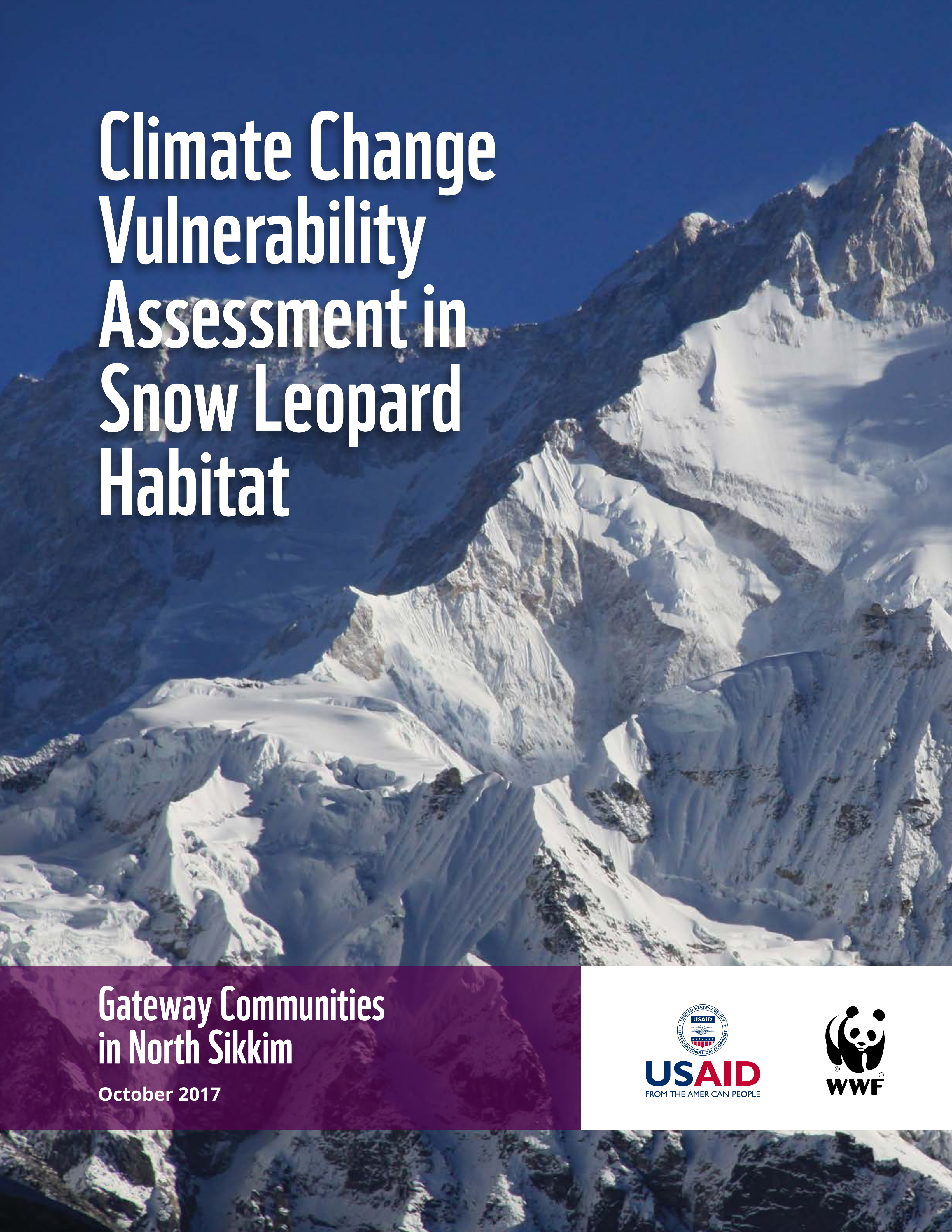

Climate Change Vulnerability Assessment in Snow Leopard Habitat

Gateway Communities in North Sikkim

October 2017

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Acronyms and Abbreviations

DAH	Department of Animal Husbandry
DFSAD	Department of Food Security and Agriculture Development
DLR Prerna	Darjeeling Ladenla Road-Prerna
DSTCC	Department of Science and Technology and Climate Change
ECOSS	Eco-Conservation Society of Sikkim
FAO	United Nations Food and Agriculture Organization
FEWMD	Forest, Environment and Wildlife Management Department
GLOF	Glacial lake outburst flood
GSDP	Gross State Domestic Product
HCCDD	Horticulture and Cash Crop Development Department
ICAR	Indian Council of Agricultural Research
IPCC	Intergovernmental Panel on Climate Change
KVK	Krishi Vigyan Kendra Agricultural Extension Center
LTDC	Lachen Tourism Development Committee
MoEFCC	Ministry of Environment, Forest and Climate Change
NTFP	Non-timber Forest Product
RMDD	Rural Management and Development Department
SAPCC	The State Action Plans on Climate Change
SARAH	Sikkim Anti-rabies and Animal Health Program
SPCB	State Pollution Control Board
STDC	Sikkim Tourism Development Corporation
TCAD	Tourism and Civil Aviation Department
USAID	United States Agency for International Development
WWF	World Wildlife Fund

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1. Introduction

India is considered to be highly vulnerable to climate change.

1.1 Background

Climate change is now considered to be one of the most persistent problems of the 21st Century. IPCC AR5 emphasizes that warming of the climate system is unequivocal and unprecedented. It threatens to bring about irreversible changes to the climate systems that have been stable for thousands of years and where humankind has flourished (IPCC, 2013). With increased evidence of a warming climate, the likelihood of disastrous damage to socio-ecological systems has also increased. From rising sea levels, melting glaciers, changes in rainfall patterns, species movements, extinction, etc., climate change brings with it unpredictable impacts and risks that our present social or even infrastructural defenses are inadequate to confront, raising critical environmental and development concerns.

With most aspects of climate change predicted to be persistent over many centuries even if CO2 emissions are stopped immediately (IPCC, 2014), mitigation and adaptation measures have become crucial to climate talks. While climate mitigation is defined as actions to limit the magnitude and/or rate of long-term climate change (IPCC, 2007a), adaptation is defined as the process of adjustment to the actual or expected climate and its effects (IPCC, 2007b). With impacts becoming more apparent, adaptation to climate change has become a necessity.

Rising temperatures, an increase in pre and post-monsoon rainfall together with an accompanying increase in relative humidity and a decrease in winter rainfall (Upadhya and Grover, 2012) have already impacted regional bio-physical and social systems but in spatially non-uniform ways. The observed trend of climate change impacts across various regions (mountainous, hilly and plains) requires an empirical basis to determine vulnerability. Mountainous regions where warming and its effects get magnified with changing altitude even over small distances are more vulnerable than other regions (Karki et al., 2009; Pathak, 2010; Shrestha et al., 1999; Shrestha and Devkota, 2010; Parajuli and Upadhya, 2016).

Mountain regions, which cover 25% of the world's land surface, are considered to be the main source of global water and a prime habitat for humans, wildlife, crops, trees and livestock. These regions directly support 12 percent of the world's population (FAO and Mountain partnership, 2014 and UN, 2011).

India is considered to be highly vulnerable to climate change. Wide-ranging adverse impacts

Lachen Village, Sikkim. WWF India

have been projected in India's climate sensitive Himalayan region, the North-Eastern region, the Western Ghats and the Coastal region. In response, India released a National Action Plan on Climate Change in 2008 with eight missions that highlighted solar, enhanced energy efficiency, Himalayan ecosystem, sustainable agriculture, sustainable habitat, water, green India and strategic knowledge. Following this, the State Action Plans on Climate Change (SAPCC) were also proposed and developed by various states along with state vulnerability assessments and plans to combat climate change. Sikkim released its plan in 2011 featuring strategies designed to take into account the likely vulnerabilities due to the projected climate change scenarios for the state.

1.2 Objectives

With this background, a vulnerability assessment exercise was undertaken with the purpose of gaining understanding on vulnerability to climate change in limited a geographic scope using desktop review, community consultations and an expert workshop. The vulnerability assessment focused on North Sikkim, in the upper catchments of the Teesta Basin around the villages of Lachen and Lachung, which are also considered gateway communities to snow leopard habitat. This exercise was conducted as part of the WWF Conservation and Adaptation in Asia's High Mountain Landscapes and Communities Project funded by USAID. This project is promoting transnational collaboration on climate-smart management of Asia's high mountain landscapes, enhanced climate adaptation, and water security practices for mountain communities throughout the snow leopard's range.

1.3 Methodology

The climate vulnerability assessment was conducted to understand the vulnerability of the target area in North Sikkim, India to climate change and development. WWF's landscape-level participatory climate vulnerability assessment method, Flowing Forward, was employed in this study (Le Quesne et al., 2010). This method measures vulnerability according to the Intergovernmental Panel on Climate Change definition, as a function of exposure, sensitivity, and adaptive capacity (Fig. 1).

