass in the last few decades indicates a warmer Himalaya comparing to the Indian land mass. There is a subtle rise in the precipitation trend over the Karakoram and Western Himalayas and the eastern part of Himalayas, a declining trend can be noticed over many areas.[11] In Himalayan region, climate change will make water availability more uncertain, both in time and space. While overall trends are difficult to decipher, there are clear indications that the frequency and magnitude of high intensity rainfall events are increasing, with negative implications for infiltration and groundwater recharge, and for long-term soil moisture and water accessibility for plants. In addition, there are indications that the dry season is becoming drier and seasonal droughts and water stress more severe. The timing and length of the monsoon period also seems to be changing. These early signs will have to be followed up and confirmed but are likely to have profound effects on agricultural and natural ecosystems alike, as well as on the availability of water for household use, industry, and energy, thereby impacting considerably on people's livelihoods and wellbeing.[12,13]

However, there has been little detailed research on observed climate change in the mountains, and generalizations have been made from scattered studies carried out at sites widely separated in space and time. Recent scientific understanding, led by the Intergovernmental Panel on Climate Change (IPCC), is that global climate change is happening and will present practical challenges for local ecosystems.



Zanskar river, Jammu & Kashmir, India: Climate change is having a severe impact on the amount of snow and ice precipitation in the Himalayas, which has serious implications for downstream water availability in both short and long term as up to 50% of the average annual flows in the rivers are contributed by snow and glacial melting. The melting glaciers would mean floods and fast run-offs in the rivers in the short term and droughts and water scarcity in the long term. Irregular availability of water is going to be the biggest hazard in future. This will alter the area's erosion, river discharge and sediment patterns.

Photo: Shailendra Yashwant for CANSA

These include the prospect of more severe weather, longer droughts, higher temperatures (milder winters), heat waves, changes in local biodiversity, and reduced ground and surface water quantity and quality. These changes will impact on everything from the natural landscape to human health, built infrastructure, and socioeconomic conditions. The global community is currently trying to understand the nexus between climate change and mountain vulnerability, especially in the most remote and highest mountains of the world – the Hindu Kush-Himalayas. To do this, we must overcome the huge information and research gaps in this field in the greater Himalayan region.

1.1 Purpose of the Paper

While a lot of research has been already conducted on climate change and its impact in the Himalayas across countries, this paper reiterates the climate change risks in light of the new IPCC AR6 report. It also aims to explore the ways in which regional cooperation among countries in the Himalayas to address climate change can happen, this includes both cooperation among states and among non-state actors. By examining the shared impacts across various sectors (agriculture, health, Energy and water etc.) and the existing and past regional cooperation to such impacts, this paper concludes the limitations on previous measures and provides various recommendations on avenues for future regional cooperation.

2. Observed and projected effects of climate change

Climate change is currently taking place at an unprecedented rate and is projected to compound the pressures on natural resources and the environment associated with rapid urbanization, industrialization, and economic development.

It will potentially have profound and widespread effects on the availability of, and access to, water resources. By the 2050s, access to freshwater in Asia, particularly in large basins, is projected to decrease.

2.1 Rising Temperatures

Rising Temperatures: Glaciers are the symbol of an inviolate environment and are visually and quantitatively among the most reliable indicators of climate change. Since the early 2000s, average temperature in the Himalayas has increased by about 1 degree Celsius, which is around four times the global average. Temperature rise is more during winter. Photo: Shailendra Yashwant for CANSA

According the International Centre for Integrated Mountain Development (ICIMOD)'s Hindu Kush Himalaya Assessment Report, in the future, even if global warming is kept to 1.5 °C, warming in the HKH region is likely be at least 0.3°C higher, and in the northwest Himalaya and Karakoram at least 0.7°C higher.[14] Warming in Nepal and on the Tibetan Plateau has been progressively greater with elevation and suggests that progressively higher warming with higher altitude is a phenomenon prevalent over the whole of the greater Himalayan region.

In many areas, a greater proportion of total precipitation appears to be falling as rain than before. As a result, snowmelt begins earlier and winter is shorter; this affects river regimes, natural hazards, water supplies, and people's livelihoods and infrastructure, particularly in basins such as the Tarim, which is dependent upon glacial melt in summer. The extent and health of high-altitude wetlands, greenwater flows from terrestrial ecosystems, reservoirs, and water flow and sediment transport along rivers and in lakes are also affected.

2.2 Precipitation Trends

Precipitation Trends: In the past decade, Himachal Pradesh has been witnessing an erratic, inconsistent, and decreasing trend of snowfall, besides a shift in the pattern of snowfall and precipitation, triggered by climate change. **Photo:** Shailendra Yashwant for CANSA

Observed precipitation trends over the HKH during last five decades are inconclusive. While the precipitation trends for the HKH are established but inconclusive over the past century, with some analyses showing that total and extreme precipitation has increased overall over the last five decades, intense precipitation has changed markedly since 1961: rising trends appear in the intensity of annual intense precipitation and also in the frequency of annual ntense precipitation day. Monsoon precipitation is projected to increase by 4–12% in the near future and by 4–25% in the long term. Monsoon precipitation is found to be the highest over the Siwalik and Pir Panjal ranges of the lower Himalaya, while it reduces northwards into the high Himalaya, Zanskar, Ladakh, and Karakoram ranges. Winter precipitation is projected to increase by 7–15% in the Karakoram, but to decline slightly in the Central Himalaya.[15]

2.3 Glacial Retreat

Glacial retreat : Climate change is already decimating mountain glaciers almost everywhere on earth at the rate of 3% every year. In India, Himalayan glaciers have lost about 10% of their volume in the past four decades. The Jemu Glacier, not very far from Lachen, has retreated by around 20 metres per year during 1975-90. **Photo:** Shailendra Yashwant for CANSA

Snow cover has reduced since the early 21st century, and glaciers have thinned, retreated, and lost mass since the 1970s, although the Karakoram glaciers have either slightly gained mass or are in an approximately balanced state. Snow-covered areas and snow volumes will decrease during the 21st century, snowline elevations will rise, and glacier mass is likely to decline with greater mass loss in higher greenhouse gas emissions scenarios.[16] The glacier shrinkage will speed up if the climatic warming and drying continues.