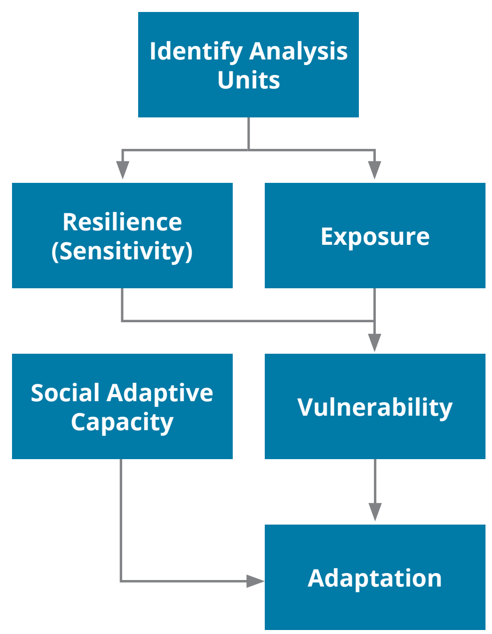


Figure 1. Vulnerability Assessment Framework under Flowing Forward

This study analyzes the factors that determine vulnerability of key human and natural systems within a landscape. The key objectives are to improve understanding of the drivers of vulnerability across these systems, prioritize the most vulnerable or resilient systems for action and propose initial actions to reduce their vulnerability or enhance their resilience to the impacts of climate change.

Figure 2. Participants involved in discussion during the expert workshop December 17, 2016, Gangtok, Sikkim. Photo: ©WWF-India/ Partha S. Ghose

This assessment process consisted of a desktop literature review as an important process to gather the necessary background information. Preliminary consultations with community members from the villages were organized to understand their perception of climate change impacts and the socio economic changes that were resulting from these impacts.

All this information was then presented during a final round of consultation with community members and relevant experts from various fields such as forestry, glaciology, wildlife, animal husbandry and tourism. An expert workshop was organized on December 17, 2016, in Gangtok to validate the already collected information, evaluate the resilience of key ecosystems and identify the adaptation options that would be useful to enhance the preparedness, adaptive capacity and resilience of vulnerable ecosystems (Fig. 2). For exposure, participants discussed and combined the impacts of climate change and development on the specific regions under the criteria of severity, extension and manifestation. To rank resilience, these criteria as defined in Flowing Forward were used: detrimental anthropogenic impact, natural variability, refugia, and connectivity (Le Quesne et al., 2010). The average was calculated, which gives the vulnerability score of the sub-unit. A quick assessment of the institutions and policies was also conducted to generate understanding of the adaptive capacity.

2. Project Site

Sikkim is a landlocked mountainous state, sharing international borders with the Tibet Autonomous Region of China, Nepal, and Bhutan.

2.1 General Site Background

Sikkim is a small mountainous state in north-east India that is situated between 27°00′ 46″ to 28°07′ 8″ N latitude and 88° 00′ 58″ to 88° 55′ 25″E longitude with an area of 7096 km^2. It constitutes only 0.22% of the total area of India. The length and width of the state are north to south for about 114 km with a maximum width of 64 km from east to west. It is a landlocked mountainous state, sharing international borders with the Tibet Autonomous Region of China, Nepal, and Bhutan.

Sikkim is rich in biodiversity, situated in the Eastern Himalayan biodiversity hotspot. It has a myriad of ecosystems, high floral and faunal diversity, abundant water resources, and good forest cover, with large climatic, topographical, and altitudinal variations within this small geographic area. It is one of the least populated states in India, with the population unevenly distributed across the state. Sikkim is divided into four administrative districts: North Sikkim, South Sikkim, East Sikkim, and West Sikkim, with North Sikkim the largest at 4226 km^2 (Fig. 3). North Sikkim is situated between latitudes 27°22′41.58″N and 28° 7′48.43″ N and longitudes of 88° 6′49.79″E and 88°53′10.34″E approximately and its elevation ranges from 600 to 8586 masl. It comprises almost 60% of the total area of the state but in terms of population it is the smallest with 43,709 inhabitants, although this represents triple the population since the 1970s (Fig. 4). Population density of North Sikkim is only 10 persons/km^2, whereas East Sikkim reports a population density of 297 persons/km^2 spread over 954 km^2.

Sikkim has one of the highest per capita incomes of any state in the country but also has the highest percentage figure below the poverty line, indicating highly uneven distribution of income. North Sikkim, which accounts for about 60% of the geographical area of the state, has lower development indicators than the East District. The North District has a literacy rate of 77.39%.

The vulnerability assessment exercise focused on the villages of Lachen and Lachung and their surroundings that fall under the Chungthang sub-division. Lachung (meaning Small Pass) village is located on both sides of the Lachung Chu River, one of the two main feeder rivers of the Teesta River. Lachen (meaning Big Pass) village is located on the right bank of the Lachen Chu, the other main feeder river of the Teesta. Lachen is situated at

Gurudongmar Lake, above Lachen village in Sikkim, WWF India

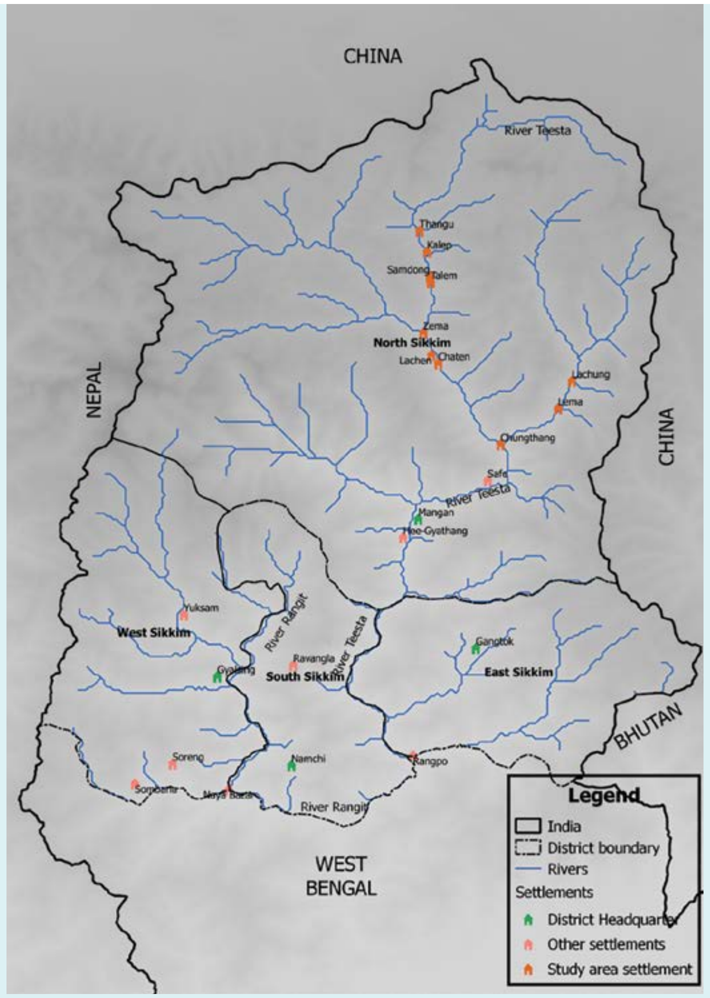


Figure 3. Map of Administrative Districts and major river basins in Sikkim

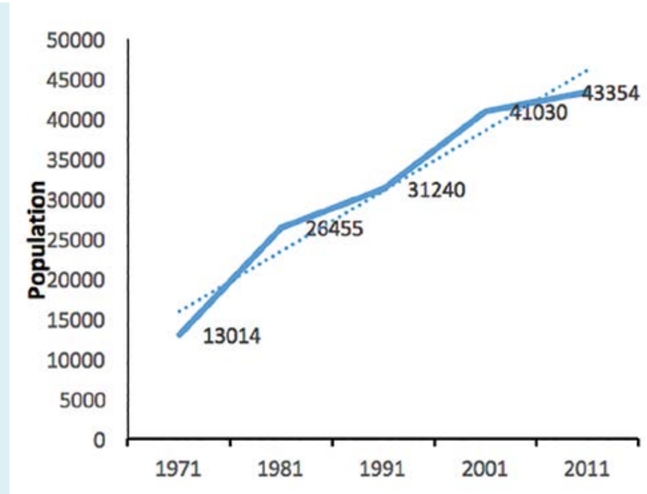


Figure 4. Decadal population status of North Sikkim. Source: Census of India 2011 and Government of Sikkim 2013

a latitude of 27°43'0.05" N and a longitude of 88°33'27.92" E, while Lachung is located at a latitude of 27°41'24" N and at a longitude of 88°44'45.6" E. Notably, the upper reaches of these areas support the key potential snow leopard habitat of the state and these villages are considered as gateway communities to these habitats.

2.2 Historical and Cultural Background

Lachen and Lachung are believed to have been settled in the early 17th century and their inhabitants are considered to be of Tibetan descent. Local people have a strong ethnic Bhutia identity and are followers of Tibetan Buddhism. In 2011, the total population of North Sikkim was 43,709, of which 39,065 were rural and 4644 were urban. The population of Lachen and Lachung villages was 1325 and 2495 respectively in 2011.

High above these villages in the Tso Lhamu Plateau, roam the semi-nomadic Dokpas, who have traditionally practiced pastoralism, moving with their yaks in the cold desert plateau area. The closure of the border towards Tibet around 1962 that led to loss of pastureland and changing lifestyles have led to a decline in this traditional livelihood option, and their numbers have been dwindling over the years.

Historically, both Lachen and Lachung were important trading posts along the inner Asian trade routes in the Eastern Himalayas. Lachen in particular was on a major trade route to Tibet. However, cross-border trade through these communities ceased with the closure of Tibet in the 1950s, which greatly impacted these communities due to the loss of both trade and livestock pastures in highland areas.

When Sikkim became part of India in 1975, it adopted the Indian administrative system. However, both Lachen and Lachung have a traditional local self-governance body called the Dzumsa, essentially an elected village council (see Box 1). Both village dzumsas function similarly and are responsible for all development and natural resource management activities as well as social justice within their respective villages.

2.3 Livelihoods

Both settlements are culturally similar and have traditionally followed agro-pastoralism-based livelihoods. In summer, Lachenpas (residents of Lachen) usually shift northward about 20 km to the settlement of Thangu for their farming activities, as arable land is limited in Lachen. They mainly cultivate potatoes, radishes, peas, and leafy vegetables. Some herders move further north to alpine areas of North Sikkim to rear livestock, primarily cows, dzo (yak-cow hybrid), yaks, and sheep. After harvest and the onset of winter they return to Lachen village.

In Lachung, however, farmland is available within the vicinity of the village. Crops cultivated in Lachung include wheat, barley, potatoes,

Box 1. **Dzumsa**

***Dzumsa*, literally meaning gathering place,** **is the traditional local governance system for Lachen and Lachung. Equivalent to the Gram Panchayats (village council) in other Indian villages, the dzumsa has management and administrative control over the village. Dzumsa consists of two Pipons or village heads, five to six members from the local community known as Chultrimpa, and five to six members from the monastery known as Gyambo. This body of people are elected annually through a democratic process by members of the public who are eligible to vote. Each household in the village is an integral part of the dzumsa system, and are expected to follow the decisions made by the council members.**

The dzumsa system is based on the principle of equity and plays a pivotal role not only in natural resource management but also in livelihood activities and all socio-cultural aspects of the village. The dzumsa makes all decisions regarding the extraction of timber, fuelwood, stone, sand, collection of medicinal plants, etc. The council also determines the agricultural calendar dates for activities such as sowing, harvesting, collection, etc., in accordance to the Lunar calendar, and also determines the herding calendar.

All members in the village are expected to follow the dates set, which ensure that people are not involved unnecessarily or competing, and community unity is maintained. Failing to do so can have dire consequences for the people such as harsh monetary fines or social boycott. While participation of women has been generally weak in dzumsas, this trend has been changing with more women now participating in dzumsa programs.

Table 1. **Land use pattern of North Sikkim**

S.No	Land utilization	Area (ha)
1	Total area of North Sikkim District	422,600
2	Cultivable area	112,310
3	Forest area	227,000
4	Land under non-agricultural use	15,230
5	Permanent pastures	12,090
6	Barren and uncultivable land	61.2
7	Fallow land	55,970

Source: HCCDD, and FSADD (Annual reports 2011-12)

and cabbage. Lachung also has lucrative apple orchards, and apples are sold as a cash crop. A considerable number of Lachungpas (residents of Lachung) also follow traditional yak, sheep, and cattle herding practices.

The land use pattern of North Sikkim is divided into cultivation areas (112,310 ha), forest areas (227,000 ha), land under non-agricultural use (15,230 ha), permanent pastures (12,090 ha), barren and uncultivable land (61.2 ha), and current fallows (55,970 ha). Gross irrigated area is 8500 ha and rain fed area is 103,810 ha (District agriculture plan 2009).

Non-timber forest products, such as bamboo, medicinal plants, fodder plants, and edible plants,play a significant role in daily life in these villages. Bamboo is used for thatching, weaving articles such as baskets for daily use, and also occasionally as an alternative to fuel wood. Fodder species such as different varieties of grasses are procured regularly from forests adjacent to the villages for stall-feeding cattle and domesticated goats and sheep. Medicinal plants such as satuwa (*Paris pollyphylla*) kutki (*Picrorhiza kurroa*), common woodworm or mugwort (*Artimesia vulgaris*), bikhma (*Aconitum* sp.), and caterpillar fungus (*Ophiocordyceps sinensis*) among others are used regularly by the communities for traditional medicinal purposes. Additionally, the plants of high medicinal value, such as satuwa and caterpillar fungus, are procured and marketed by the communities to boost their income. Communities of Lachung earn between INR 1000 to INR 300,000/year by selling species such as satuwa and caterpillar fungus to buyers from outside the state.

Over the years, there has been a clear shift in both Lachen and Lachung communities to tourism as their primary source of income. More than 50% of the families are now engaged in the tourism sector or allied activities.

Figure 5. A panoramic view of temperate forest dominated by silver fir (*Abies* sp.). Photo: ©WWF-India/Partha S. Ghose

2.4 Forests and Biodiversity

Forest ecosystems types by elevation in the study area of North Sikkim include upper temperate broadleaf forests (2400m–2800m), mixed conifer forests (2800–3200 m), sub-alpine forests (3200m–4000m) and alpine scrub meadows in higher areas (4000m–5500 m). The region is also known for its unique mix of rhododendron species and rare mammals such as the red panda and snow leopard. Below is a brief description of the goods and services that ecosystems in North Sikkim provide and the role biodiversity plays in providing these services.

Temperate oak forest, mixed conifer forest, sub-alpine forests and alpine scrub meadows in the higher reaches characterize this landscape (Fig. 5). Sub-alpine and temperate forests are important for being the recharge area for countless mountain springs that are the main sources for water in the villages. The forests provide fuel wood, non-timber forest products (NTFP), and building materials for the communities. They form important habitats for key species such as red panda and Asiatic black bear and are diverse in flowering plants such as rhododendrons, magnolia, etc.

Alpine meadows and scrublands that serve as pastureland for herding communities are sources of water, and form habitat for blue sheep and snow leopards (Fig. 6). These alpine meadows hold immense cultural importance for the local population, attract tourists for their natural beauty, and provide opportunities for adventure sports. Alpine meadows, which lie above the tree line but below the snow line, function as “sponges” by absorbing melting snow and acting as natural water towers.

Figure 6. A panoramic view of alpine meadows at Jachu Valley, North Sikkim. Photo: ©WWF-India/Partha S. Ghose

Figure 7. Road construction is one of the major developmental activities of North Sikkim. Photo: ©WWF-India/Partha S. Ghose

Two important Protected Areas of the state are located close to the villages of Lachen and Lachung. Khangchendzonga National Park, which is the largest PA, covers 1784 km^2 and its boundary is close to Lachen. Lachung is located in close proximity to the Shingba Rhododendron Sanctuary. Both are popular destinations for nature lovers and the forests are home to a wide diversity of flora and fauna that attracts tourists.

2.5 Hydrology

The upper catchment of the Teesta River basin forms a vast network of interconnected glaciers, glacial lakes, and river systems. A myriad of streams and rivers originating in the high altitude areas all flow downstream into the Lachen and Lachung valleys, meeting further south in Chungthang to form the Teesta River. The river's source lies in the glacial lake Khangchen Tso at an elevation of 5280 m and is fed by the Teesta Khangshe glacier, where it originates as Chhombo Chhu. The high altitude wetlands of Tso Lhamu and Gurudongmar also flow into the same rivulet as does the stream from Zemu glacier. North district is the hydrological estate of Sikkim as it holds a pivotal position in controlling the water regime in the entire Teesta basin (MOEF, 2007 now has changed to MOEFCC).

2.6 Development impacts

Since 1975, the road network has slowly and steadily expanded throughout the state and both Lachen and Lachung have been connected by road. However, heavy rainfall for several months per year, poor maintenance, and an increasing problem of landslides often disrupts this connectivity.

More than 64% of the population depends on agriculture. However, the share of agriculture and allied activities in Gross State Domestic Product (GSDP) has been gradually declining from 38.36% in 1993–1994 to 29.78% in 1999–2000. The secondary sector has been the fastest growing sector, at 13% of GSDP between 1999–2000 and 2007–2008. It is driven mainly by construction and hydroelectric power generation.

Sikkim has been exploiting its huge hydro power potential and at present, the total installed capacity of the state is 95.70 MW. Total hydro-power potential in the state is 5352.7 MW. The largest state project, at Chungthang village on the Teesta River, has recently been commissioned, but Lachen and Lachung villages have so far resisted the possibility of harnessing hydro power through their traditional governance institution, the Dzumsa. This is because the Bhutias of Lachen and Lachung consider water bodies to be scared, and thus rejected proposals to construct dams in their area. The concerns raised by the respective Lachen and Lachung dzumsas have included disrespect of the river systems, an influx of migrant workers from outside the state, environmental hazards, and socio-cultural disintegration. In general, cutting through the mountains goes against their local belief systems of maintaining the integrity of the land and the river. Educated youth and environmentally conscious people in Lachen and Laching mobilized to raise the awareness of the rest of the communities about the negative impacts of dams. Consequently, authorities in both villages have opposed dam building. Residents of Chungthang who permitted a dam to be built, have suffered from noise pollution, increased landslides, traffic jams, an influx of laborers, and insufficient compensation. Additionally, the 2011 earthquake caused tunnel collapses, increasing human causalities. In the future glacier lake outburst floods (GLOFs) could potentially damage the dam/area further and likely threaten lives further downstream. Consequently, dam construction has yet to commence in Lachen and Lachung villages.