In the coming decades many glaciers in the region will retreat, while smaller glaciers may disappear altogether. Various attempts to model changes in the ice cover and discharge of glacial melt have been made by assuming different climate change scenarios. Regional scale studies show volume losses between -9 and -32% by 2030 under moderate warming scenarios (RCP4.5), and between -8.7 and -26.1% for higher-emission scenarios (RCP8.5).[17]

2.4 Runoff

Photo: Shailendra Yashwant for CANSA

One of the main concerns in relation to climate change in the Himalayan region is the reduction of snow and ice, which reduces the water storage capacity.[18] Initially, it is likely that the stable base-flow – derived from melting ice and snow – will increase, particularly during warm and dry seasons. It is not unlikely that this will appear as a positive, comforting sign, deterring, and delaying required emergency initiatives. However, as the far-away and high-altitude reservoirs of snow and ice continue to decrease, eventually disappearing, the variability of downstream runoff will increase, potentially dramatically, and progressively reflect direct rainfall-runoff, which in turn will mirror precipitation and evapotranspiration rates.

In Asia, climate change induced glacial melt could seriously affect half a billion people in the Himalayan region overall and a quarter of a billion people in China, who all depend on glacial melt for their water supply. In South Asia, hundreds of millions of people depend on perennial rivers such as the Indus, Ganges, and Brahmaputra – all fed by the unique water reservoir formed by the 16,000 Himalayan glaciers.[19] The current trends in glacial melt suggest that the low flow will become substantially reduced because of climate change. The effect of this on, for example, food production and economic growth is likely to be unfavorable.

2.5 Natural Hazards

Himalayan flash floods, Leh, India: A cloudburst is an extreme amount of precipitation, sometimes accompanied by hail and thunder that normally lasts no longer than a few minutes and causes flash floods that discharge a large amount of water in a small area in a very short time. Nearly 260 people died in the 2010 Leh floods. Due to climate change cloudbursts are becoming highly localized and are exponentially rising loss and damage to property and agricultural land. **Photo:** Shailendra Yashwant for CANSA

According to the United Nations International Strategy for Disaster Reduction (UNISDR), seven of the top ten natural disasters by number of deaths occurred in ICIMOD member countries. This indicates not only the prevalence of disasters in the region, but also the susceptibility of the region to such events. Climate change involves, perhaps most seriously, changes in the frequency and magnitude of extreme weather events. There is widespread agreement that global warming is associated with extreme fluctuations, particularly in combination with intensified monsoon circulations.

The HKH accounted for 21% (4,115 of 18,956) of the major disaster events recorded between 1980 and 2015 in the Em-DAT global database, and 36% of the major events in Asia. Floods and landslides are the most frequently occurring natural hazards, particularly during the monsoon season.[20]

Floods, both riverine and flash floods, are the most common hazards in the HKH and account for 17% of people killed and 51% of the damage. An increase in the frequency of high intensity

rainfall often leading to flash floods and landslides has been reported.[21] In the eastern and central Himalayas, glacial melt associated with climate change, has led to the formation of glacial lakes behind terminal moraines. Many of these high-altitude lakes are potentially dangerous. The moraine dams are comparatively weak and can breach suddenly, leading to the sudden discharge of huge volumes of water and debris. The resulting glacial lake outburst floods (GLOFs) can cause catastrophic flooding downstream, with serious damage to life, property, forests, farms, and infrastructure. In Nepal, twenty-five GLOFs have been recorded in the last 70 years, including five in the sixties and four in the eighties.[22] There is an indication that the frequency of GLOF events has increased in recent decades. In the HKH region two hundred and four glacial lakes have been identified as potentially dangerous which can burst at any time.[23,24]

Countries	Climate Risk Profile
Nepal	• Warming in Nepal is projected to be higher than the global average. By the 2080s, Nepal is projected to warm by 1.2°C–4.2°C, under the highest emission scenario, RCP8.5, as compared to the baseline period 1986–2005. The range in possible temperature rises highlights the significantly lower rates of warming expected on lower 21st century emissions pathways. • Rises in maximum and minimum temperatures are expected to be stronger than the rise in average temperature, likely amplifying the pressure on human health, livelihoods, and ecosystems. Temperature increase is expected to be strongest during the winter months. • Climate change is already having significant impacts on the environment in Nepal, species' ranges are shifting to higher altitudes, glaciers are melting, and the frequency of precipitation extremes is increasing. • Natural hazards such as drought, heatwave, river flooding, and glacial lake outburst flooding are all projected to intensify over the 21st century, potentially exacerbating disaster risk levels and putting human life at risk. • Modelling has suggested that the number of people annually affected by river flooding could more than double by 2030 as a result of climate change. At the same time the economic impact of river flooding could triple.
Bhutan	• While data are limited, historical records indicate an increase in annual temperatures of just under 1°C over the 20th century in Bhutan, with daily minimum temperatures increasing at a greater pace than daily maximum temperatures. • Projections of temperature rise in Bhutan are slightly greater than the global average: 3.9°C compared to 3.7°C by the 2090s under the highest emissions pathway, RCP8.5. • Flooding is the most significant climate-related hazard faced by Bhutan, with most of the country's agricultural land and infrastructure located along drainage basins that are highly vulnerable to heavy monsoon rains and glacial-lake outbursts. The impact of flooding on human health and livelihoods is expected to grow and could be 4% of GDP by the 2030s. • Climate models project a significant increase in the likelihood of heatwaves and droughts. These are likely to impact more severely on communities in Bhutan's lowlands. • Higher temperatures are projected to also contribute to increased snowmelt which could change patterns of river discharge and water availability. Impacts on infrastructure could grow significantly in the second half of the 21st century.