Due to the international border with China on the northern and eastern boundaries of North Sikkim district, there is a large border patrol presence, which has been a major stress on the high altitude ecosystems. The region has witnessed steady expansion of the number of border patrol camps and accompanying infrastructure, including the steady expansion of the road network, which has both improved connectivity for the local people and facilitated tourist arrivals (Fig. 7).

Tourism has become one of the mainstays of Sikkim's economy, including in North Sikkim. During the 1980s, tourist arrivals showed only small growth but from the early 1990s tourist numbers have increased sharply every year. While tourism has brought economic benefits for the community, the environmental impact has grown rapidly in the 2000s, leading to heavy urban expansion and a rise in hotel construction in the villages of Lachen and Lachung. Tourism has brought a steep rise in vehicular movement, growth, and issues of waste and pollution. As seen across the state of Sikkim, the declining trend of agriculture is seen also in these villages.

Certain practices of the communities such as over extraction of resources for profit, introduction of new varieties of plants and livestock, and loss of traditional knowledge also pose threats to biodiversity. In particular, a decline in use and knowledge of local medicinal plant species may be leading to a decline in protection and management of these species. However, loss of traditional knowledge has also resulted in certain species no longer being exploited for food and rituals.

The Lachen and Lachung valley are also prone to disasters, so much so that the Lachung village has been relocated three times in the past. The community noted two notable events, the first being the GLOF near Muguthang, about 25 km northwest of Lachen, that occurred in 1965 ,which led to massive destruction in Lachen. A similar GLOF event was reported from Sebu Chho Lake, located about 28 km north of Lachung, which occurred prior to 1965, as evidenced by the eroded moraines in the Sebu Chhu valley, attesting to a past breach of the lake moraine dam (Kumar and Prabhu, 2012). The September 18, 2011 Sikkim earthquake also triggered massive landslides some that are still active, which cause loss of property and occasionally human lives.

To summarize, the main threats to biodiversity in North Sikkim include infrastructure development, such as roads and border patrol camps, tourism, and a decline in awareness of the importance of local biodiversity.

3. Climate Trends and Projections

Its extreme altitudinal variation has a huge influence on the climate of Sikkim.

3.1 Climate change and its impacts

Its extreme altitudinal variation has a huge influence on the climate of Sikkim. However, the long-term data acquired from ground stations that measure air temperature, precipitation, humidity, and snowfall are not available for North Sikkim. Nevertheless, an examination of climate change and its impact in North Sikkim can be compiled from modeled historical climate data for North Sikkim, research findings from remote sensing satellite data, and community and expert observations.

Based on modeled historical meteorological data from the India Water Portal, annual mean minimum, annual mean maximum, and annual mean overall temperature in North Sikkim have increased by about 0.8, 0.6, and 0.7 °C, respectively, between 1901 and 2002 (Figs. 8–10). Warming over the 20th century was greater during winter months, from December to April (about 1.0° C) than during summer months of June to September (about 0.2° C).

The difference could relate to the snow and ice feedback phenomena in the North Sikkim mountain climate, with less ice and snow cover in winter resulting in warmer winter temperature (Basnett et al., 2013). Similarly, the range of deviation for annual mean maximum and annual mean overall temperature from the 102 year average for the 1901–2002 reference period was -1.1 to 1.1° C, -0.9 to 1.1° C and -0.9 to 1.1° C, respectively (Figs. 8–10). Notably, the greatest rate of warming has been observed since the early 1980s. An analysis of the 22-year period from 1981–2002 shows an increase in the annual mean minimum, maximum, and average temperature of 1.02, 0.8, and 0.8° C, respectively with respect to the 102 year average for the 1901–2002 reference period.

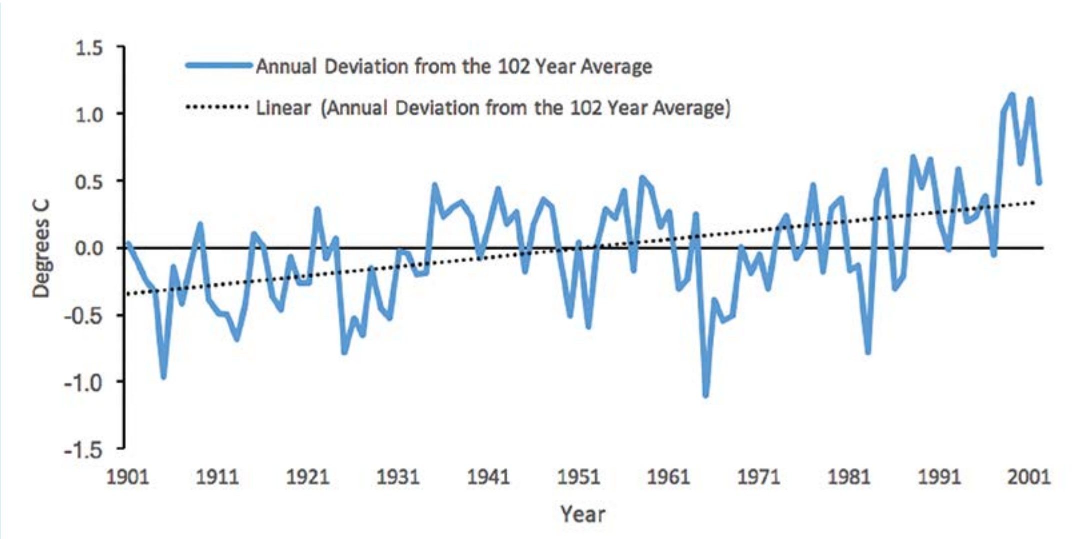


Figure 8. Deviation of annual mean minimum temperature from the 102-year average based on modeled data for North Sikkim for the 1901–2002 reference period

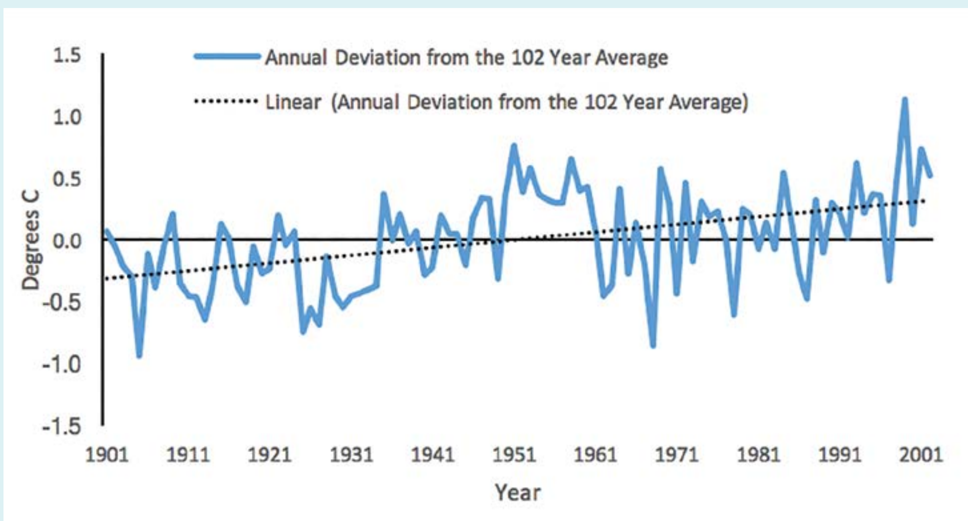


Figure 9. Deviation of annual mean maximum temperature from the 102-year average based on modeled data for North Sikkim for the 1901–2002 reference period

The modeled precipitation data for the 1901–2002 reference period in North Sikkim do not indicate a distinct trend towards drier or wetter conditions in the district (Fig. 11). However, the total amount of annual rainfall is estimated to have decreased slightly in North Sikkim over the this 102 year period. This is consistent with the findings of the State Action Plan on Climate Change for Sikkim (SAPCC, 2011). SAPCC reported that total annual rainfall has decreased by around 250 mm during the period 1983 to 2009 in Sikkim state.

Winter rainfall is decreasing and in recent years the state has experienced variable onsets of monsoons, erratic rainfall in monsoon periods, and rain in short intense bursts, with monsoon periods extending into autumn. From 2008 to 2009, the state witnessed one of the driest winters in living memory (SAPCC, 2011). According to Bawa and Ingty (2012), and Basnett et al. (2013), North Sikkim faces increasing minimum and average temperature, a shift in timing of snowfall, a decline in snowfall amount, an expansion of old lakes and formation of new lakes and glacier retreat. Further, Telwala et al. (2013) observed that

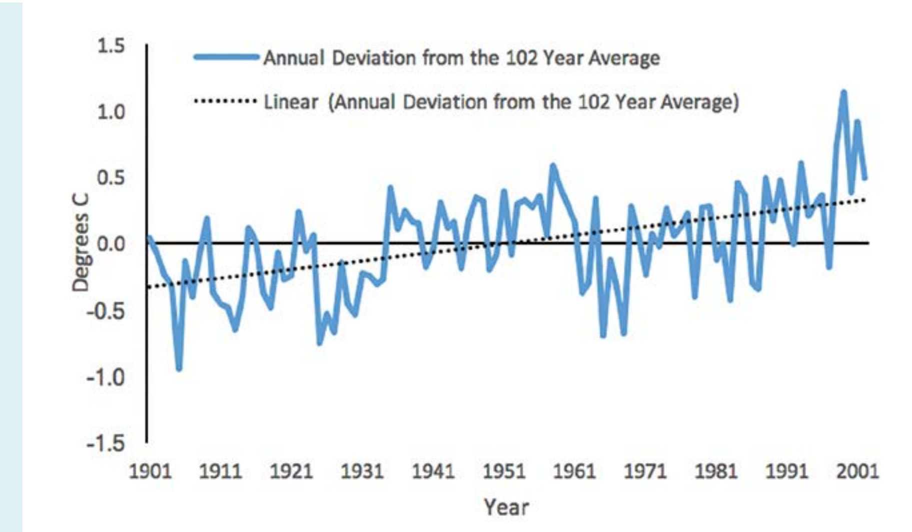


Figure 10. Deviation of annual mean temperature from the 102-year average based on modeled data for North Sikkim for the 1901–2002 reference period

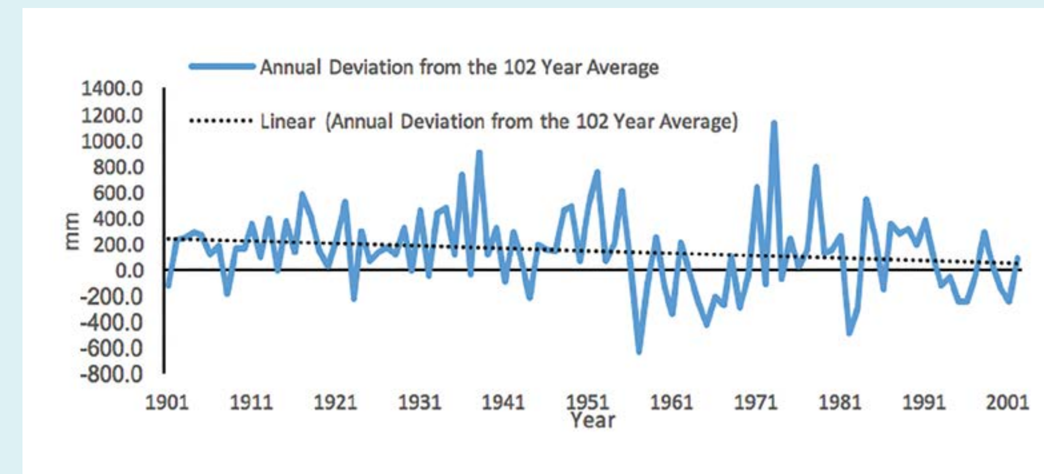


Figure 11. Deviation of annual total precipitation from the 102-year annual mean based on modeled data for North Sikkim for the 1901–2002 reference period

mean temperature in Lachen and Lhonak valleys in 2010, when compared to 1850, increased in the summer and winter months by 0.76 ± 0.25° C and 3.65 ± 2° C,, respectively.

Perhaps the biggest challenge of warming due to climate change in the high altitudes lies in the melting glaciers and the negative impacts this is likely to have on the freshwater systems. Rapid melting of certain glaciers in high altitude areas in Sikkim has increased significantly over the last 50 years (Kumar et al., 2012).

The community consultation echoed the science. According to them, glaciers have significantly receded and there is less snow in the winter months. Previously more than 3– 4 feet of snow was recorded, currently it's barely 1–2 feet. Most mountains surrounding the villages that were snow-bound throughout the year are now without snow cover from June to August or early September. In many parts of the Himalayas, as in Sikkim, the number of glacial lakes has also increased. Increases in water volume enhance the risk of GLOFs. Gurudongmar, Khangchung Cho, and Tso Lhamu are said to be increasing in total area

(Kumar et al., 2011). According to Kumar et al. (2011), the lakes at the terminus of the Gurudongmar glacier have increased recently when compared to 1965. Kumar et al. (2011) also reported that the Khanchung Chho and Chho Lhamo lakes that feed the Teesta has grown significantly, indicating the possibility of GLOF events in the region.

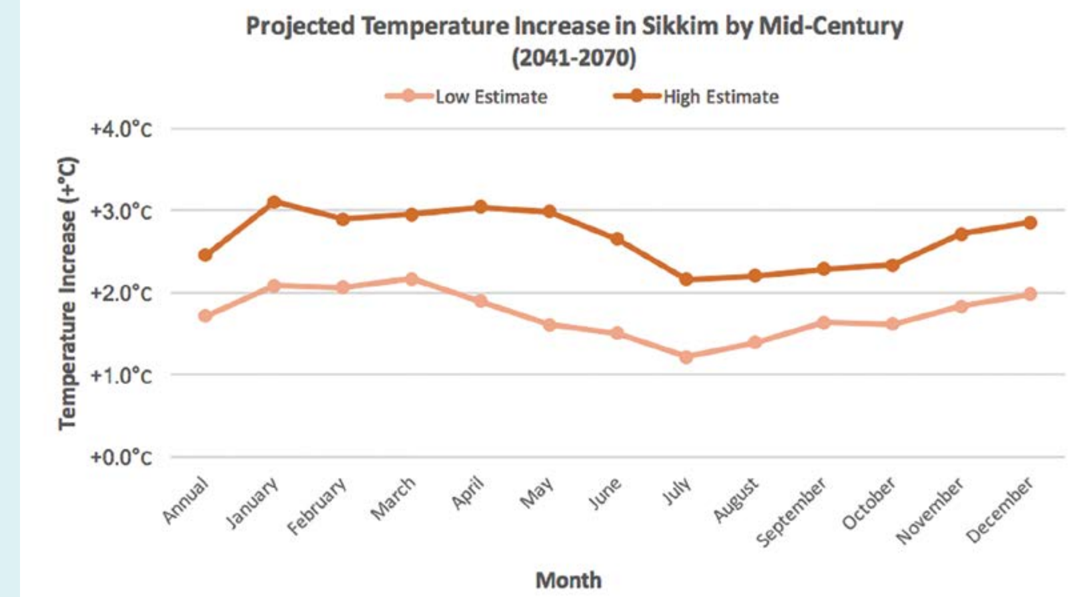
Community members reported that in recent years some of the wetlands had dried up significantly. The primary role of these wetlands is to provide water to both valleys and at lower elevations. Any changes ecologically could have direct impacts to freshwater systems in the state of Sikkim, since Teesta has its source in these upper reaches.

Though drying of springs are reported from other parts of the state, as of now, there has been no significant change in water availability in both the Lachen and Lachung villages, but this is because of the multiple sources of water available. However, no studies have been done to map springs hydrology in these areas.

Globally, there has been upward migration of species during the last century (Walther et al., 2005) and the warming of the Sikkim Himalaya could have resulted in an upward migration of the range margins of certain plant and animal species (Telwala, 2012). With warming trends continuing, forests are likely to expand upward in elevation but also could be threatened by new pest outbreaks with warmer temperatures. Fragmentation of the upper broadleaf forests due to development activities is already happening; however, no studies on biodiversity or genetic diversity loss have been undertaken. Changes in species composition and decreasing productivity of alpine grasslands have been reported (Sharma et al., 2009) in certain Himalayan alpine regions. This was corroborated by the interaction with the locals, who also pointed out that the grazing pastures are rapidly drying up. The quality of grass has decreased, mainly due to less snowfall. Additionally, expanding border patrol infrastructure and presence has decreased movement and pasturelands.

While specific phenological changes were not reported in the community consultation, S.T Lachungpa et al. (2011) reported Nepalese alder (*Alnus nepalensis*), which usually occurs within an elevation range of 1800–2100 m, is now found in the Lachung valley at more than 3000 m. Certain phenological changes in rhododendron blooms were also reported. Some birds, insects, mammals, and plants are already showing changes in their geographic distribution and have moved northwards or to higher altitudes in response to the changing climatic conditions in Sikkim. Increasing evidence shows that many species within the northern limit of their range, currently in the tropical and subtropical regions in Sikkim, are expanding further north and onto higher ground. For example, the Himalayan keelback snake (*Amphiesma plateceps*) usually occurs between 1500–1800 m while the rosebelly worm-eating snake (*Trachischium guentheri*) is generally found from 900–2100 m, but now have been observed in Sikkim at 2600 and 2700 m, respectively (Acharya and Chettri, 2012). In contrast, the southern limits of some cold-adapted species may be pushed further northwards and upwards in elevations as temperature increase (SAPCC, 2011). Due to limited space in a shrinking alpine zone, some species like the snow leopard may be adversely affected by alpine habitat fragmentation as forest species move upslope (Forrest et al., 20012).