Countries	Climate Risk Profile
India	• Historical temperature rise in India has been slightly lower than the global average, however projections of future change are in line with, or slightly above, those expected globally. • By the end of the century, average temperature in India is projected to increase by 1.1°C–4.1°C over the 1986–2005 baseline, with the rate of warming dependent on the 21st century emissions pathway. • Projected temperature rises are strongest in the northern regions of India, and annual minimum and maximum temperatures are expected to increase at a greater magnitude than national average temperatures. • Disaster risk reduction and adaptation should be considered very high priorities in India in order to protect communities from the widespread and diverse increases in projected hazard intensities. • Intensification of climate extremes is projected in India, with increased drought risk, and increases in the quantity of precipitation during heavy rainfall events. • Without adaptation measures, extreme river floods are expected to affect an additional 13 to 34 million people by the 2040s and coastal flooding is expected to affect an additional 5 to 18 million people by the 2070s to end of the century
Pakistan	• Pakistan faces rates of warming considerably above the global average with a potential rise of 1.3°C–4.9°C by the 2090s over the 1986–2005 baseline. The range in possible temperature rises highlights the significant differences between 21st century emissions pathways. • Rises in the annual maximum and minimum temperature are projected to be stronger than the rise in average temperature, likely amplifying the pressure on human health, livelihoods, and ecosystems. • Changes to Pakistan's rainfall and runoff regimes, and hence its water resources, are highly uncertain, but an increase in the incidence of drought conditions is likely. • The frequency and intensity of extreme climate events is projected to increase, increasing disaster risk particularly for vulnerable poor and minority groups • An increase in the number of people affected by flooding is projected, with a likely increase of around 5 million people exposed to extreme river floods by 2035–2044, and a potential increase of around 1 million annually exposed to coastal flooding by 2070–2100.
China	• The projected temperature increases in China due to climate change is expected to be above the global average. The highest emission pathway (RCP8.5) projects an increase of average temperatures in China to rise by 2.5°C by the 2050s and 5.2°C by the 2090s; more significant temperature increases are expected in northern and western regions. • Increases in annual maximum and minimum temperatures are projected to be larger than the increase in average temperature, increasing the potential health, livelihood, and ecosystem risks of global warming. • The impacts of hazards and sustained changes will not be equally distributed, they will likely be experienced most strongly by marginalized and asset-poor communities. • Increased heat stress, compounded by the urban heat island effect, represents a major threat to human health, productivity levels, and energy demand in many of China's megacities. • Hazards such as droughts, floods, and heatwaves are all expected to increase in probability, and increased loss and damage will be difficult to avoid without significant adaptation efforts.

Source: ADB, Climate Risk Country Profile: Nepal, Bhutan, India, Pakistan, China

3. Impacts on livelihoods and the environment

Impacts on Agriculture : In the 2022-23 winter period (October-April), there was an overall reduction of about 14.05 % in the total area under snow cover in Himachal Pradesh in comparison to 2021-22. The reduction in snow cover is bad news for apple orchards of Himachal Pradesh. The temperate fruit requires a 90-day chill and snowfall of at least four to five inches. If there's less snow cover then the chilling hours' requirement for Apple would not be met and the incidence of pests and weeds would also increase, and eventually in the long run, apple crop's productivity and production will suffer.

Photo: Shailendra Yashwant for CANSA

Climate change has made the future of mountain indigenous people and their livelihoods more vulnerable and uncertain. The available scientific evidence suggests that climate change will place significant stress on the rural livelihoods of mountain people. Climate-related hazards have impacted human populations in many areas including agri-cultural production, food security, water management and public health. The level of impacts and coping strategies of populations depends heavily on their socio-economic status, socio-cultural norms, access to resources, poverty as well as gender.

Impacts and Vulnerabilities from Climate Change	
Agriculture and food security	• Increase in soil erosion • Increase in pests and disease • Reduced crop yields • Damage to crops and livestock • Increase in food insecurity • Loss of livelihoods
Ecosystem	• Increased incidence of pests and diseases • Increase in forest fires • Increased erosion of hillslopes • Depletion of wetlands and reduced fish stocks • Biodiversity loss • Loss of livelihoods
Water	• Increased water stress for agriculture and households • Decreased surface water and groundwater recharge • Reduced water quality • Reduced hydropower potential
Health	• Increased heat stress • Increased incidence of vector-borne diseases (malaria, Japanese encephalitis, kala-azar) • Increased incidence of waterborne diseases (cholera, diarrhea) • Increased incidence of injury from flooding
Infrastructure	• Damage to human settlements • Increased risk of injury or death • Displacement of populations • Damage to buildings and schools • Damage to roads, bridges, and transportation • Damage to water and energy supply systems
Tourism	• Loss of natural attractions • Decrease in ecotourism activities

Source: USAID, Climate Risk Profile: Nepal, Bhutan, India, Pakistan, China

3.1 Agriculture

Photo: Shailendra Yashwant for CANSA

Agriculture is a source of both income and food security. Increasing temperatures and water stress are expected to lead to a 30% decrease in crop yields in Central and South Asia by the mid-21st Century.[25] At high altitudes and latitudes, crop yields should increase because of reductions in frost and cold damage. It will be possible to grow rice and wheat at higher latitudes than is currently the case in China. Irrigated lowland agriculture, found in all of the large basins receiving their runoff from the Hindu Kush-Himalayan system, is projected to suffer negatively from lack of dry season water.