Figure 12. Projected range (low to high estimate*) in annual and monthly temperature increase (°C) in Sikkim by mid-century in reference to the 1980–2005 baseline (also see Appendix 1). ***Note:** The low estimate refers to the 25th percentile of the 42 model outcomes under the RCP4.5 and RCP8.5 greenhouse gas emissions scenarios. The high estimate refers to the 75th percentile of the 42 model outcomes under the RCP4.5 and RCP 8.5 greenhouse gas emissions scenarios.



3.2 Projected climate

Very limited information is available for North Sikkim to project climate change in the future and its impact. The projections discussed below are therefore based on the future scenario for Sikkim as a whole, and the same projection is used to mirror trends for North Sikkim (Peters et al., 2017).

3.2.1 Temperature Projections

For the 1980–2005 reference period for Sikkim's current climate, mean monthly temperatures have averaged about 14°C. This temperature ,is used as the model baseline for the climate scenarios discussed below (Peters, et al., 2017). The coldest months of the year occur between December and February. From March to May, temperatures begin to warm, and as a result snow begins to melt, providing water for ecosystems and people. June to September are the warmest months and include the summer rainy season, and in October temperatures begin to cool and snow begins to accumulate again in the mountains.

As a result of climate change, annual temperature is projected to increase over the course of the coming decades, as predicted by an average of 21 climate models under IPCC scenarios RCP 4.5, an intermediate emissions scenario followed by stabilization, and RCP 8.5, a high emissions scenario (IPCC 2014). For the time period from 2011–2040 (near-term), annual average temperature is likely to increase by 0.8˚C to 1.2˚C above the baseline, and for the 2041–2070 (mid-century) the average temperature is projected to increase by 1.7˚C to 2.5˚C for the two scenarios, respectively (Peters et al., 2017, Appendix 1).

While all months are projected to see increases in average temperature throughout the year, the cooler months between December and March are likely to see slightly greater

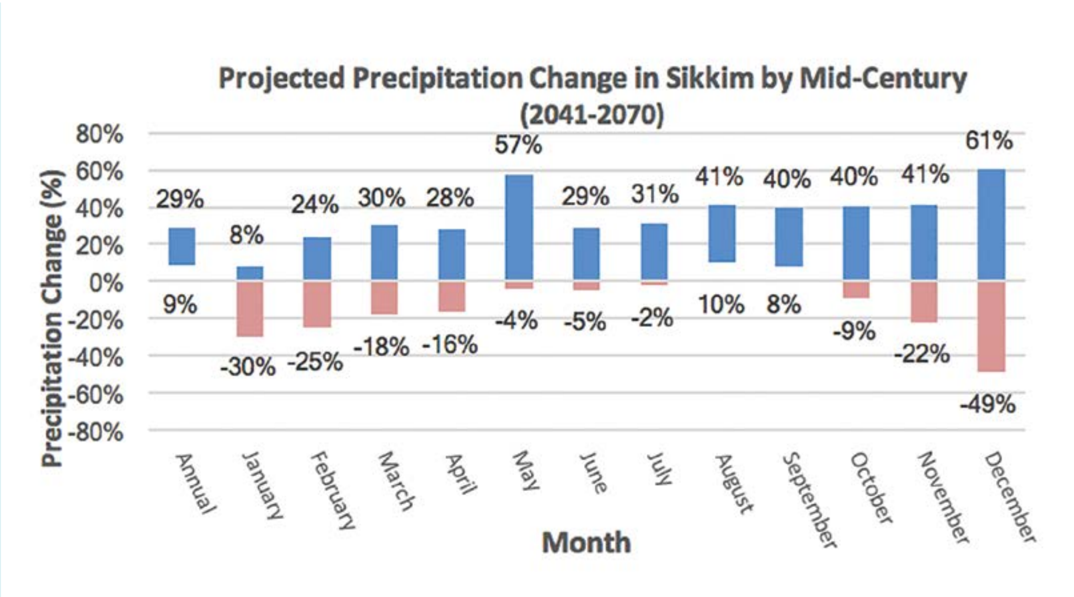


Figure 13. Projected range (low to high estimate*) in annual and monthly precipitation change (%) in Sikkim by mid-century in reference to the 1980–2005 baseline (also see Appendix 1). ***Note:** The low estimate refers to the 25th percentile of the 42 model outcomes under the RCP4.5 and RCP8.5 greenhouse gas emissions scenarios. The high estimate refers to the 75th percentile of the 42 model outcomes under the RCP4.5 and RCP 8.5 greenhouse gas emissions scenarios

magnitude of warming than in the warmer months. The highest projected warming trend occurs in March, where a 1.1˚C to 1.5˚C increase above average is expected in the near-term and a 2.2˚C to 3.0˚C increase by mid-century (Fig. 12). It also appears that the warming trend in January will increase the monthly baseline temperature by 0.9°C to 1.6˚C above historical temperatures in the near-term, and between 2.1°C and 3.1˚C by mid-century (Fig. 12) (Peters et al., 2017, Appendix 1). Warmer spring and autumn may result in changes to the freeze-thaw cycle, with snow melt occurring earlier in the year and snow accumulation after the summer occurring a few weeks later.

3.2.2 Precipitation Projections

The model baseline for the 1980–2005 reference period shows that the Sikkim region received an annual mean total precipitation amount of about 182 cm per year during this period, the majority occurring between the months of April and October. November to February are the driest months, and March and April typically experience small amounts of precipitation.

In the near-term (2011–2040), Sikkim is projected to see an annual precipitation increase of 5–17% above the annual baseline. By mid-century (2041–2070), total annual precipitation is projected increase by 9–29% above the model baseline (Fig. 13) (Peters et al., 2017, Appendix 1). While the total annual rainfall is projected to increase with a warming climate, as with temperature, these changes in rainfall are expected to have a high degree of seasonality. Precipitation is projected to increase during the wettest months of the year, but change in precipitation during the drier months, whether an increase or decrease, is uncertain.

In the rainiest months of May through October, it appears likely that monthly precipitation will increase overall. The greatest future increase is expected in May, by up to 47% above the baseline in the near-term, and by up to 57% through mid-century (Fig. 13) (Peters et al., 2017, Appendix 1). The second rainiest month, August, is also projected to see an increase in precipitation.

Months that historically receive less precipitation are, in general, equally likely to see an increase or decrease in rainfall over the next few decades. However, the actual projected amount of precipitation will not be significantly large due to the very low baseline amounts that presently occur during the dry season (Peters, et al., 2017, Appendix 1). In mid-century, the drier months are slightly more likely to receive more precipitation than a decrease, but the low baseline values in these months mean that these large percentage shifts may not amount to very much actual rainfall change. January is the only month that is somewhat more likely to see a decrease in precipitation rather than an increase in both the near-term and by mid-century (Fig. 13).

Cleanup of Gurudongmar Lake, WWF India

4. Vulnerability Assessment

Sikkim's geographic position and extreme elevation range create unique micro-climates and ecosystems.

4.1 Introduction to the vulnerability assessment process for North Sikkim

In Sikkim, communities are beginning to experience the impacts of climate change, including recent changes in historical precipitation patterns, rising temperatures, and shifts in seasons. Sikkim's geographic position and extreme elevation range create unique micro-climates and ecosystems. Life, livelihoods, and cultures have been nurtured by and are dependent on this natural setting and changes are likely to have profound implications on Sikkim.

For the purpose of analysis the following biodiversity elements that have direct linkage to ecosystem services and human well-being have been selected: 1) snow leopard and its prey species; 2) forests that include upper temperate broadleaf forest, sub-alpine forest, and alpine scrub meadows; 3) wild edible plants, medicinal plants, aromatic plant species for incense, and caterpillar fungus (cordyceps); and 4) traditional crops and livestock that includes yak, cattle (including yak-cow hybrids known as dzo), and Tibetan sheep. In view of very scant information on the current state of biodiversity in Sikkim, people's perception of the status has been taken into account.

At the expert workshop held in Gangtok on December 17, 2016, resource persons from various fields came together to validate the information collected from desktop review and community consultations, evaluate the resilience of key ecosystems, and identify the adaptation options that would be useful to enhance the preparedness, adaptive capacity, and resilience of vulnerable ecosystems in the North Sikkim District.

For the purpose of the assessment, three distinct ecological zones were delineated for the project site in the upper catchment of Teesta River basin of the North Sikkim District: the Middle Mountains, High Mountains, and High Himalayas, described (Table 2).

Argali in Sikkim, Partha Sarathi Ghose /WWF India

Table 2. **Ecological zones and their major ecosystems in the North Sikkim study area**

Ecological Zone	Characteristics	Major Ecosystems
High Himalaya (>5000 m)	Very cold environment, high and rugged mountains, partially or fully covered by snow, ice, and glaciers, headwater of many rivers, rocky areas, religious, sacred, and historical places, transhumance system, border patrol camps	Snow glaciers and glacier moraines, cold desert and high altitude pastures, glacial lakes
High Mountain (3500-5000 m)	Seasonal snow, lower limit of glaciers, large number of lakes, debris-covered lands, mountain cliffs, transhumance and human settlement and border patrol camps	Glaciers and glacier moraines, Alpine meadows and scrub lands, Sub-alpine forest, agro-ecosystem, wetlands, river/streams
Middle Mountain (2300-3500 m)	Seasonal snow, mountain cliffs, heavy precipitation, major human settlements, border patrol camps	Temperate broad-leaf and coniferous, and sub-alpine forest, agro-ecosystem, rivers/streams/springs

Middle Mountain: The middle mountains are characterized by seasonal snow, mountain cliffs, and heavy precipitation, comprises the temperate and the sub-alpine forests, and ranges between 2300–3600 m. The lower reaches of the ecoregion is predominated by temperate broadleaf and coniferous forest. The important tree species found in this forest type include Castonopsis hystrix , Lithocarpus pachyphylla, Tsuga dumosa, Picea smithiana, Abies densa, Rhododendron arboreum, R. campanulatum, R. barbatum, R. campanulatum, and R. falconeri among others. Some of the important fauna of this ecoregion are red panda (Ailurus fulgens), leopard (Panthera pardus), clouded leopard (Neofelis nebulosa), Asiatic black bear (Ursus thibetanus) Himalayan serow (Capricornis thar), Himalyan tahr (Hemitragus jemlahicus) musk deer (Moschus moschiferos), satyr tragopan (Tragopan satyra), blood pheasant (Ithaginis cruentus), and kalij (Lophura leocomelanos) (Fig. 14). The major settlements are limited to occasional villages and the township of Chungthang. Source: HCCDD, and FSADD (Annual reports 2011-12)

Figure 14 (Right). Red panda (*Ailurus fulgens*), an iconic species of Middle Mountain forests and the state animal of Sikkim. Photo: Himal Rakshaks, Yambong Cluster

Figure 15 (Far right). Blue sheep (*Pseudois nayaur*) photographed at Bamzey, North Sikkim. Photo: ©WWF-India

High Mountain: High mountain eco-region ranges from 3500–5000 masl. This region is characterized by seasonal snow, the lower limit of glaciers, mountains cliffs, alpine pastures, and transhumance and human settlement. The major ecosystem components of this ecoregion are glaciers and glacial moraines, alpine meadows and scrub lands, sub-alpine forest, agro-ecosystems, wetlands, and river/streams. The alpine meadows and pastures are dominated by alpine scrubs and grasslands. Common plant species like R. thomsonii, R. anthopogon, and R. *setosum, Juniperus* sp., *Aconitum* spp., *Eriophyton* spp., *Pedicularis* spp., *Rheum nobile* and *Saussurea simpsonianan* among others grow profusely. Important fauna of this area include snow leopard (*Panthera uncia*), blue sheep (*Pseudois nayaur*), Tibetan wolf (*Canis lupus chanco*), red fox (*Vulpes vulpes*), and Himalayan monal (*Lophophorus impejanus*) among others (Fig. 15).

High Himalaya: Above 5000 m, this region is characterized by a very cold environment partially or fully covered by snow, ice, and glaciers. The high Himalayas are recognized as the headwaters of many rivers. Major land cover types within this ecoregion include snow and glaciers, glacial moraines, cold desert, and high altitude pastures. The pasturelands are dominated by plants of the genera *Stipa, Elymus, Carex, Kobresia, Pedicularis, Lonicera*, etc. The globally endangered snow leopard (*Panthera uncia*), Tibetan argali (*Ovis ammon hodgsoni*), Tibetan gazelle (*Procapra picticaudata*), southern kiang (*Equus kiang polyodon*), Tibetan wolf (*Canis lupus chanco*), Tibetan sand fox (*Vulpes ferrilata*), red fox (*Vulpes vulpes*), and globally vulnerable black-necked crane (*Grus nigricollis*) are important wildlife found in this ecoregion (Fig. 16).

Figure 16. A herd of male Tibetan argali (*Ovis ammon*) at Tsho Lhamo plateau. Photo: ©WWF-India/Partha S. Ghose

The vulnerability assessment was conducted by seeking inputs from the participants of the December 17, 2016 expert workshop on the impacts of climate change in the three broad ecological zones discussed above. The first topic discussed was the impact of climate change on each of the three ecological zones as understood or observed or studied by the expert group. Secondly, inputs on climate impacts on water resources were also separately assessed. Finally, an assessment of development impacts on these ecoregions was also made.

4.2 Expert workshop findings on climate vulnerability

The tables below summarize climate impacts highlighted by the expert workshop participants for each of the three study region ecological zones (Table 3) and on water resources in the study area in general (Table 4).

Table 3. **Impact of climate change on ecological zones in the North Sikkim study area**

Ecological Zone	Impacts on Ecological Zone as a whole
High Himalaya (>5000 m)	• Increase in minimum temperature for December that has led to substantial decrease in snowfall during this month over last 20 years. This is similar to the findings of Prasad et al. (2009), which reported an increase in temperature during the winter months and less snowfall and lower annual snow cover on glaciers in the Western Himalayas. • Increase in average temperature • Shift in the timing, and decrease in amount of snowfall (Bawa and Ingty, 2012) • Observation of species movement to higher altitudes; for example, the house crow (*Corvus splendens*), generally found below 3000 m, is now observed on the Tso Lhamo plateau above 5000 m. • Habitat of snow leopard at risk from rising temperature • Changes in species composition and decreasing productivity of grasslands (Sharma et al., 2009)
High Mountain (3500-5000 m)	• Increase in minimum temperature during the winter months • Increase in average temperature • Upward shift of animal and plant species to higher elevations • Increased incidence of protozoan parasite diseases in yaks due to increasing temperature. Both protozoa parasites and their vectors thrive well under higher temperature and humidity. This has lead to decrease in yak numbers due to increasing incidence of both protozoan parasites and skin diseases. • Skin diseases observed among the domesticated yaks and sheep as well as wild ungulates such as blue sheep and Himalayan goral due to increasing temperature and humidity • Decrease in snowfall and more erratic occurrence and timing of snowfall is impacting the livelihood of pastoralist communities, including by affecting fodder productivity in mountain pastures used by livestock. • Decreased agricultural production due to increasing incidence of crop insect/pest and disease outbreaks as well as more erratic weather conditions
Middle Mountain (2300–3500 m)	• Decrease in winter precipitation • Precipitation patterns more erratic • Summers becoming increasingly warmer and mosquitoes now found in mountain villages where they never occurred before • Increasing incidence of crop insect/pest and disease outbreaks is lowering agricultural productivity. • Increasing incidence of forest fires • Pasture degradation and a decline in water availability in pastures is affecting yak grazing. • Increase in temperature which is believed to be contributing to more frequent hoof and mouth disease outbreaks • Shift of species to higher elevations as temperature rises, for example, Nepalese alder and the Himalayan keelback snake and the rosebelly worm-eating snake (see above) • Changes in phenology, including trees that are leafing earlier and flowers blooming earlier than in the past, such as for the tree rhododendron (*Rhododendron arboretum*) bloom • Increasing human-wildlife conflict due to crop raiding by wildlife, possibly due to a decline in wild food found in forests and over-exploitation of wild edible fruits by humans

Table 4. **Impact of climate change on water resources in the North Sikkim study area**

Ecological Zone	Impacts on water resources
High Himalaya (>5000 m)	• Rising temperatures causing retreat and thinning of glaciers, fewer frost days, and winter warming. Basnett et al. (2013) reported an overall reduction in glacier area in all of Sikkim of 6.9 ± 1.5 km² from 1989–2010 (in both High Himalaya and High Mountain) due to climate impacts • Formation of new glacial lakes, and rapid expansion of old glacial lakes. Basnett et al. (2013) also noted the recent occurrence of glacial lakes on debris covered glacial surfaces. • At the South Lhonak Glacier, South Lhonak Lake has grown rapidly from an area of 18 ha in 1980s to 126 ha in 2013 due to the lake capturing the melt water of the South, North and main Lhonak glaciers (Department of Science and Technology and Climate Change, 2016) • Higher chances of extreme weather events and natural disasters such as glacial lake outburst floods (GLOF), flash floods, landslides, and avalanches • Shift in timing, and decrease in the amount of snowfall (Bawa and Ingty, 2012).
High Mountain (3500-5000 m)	• Glacier retreat • Increase in the size and number of glacial lakes • Shift in timing, and decrease in amount of snowfall (Bawa and Ingty, 2012) • Change in discharge from glacier-fed rivers; more in wet season and less in dry season, with discharge from about 42% of water sources having declined by over 50% during the dry period (Tambe et al., 2013)
Middle Mountain (2300–3500 m)	• Average temperature from 17 locations in North Sikkim observed during the 2007–2010 period showed a dramatic increase over temperature measurements taken in 1850, exhibiting a high degree of seasonality with summer and winter temperatures being 0.76 ± 0.25° C and 3.65±2° C higher, respectively (Telwala et al., 2013). • Decline in winter rainfall • More erratic rainfall patterns • Decrease in soil moisture content • Reduction in discharge of springs and conversion of formerly perennial springs to seasonal springs • Growth in the size and number of glacial lakes at higher altitudes have increased the threat of GLOF disasters for downstream livelihoods and water sources

Tables 5 and 6, next pages, summarize the impacts of economic development on ecological zones and water resources in the North Sikkim study area as noted by the participants of the December 17, 2016 expert workshop.