Considering that the reported or projected glacial meltwater component amounts to, for example, 20 to 40% in rivers in Western China, 50% or more in the Indus, and 30% in the major rivers in Nepal during the pre-monsoon season, the implications of dry season water stress are likely to be massive.[26,27] In addition, an increase in agricultural water demand by 6 to 10% or more is projected for every 1°C rise in temperature. As a result, the net cereal production in South Asian countries is projected to decline by at least between 4 to 10% by the end of this century, under the most conservative climate production projections.[28]

3.2 Ecosystems

Endangered ecosystems, Ladakh, India.: The Himalayas have a very fragile ecosystem and contain a series of climatically very different zones within short distances and elevations. They display a range of micro-habitats with great biodiversity. Mountain ecosystems are extremely sensitive to climate change and are beginning to show signs of fragmentation and degradation. Climate change has exacerbated the debilitating impacts of reduced forest cover, accelerated soil erosion, increased silting of water bodies, drying-up of springs and the disappearance of many . **Photo:** Shailendra Yashwant for CANSA

Changing climate impacts the main ecosystems (forests, grasslands, rangelands, wetlands, mountains, and agro-ecosystems). Increasing temperatures and rainfall variability have resulted in shifts in agro-ecological zones, prolonged dry spells and higher incidence of pests and diseases. An increase in the frequency and intensity of droughts can lead to forest fires; in 2016, fires impacted 50 districts and damaged 12,000 community forests in Nepal. Due to increasing drought, wetlands (especially in the Terai) have been depleted, resulting in destruction of aquatic plants and fish. Many species are at risk of losing habitat and water sources; some species may migrate.

Mountain ecosystems are sensitive to global warming and show signs of fragmentation and degradation.[29] Species in high-elevation ecosystems are projected to shift to higher altitudes, although alpine plant species with restricted habitat availability above the tree line are projected to experience severe fragmentation, habitat loss, or even extinction if they cannot move to higher elevations.[30] In the eastern Himalayas, forest vegetation will expand significantly; forest productivity will increase from 1 to 10%; and it is expected that forest fires and pests such as the North American pine-wood nematode (Bursaphelenchus xylophilus) will increase as dryness and warmth increase.[31]

3.3 Human Health

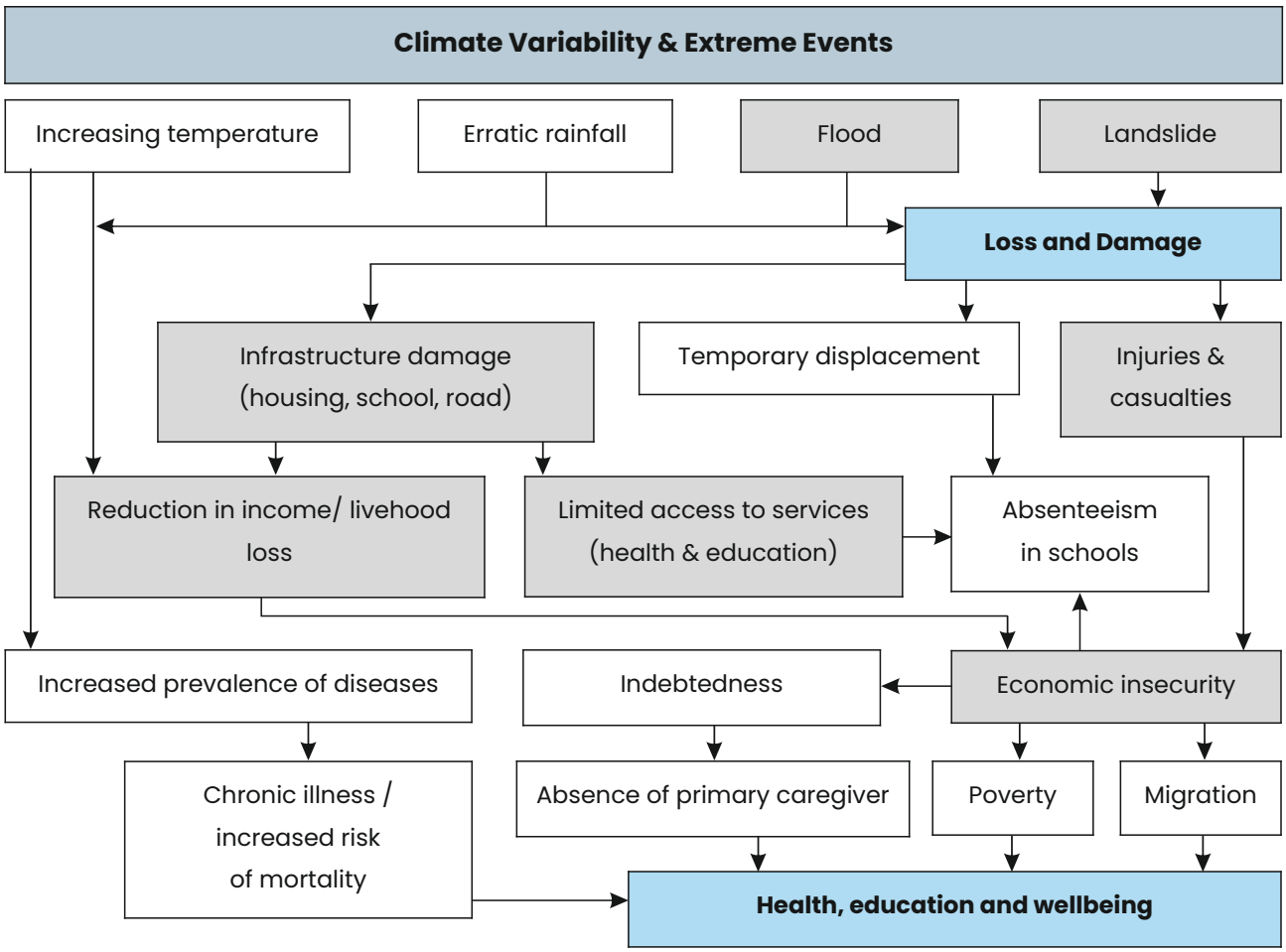
Human Health: Climate change is implicated in the geographical expansion of autochthonous cases of Vector borne diseases to non-endemics areas of high mountains in Nepal. The expanded spatial distribution and increased incidence of chikungunya and dengue over the last decades in the Himalayan region have been associated with climate change. Increasing number of confirmed cases of Japanese encephalitis in Himalayan highlands, which were previously confined to the lower southern plains, have also been linked with climate change. **Photo:** Shailendra Yashwant for CANSA

The impact of climate change on health conditions can be broken into three main categories: (i) direct impacts of for example, drought, heat waves, and flash floods, (ii) indirect effects due to climate-induced economic dislocation, decline, conflict, crop failure, and associated malnutrition and hunger, and (iii) indirect effects due to the spread and aggravated intensity of infectious diseases due to changing environmental conditions. The latter effect includes the expansion of vector-borne diseases such as malaria and dengue and water-related diseases such as diarrhoea. Regions such as the Hindu Kush-Himalayas, located at the fringe of the current geographic distribution of these and many other diseases, are particularity susceptible to the negative effect of rising temperatures. It is projected that the spread of malaria, Bartonellosis, tick-borne diseases and infectious diseases linked to the rate of pathogen replication will all be enhanced. Malaria mosquitoes have recently been observed at high altitudes in the region.[32] Endemic morbidity and mortality due to diarrhoeal disease associated with floods and droughts are expected to rise in East, South and Southeast Asia due to projected changes in the hydrological cycle. Empirical studies project that the population at risk of dengue fever will be larger in India and China. In these countries, a high increase in mortality due to heat stress is also projected.

3.4 Infrastructure

Photo: Shailendra Yashwant for CANSA

Valuable infrastructure, such as hydropower plants, roads, bridges, and communication systems, will be increasingly at risk from climate change. Entire hydropower generation systems established on many rivers will be in jeopardy if landslides and flash floods increase, and hydropower generation will be affected if there is a decrease in the already low flows during the dry season. A specific hazard related to glacier retreat are the formation of pro-glacial lakes and in some cases the events of glacial lake outburst floods (GLOFs). These can have a devastating effect on important and vulnerable infrastructure downstream such as hydropower stations. With climate change, the complexity and variability of river flow generation will both rise and become increasingly difficult to predict. For example, although the annual average proportion of meltwater in river flow has been estimated at 13% for rivers flowing to the Ganges from Nepal, from March through May the monthly average proportion is more than 30%.[33,34] This could have serious implications on river flows and water availability for power plants for about six months per year. The landmark Qinghai-Tibet Railway, built at a huge cost and associated with important development objectives, is partly built on permafrost. Projected widespread permafrost melting on the Tibetan Plateau can threaten future railway services.[35,36]



Efforts to reduce vulnerability and enhance the adaptive capacity of at-risk groups need to take a proactive approach that address the social processes leading to vulnerability and the structural inequalities that are often at the root of social-environmental vulnerabilities. Effective adaptation includes both the establishment of adaptive capacity (aware-ness, governance, and knowledge) and the adaptation itself (change of behaviour, practices, and livelihoods according to new conditions).[37] The scale of adaption may be local, national, or regional; the context of the adaptation will determine the type of adaptation (e.g., new farming practices in a rural context or water demand management in an urban context); and the approach to adaptation may focus on general poverty alleviation, enhanced transparency in decision making, or the empowerment of women, among other things. It should be noted that much of the adaptation to climate change will be found outside the sphere of natural sciences. For example, to focus only on flood-safe housing or new types of pest-resistant crops is not enough. The focus must include enhanced capacity to adopt (implying a comprehensive approach) new adaptation strategies.

As poverty is widespread in the Himalayan region, the empowerment of poor people to adapt to climate change is critical. Examples of adaptation at different levels may include good governance to mainstream climate change into development and institutional reform; general political reform and associated openness (ibid); health education programmes; and the development of early warning systems for floods, flash floods, and droughts.

4. Regional response to climate impacts

Photo: Shailendra Yashwant for CANSA

The effects of climate change across the Himalayan region are not contained within political boundaries but instead extend across borders, highlighting the transboundary nature of this issue. Due to the shared resource systems within the region, the impacts of climate change can have significant cross-border implications that may lead to political instability and conflict at the regional level.[38] Therefore, it is essential to adopt a broader perspective that encompasses eco-regions and transcends national boundaries to reverse or adapt to these impacts.

The challenges faced by the countries of the Himalayan region are common in nature, necessitating common approaches to address them. To achieve this, it is crucial to shift from national perspectives to a transboundary perspective that promotes greater cooperation among Himalayan countries. Adaptation to the impacts of climate change can be instrumental in this process and can benefit the region as a whole.

Although the upstream-downstream linkages between mountains and plains provide a strong foundation for regional cooperation, there are currently limited examples of cross-country adaptation projects or programmes in the Himalayan region. This lack of cooperation can be attributed, in part, to the region's political complexity and ecological fragility, making it one of the most challenging areas to implement transnational environmental governance.

To promote effective global environmental governance, regional or transnational cooperation has become crucial. However, it is yet to be seen in the Himalayan region due to the challenges posed by its unique political and

ecological circumstances. Nevertheless, given the significant cross-border implications of climate change across the Himalayan region, greater cooperation among Himalayan countries is vital to address this challenge effectively.

4.1 Regional Cooperation for Energy

Energy is one of the most important pillars of sustainable development. In South Asia, hydropower is one of the most important climate friendly sources of energy. With a potential estimated to be 500,000 MW, the region has abundant opportunities for hydropower development. Energy security can open opportunities for development and employment and contribute to the national GDP. Moreover, innovative solutions such as electric transportation and a clean source of domestic and industrial energy supply would significantly improve the deteriorating environmental condition of the region. Many countries in the region have been able to tap only a small fraction of their available potential. Out of the 42,000 MW potential reported in Nepal, only about 2% is harnessed so far, whereas Pakistan has harnessed 11% of its total potential. These countries are still energy deficient. South Asia's economies are developing fairly rapidly, but energy production has not kept pace with rising demand. More than one-in-four people in South Asia live without electricity. And more than 80% of people use wood or dung for cooking – lacking access to affordable alternatives.[39]

Transboundary cooperation in sectors like renewable energy will provide valuable economic resources for individual countries while also reducing carbon emissions across the region. For instance, one study found that hydropower investment in a South Asian transboundary river basin is projected to yield benefits that are 30 times the cost. In transport, trade, tourism, and infrastructure countries in the region can develop linkages and maximize the collective benefits from sustainable development.[40] Remote and topographically difficult, Ladakh, in northern India, has been an energy-deficient region. Ladakh Ecological Development Group (LEDeG) installed a 30kW micro-hydro power unit in Udmaroo village of Nubra Block, with support from the European Union, the Sir Dorabji Tata Trust and international NGOs. As a result, villagers now have domestic lighting and can use machinery for carpentry, flour-milling and oil-pressing, reducing drudgery and supporting incomes.[41]

The hydropower potentials are primarily concentrated in the mountain regions, but the major users of the energy are the urban areas and industries in the plains. Strong technical and political barriers separate those regions, which is one of the major reasons of slow progress in hydropower development. However, recent trends have shown some positive change. In the recent 18th SAARC summit in Kathmandu, the SAARC member countries signed a Framework Agreement on Energy Cooperation. This agreement has opened up the energy market in South Asia, and thereby possibilities for cooperation in the energy sector. However, it remains to be seen to what extent the collaboration would play a role in energy security.

4.2 Regional Cooperation for Food and Water

The connection between water and food is critical since both are essential for human survival and development. In the Himalayan region, agriculture is a significant contributor to

the GDP of countries. For example, in Nepal, it accounts for 35% of the national GDP. The Indus and Ganges river systems provide irrigation for over 300,000 hectares of agricultural land. However, ensuring access to water resources for food production and their sustainable management is a challenge that must be addressed from the local to national level. As the population grows amid rapid environmental and socio-economic changes, equitable access to vital resources has become a significant question. Efficient use of water resources for agricultural purposes, in which technological innovation plays a crucial role, is necessary for sustainable solutions to these problems.

Water plays a critical role in maintaining different ecosystem services in riparian areas, with freshwater ecosystems being highly dependent on the specific flow regime of rivers. However, the downstream areas' flow regime changes due to infrastructure development, impacting communities dependent on water resources for livelihoods such as fishing. Unfortunately, monitoring of the minimum flow requirement in the region is weak. Despite this, some bilateral programs, such as the Koshi River Watershed Management Programme between Nepal and India, have been implemented since the 1980s and 1990s to regulate water supply and minimize flooding. Afghanistan and Pakistan are currently negotiating a similar water-sharing agreement for the Kunar River in the Kabul Basin. The Ganges Water Treaty between India and Bangladesh and the Indus River Water Treaty between India and Pakistan focus mainly on ensuring the generation and sharing of power. Formal cooperation between China and India on transboundary water management remains limited.

Water resources are essential for irrigation, food, hydropower, sanitation, industry, and many important ecosystem services in the Himalayan region. As such, water directly contributes to the national GDP and to livelihoods and income generation at the local level. Although water is the foundation of sustainable development, water management in the Himalayan region remains fragmented and uncoordinated, and fails to consider relevant regional issues.[42]

4.3 Regional Cooperation for Disasters

The physical geography of the Himalayan region makes it susceptible to a range of water-induced hazards such as floods, droughts, landslides, and glacial lake outburst floods. Monsoon season floods cause devastation to both the mountains and the downstream plains, often crossing borders. Trans-boundary floods account for 10 percent of global floods, but result in over 30 percent of flood-related deaths and displace nearly 60 percent of affected populations. The region's social and economic context makes its inhabitants particularly vulnerable to natural disasters. However, a lack of comprehensive policy, governance mechanisms, and mitigation measures increase the region's vulnerability. Trans-boundary disasters such as riverine and glacial lake outburst floods emphasize the need for regional cooperation to mitigate their negative impacts. While small-scale bilateral flood risk reduction efforts exist in areas like the Ratu River between Nepal and India, they are insufficient in the face of increasing extreme weather events expected with climate change.[43]

The government of India announced a Coalition for Disaster Resilient Infrastructure (CDRI) at the

UN Climate Action Summit in September 2019.[44]

This has been envisaged as a global partnership that aims to promote resilience of new and existing infrastructure systems to climate and disaster risks. As of 2023, there are 31 members of the CDRI, and given the huge and transnational nature of disasters, it is crucial for international and regional cooperation to continue to identify new ways to address climate induced disasters and respond effectively.[45] This also requires using and sharing modern technology, innovation, and transparent communication across the member countries.

4.4 Avenues for cooperation

To enhance regional cooperation in the Himalayan region, it is important to look at successful multilateral cooperation mechanisms established in other mountainous regions around the world. The Arctic Council, Alpine Convention, and Carpathian Convention are examples of such mechanisms that could serve as models for the Himalayan region. These institutional mechanisms were created to promote environmental protection and sustainable development and have resulted in legally binding protocols and agreements on various issues.[46]

The Lima Adaptation Knowledge Initiative, implemented through the UNFCCC's Nairobi Work Programme in collaboration with UN Environment, has also taken steps to foster regional cooperation among vulnerable subregions by identifying priority knowledge gaps and soliciting partnerships to bridge these gaps. The Himalayan region could benefit from similar knowledge-based partnerships for adaptation.

These institutional mechanisms have helped countries in other mountainous regions to cooperate on environmental protection, cultural and natural heritage conservation, sustainable development, and climate change mitigation and adaptation. They have also provided formal mechanisms through which the regions' voices are unified and strengthened on the global stage. The Himalayan region can establish its own institutional structure and mandates tailored to the specific needs of its countries.

5. Conclusion

Photo: Shailendra Yashwant for CANSA

The Himalayan region is facing an urgent environmental crisis that demands immediate action. The estimated cost of climate mitigation and adaptation in the six Himalayan countries is staggering, with USD 1,085 billion needed for mitigation and USD 270 billion for adaptation.[47]

Regional experts have been calling for global support and collaboration to increase the resilience of the region, and a broad regional framework of cooperation that identifies specific opportunities for engagement would be a positive step forward.

The Himalayan region is home to one of the most dynamic and complex mountain systems in the world, which is extremely vulnerable to global warming. Although uncertainties about the rate and magnitude of climate change prevail, there is no question that climate change is already changing the ecological and socioeconomic landscape in the Himalayan region, particularly in relation to water. It is imperative to revisit and redesign research agendas, development policies, and manage-ment and conservation practices, and develop appropriate tech-nologies to mitigate carbon emissions. Adaptation and mitigation measures can create opportunities as well as offset the dangers of a warming planet, but they must be identified and adopted ahead of, rather than in reaction to, dangerous trends. Policies should be 'adap-tation friendly.' The private sector and citizens in the mountains must share the responsibility of mitigating carbon emissions, as elsewhere.

The urgency of environmental issues in the Himalayan region is further underscored by disasters such as recent floods in Pakistan and the 2017/18 floods in Nepal and India, which resulted in hundreds of deaths, as well as ongoing problems such as air pollution, erratic rainfall, heatwaves, and environmental degra-dation. To improve environmental governance in the region, four opportunities should be explored:

(1) Strengthening the interface between science, policy, and practice;

(2) Strengthening institutional capacity to implement new policies;

(3) Scaling up community-based environ-mental management systems by creating more enabling regulatory frameworks and appropriate local institutional arrangements; and

(4) Strengthening transboundary cooperation among the Himalayan countries. By prioritizing these opportunities, the region can move to-wards a more sustainable and resilient future.[48]

5.1 Recommendations

Lachen, Sikkim, India: Lachen, the home of Lachenpas, the indigenous people of north Sikkim is in grip of a climate calamity. Unseasonal rainfall, unusually stormy weather, landslides, receding glaciers, short winters, accelerated snowmelt, longer summers, fears of water scarcity, failed crops, mosquitoes, and a clear and present threat of a glacial lake outburst floods (GLOF). But the biggest worry for the Lachenpas is the barren patches on the Angden Lama peak (top left) that is a constant reminder of how climate change will change everything for them in the near future. "If there is water, there is a village, if not, there is nobody." is an old saying amongst the people of the Himalayas. **Photo :** Shailendra Yashwant for CANSA

5.1.1 Develop joint scientific programmes for climate change assessments

In order to effectively develop a climate change policy that includes both adaptation and mitigation measures, it is crucial to have access to credible and up-to-date scientific knowledge. However, the current state of research highlights a significant lack of field observations. To address this gap, it is essential to establish a strong scientific foundation in collaboration with government agencies and academia across the borders. Remote sensing technology presents an opportunity for regular and repeated monitoring of snow cover, particularly in regions such as the Himalayas, where countries like China and India can take the lead and share results with those lacking the necessary technological infrastructure. To achieve a comprehensive understanding of the situation, studies must utilize both ground-based and satellite-based monitoring. Global models often fail to adequately represent the Himalayan region due to their coarse resolution. As such, it is crucial to develop regional climate models with higher resolution to cover these "hotspots." These models should be run for shorter periods, around 20 years, to ensure the accuracy of the data.

Poly-house vegetable farming , Kawre, Nepal, In the Himalayas people's livelihoods are directly tied to the food, fodder, and fuel, provided by their environment. The local economy is characterized by persistent poverty, remoteness, limited accessibility to economic & employment opportunities. The changing climate and its effects on glaciers and forests and resulting water will affect the soil's moisture and the availability of water, which is likely to have a strong impact on food production. This will increase food insecurity, particularly amongst the poor and marginalized families. Poly-houses such as these are being promoted in Nepal by Center for Rural Technology (CRT) is helping farmers to grow vegetables in tunnels covered with plastic that protects the plants from extreme weather and ensures a bumper crop.

Photo : Shailendra Yashwant for CANSA

5.1.2 Supporting community-led adaptation

A promising approach to local level adaptation and vulnerability is to prioritize "bottom-up" community-led processes that draw upon local knowledge, innovations, and practices. The key is to empower communities to adapt to the changing climate and environment through their own decision-making processes and participatory technology development, with external support as needed. For instance, Tibetan nomads have already taken notice of the earlier spring and moved their yaks to alpine meadows earlier than usual. In the floodplains of Bangladesh, farmers construct homes on stilts, while Nepali farmers store crop seeds for post-disaster recovery. The most vulnerable groups, including women, the poor, and those living in precarious habitats such as along riversides and steep slopes, should receive priority attention. By prioritizing community-led approaches, we can better facilitate adaptation to the changing climate and mitigate vulnerability at the local level. By working collaboratively with communities, we can empower them to identify their own needs and craft tailored solutions, thereby promoting resilience and sustainability.

Photo: Shailendra Yashwant for CANSA

5.1.3 Facilitation of international policy dialogue and cooperation

Regional and international cooperation needs to advance in order to address the ecological, socioeconomic, and cultural implications of climate change in the Himalayas. The international community, including donors, decision-makers, and the private and public sectors, needs to be involved in regional cooperation ventures. This is of particular importance for achieving sustainable and efficient management of transboundary rivers.[49]

While transboundary landscape management initiatives are emerging and the age-old practices of trans-community collaboration at the community level are advancing, these collaborations are not directly endorsed or informed by formal treaties between the participating nations, and the small-scale transboundary activities are not strongly linkedto the larger processes of cooperation emerging at the regional level. One of the more important regional collaborative platforms with potential for improving collaborative gover-nance of natural resources is the South Asian Association for Regional Cooperation (SAARC). SAARC has identified environmental restoration, disaster risk reduction, and climate change as priority areas for regional cooperation, and the SAARC countries have collectively agreed that sustainable development and environmental management are the most significant issues in the region. Awareness and knowledge among stakeholders generally about the impacts of global warming and the threat to the ecosystem, communities, and infrastructure are inadequate. The media and academia together can play a significant role in public education, awareness building, and trend projection.

Photo: Shailendra Yashwant for CANSA

5.1.4 Knowledge-Sharing Platforms to Facilitate Regional Cooperation

The Himalayan region boasts diverse and rich experiences in environmental management that could potentially be shared across borders. Unfortunately, current practices tend to be isolated within individual countries and not widely disseminated across the region. To promote multi-scalar governance of the Himalayan region as a comprehensive eco-region, there needs to be a trans-community collaboration among local actors and vertical linkages between regional and local practices of resource governance across multiple countries. Due to the ecological complexity and political sensitivities of regional environmental gover-nance, multiple pathways and approaches for regional knowledge-sharing and policy engagement platforms need to be envisioned. These platforms could facilitate the develop-ment and implementation of common methodologies at the landscape level and shape common policy agendas. Documenting and sharing local-level good practices, such as those related to watershed management, poverty reduction, and community-based environmental management and climate change adaptation, would greatly enrich the regional knowledge-sharing platform and help establish a regional-level collaborative mechanism.

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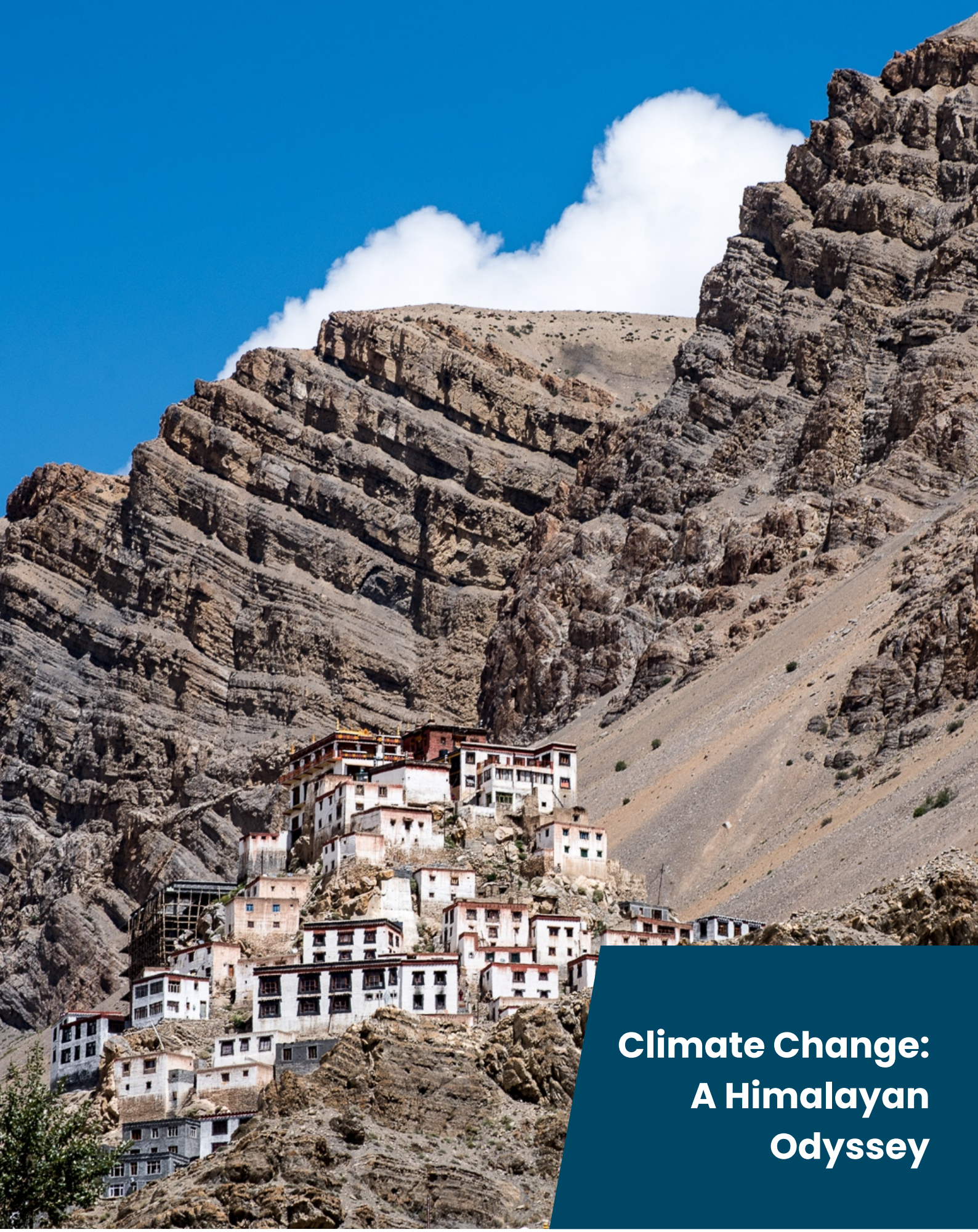

Climate Change: A Himalayan Odyssey

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