Table 5. **Impacts of economic development by ecological zone in the North Sikkim study area**

Ecological Zone	Development Impacts
High Himalaya (>5000 m)	• Degradation of high altitude pastures due to an increase in road construction activities, expansion of border patrol camps for border security needs, and an increase in tourism • Increasing vehicular movement in the high-altitude areas may lead to deposition of black carbon emission on snow and glaciers that could ultimately increase melt rates. • Habitat of snow leopards and prey species decreasing due to increased road construction and grazing by domestic livestock • Increasing problem of feral dogs competing with wild carnivores such as snow leopards and Tibetan wolves for prey, with feral dogs now begin the dominant predators in high-altitude areas of North Sikkim • Increased human-wildlife conflict, particularly depredation on livestock by both feral dogs and wild predators • Increased human habitation and tourism leading to waste accumulation • Unsustainable practices of harvesting caterpillar fungus and other NTFPs. Although the Sikkim Forest Department has a new NTFP collection policy it may take time for implementation. • Recent decline in traditional rotational grazing practices and increasing sedentarization of highland pastoralists due to inadequate pastures leading to overgrazing impacts on high altitude pastures around homes of pastoralists • Poaching of wildlife
High Mountain (3500-5000 m)	• Increasing vehicular movement in the high-altitude areas may lead to deposition of black carbon emission on snow and glaciers that could ultimately increase melt rates • Habitat of snow leopards and prey species decreasing due to increased road construction and grazing by domestic livestock • Increasing problem of feral dogs competing with wild carnivores such as snow leopards and Tibetan wolves for prey, with feral dogs now begin the dominant predators in high-altitude areas of North Sikkim • Increased human-wildlife conflict, particularly depredation on livestock by both feral dogs and wild predators • Increased human habitation and tourism leading to waste accumulation • Unsustainable practices of harvesting caterpillar fungus and other NTFPs. Although the Sikkim Forest Department has a new NTFP collection policy it may take time for implementation. • Recent decline in traditional rotational grazing practices and increasing sedentarization of highland pastoralists due to inadequate pastures is leading overgrazing impacts on high altitude pastures around homes of pastoralists • Loss of traditional knowledge such as the use of water mills for grinding grain, which has stopped in Lachung. In addition, loss of traditional knowledge on curing yak diseases and treating yak stress brought on by climate change , leading to yak disease • New skin disease outbreaks among domesticated yaks and sheep as well as wild ungulates such as blue sheep and Himalayan goral that were likely introduced by tourists, construction workers, and other non-residents traveling in North Sikkim with their own meat supplies brought up from lowland areas

Table 5. Impacts of economic development by ecological zone in the North Sikkim study area (Continued)

Ecological Zone	Development Impacts
Middle Mountain (2300–3500 m)	• Habitat degradation from infrastructure construction for border security and tourism needs • Increasing incidence of forest fire • Decrease in agricultural productivity due to increasing incidence of pest and disease outbreak and shortage of livestock manure for fertilizing fields • Decline in yak herding due to pasture degradation and a decrease in water availability • Increasing human-wildlife conflict, particularly raiding of crops by wild animals, which may be due in part to over-harvesting of wild forest foods such as edible fruits by humans, leading to direct competition between humans and wildlife for food resources • Increasing amounts of solid waste due to increasing tourism, labor camp populations, and other permanent human habitations locations • Decline of traditional knowledge on use of wild food species, wild medicinal plants, and use of wild plants in local rituals may result in reduced protection of these plants • Increasing use of firewood contributes to black carbon emission, forest degradation, and a reduced capacity for forests to function as carbon sinks. • Over-exploitation of NTFPs such as satwa (Paris polyphyla) • Fragmentation of upper broadleaf forests due to development activities including road building and hydro-power construction • Increased proliferation of invasive species

Table 6. **Impacts of economic development on water resources in the North Sikkim study area**

Ecological Zone	Impacts on Water Resources
All 3 Ecological Zones	Quality: • Water sources polluted by increasing presence of tourists, laborers, and other non-native populations • Water quality adversely affected by poorly planned road construction, although expert workshop participants cited a need for a detailed study to confirm this Quantity: • Area of Gyamtsona Lake decreasing due to diversion of its source spring • Discharge from springs declining particularly during dry season (According Tambe et al. (2012), spring discharge during dry season has fallen by as much as 35–50%. • Number of perennial springs declining • Water flow to downstream dams reduced Other: • Fresh water biodiversity threatened by introduction of exotic trout

There was broad agreement that climate change, in combination with other stressors such as economic development activities, will impact natural systems to different degrees, in different ways, and at varying rates of speed. There was also broad agreement that human communities vary with respect to how climate change and related natural hazards will affect them. These ideas lie behind much of the work on vulnerability, which has roots in research on risk, hazards, and disasters, entitlements and human ecology as well as political ecology and traditions and which, taken together, identify a wide array of variables that may influence the way coupled systems experience and respond to changes (Agder, 2006, 271; Cutter, 2009; Fussel, 2009).

4.3 Ecosystem and Biodiversity Vulnerability Rankings

Following the general discussion of climate change impacts on the three defined ecological zones in North Sikkim, summarized above, expert workshop participants assessed the degree of vulnerability of 19 key ecosystems and biodiversity elements across the three ecological zones to these impacts (Table 7). For this analysis, the degree of vulnerability of the key ecosystems and biodiversity elements were ranked as low, medium, or high based on four criteria adapted from Flowing Forward (Le Quesne et al., 2010). These criteria were: 1) Human Disturbance, the extent to which an ecosystem already faces detrimental non-climatic pressure from human activities; 2) Natural Climate Variability, the extent to which the local climate varies naturally, including variations in occurrence of extreme weather events such as floods, drought, heat waves, and cold spells; 3) Refuge Capacity, the ability of an ecosystem to provide critical species with refuge from climatic shocks, particularly through microclimatic variation on local scale, and 4) Habitat Connectivity, the extent to which an ecosystem can provide migration corridors to allow key species to migrate from habitat rendered unsuitable by climatic change to suitable habitat or refuge areas. After ranking the vulnerability of each ecosystem and biodiversity element under each of the four criteria, overall vulnerability rankings were determined by expert workshop participants (Table 7).

Table 7. **Vulnerability rankings of key ecosystems and biodiversity elements in North Sikkim to climate change impacts with corresponding threats.**

Ecosystem/Key Biodiversity Elements	Vulnerability Ranking				Overall Ranking
	Human Disturbance	Natural Climate Variability	Refuge Capacity	Habitat Connectivity	
High Himalaya (>5000 m)					
Snow, Glaciers and Glacial Moraines	High (1, 2, 3)*	Medium (25, 26, 27)	Low	High (39)	Medium
Cold Desert and High Altitude Pastures	High (1, 2, 3, 4)	Medium (27)	Low	Medium (40)	Medium
High Altitude Wetlands	High (1, 5)	Medium (25, 27)	High (34)	High (40)	High
Snow Leopards	High (2, 6)	Medium (27, 28)	High (35)	Medium (1)	High
NTFPs (including Cordyceps)	High (7, 8, 9)	Medium (28, 29)	Low	Low	Medium
High Mountain (3500–5000 m)					
Glaciers and Glacial Moraines	High (1, 2, 3)	Medium (25, 26, 27)	Low	High (39)	Medium
Permafrost	Low	High (28)	N/A	N/A	Medium
Alpine Meadows and Shrub Lands	High (7, 10)	Medium	Low	Low	Medium
Sub-alpine forest	High (1, 11)	High (15, 30, 31)	Medium	Medium	High
Agriculture	Medium (12)	Medium	High (36)	Medium	Medium
Pastoralism	High (1, 3, 10)	Medium	N/A	N/A	High
Wetlands	High (5)	Medium (27)	High (34)	High (40)	High
River/Streams	High (13, 14)	High (32, 33)	High (37)	Low	High
Snow Leopards	High (2,6)	Medium	High 35)	Medium	High
NTFPs (including Cordyceps)	High (7,8,9)	Medium	Low	Low	Medium
Middle Mountain (2300-3500 m)					
Temperate Broadleaf and Conifer Forest	High (7, 11, 15, 16, 17, 18)	Medium	Medium	Medium	Medium
Sub-alpine Forest	High (1,11)	High (15, 30, 31)	Medium	Medium	High
Agro-ecosystems	Medium	Medium	High (36)	Medium	Medium
Rivers/Streams/ Springs	High (1, 13, 14, 19, 20, 21, 22, 23, 24)	High (32, 33)	High (37, 38)	High (41)	High

Table 7. Vulnerability rankings of key ecosystems and biodiversity elements in North Sikkim to climate change impacts with corresponding threats. (Continued)

* Corresponding threats by number are shown below:

Human Disturbance
1. Poorly planned road construction
2. Increasing vehicle traffic
3. Expansion of border patrol facilities
4. Decline in traditional rotational grazing practices
5. Declining water quality due to increasing tourism and/or construction crews and/or border patrol staff
6. Growing feral dog populations
7. Unsustainable NTFP collection practices
8. Habitat degradation
9. Loss of traditional knowledge
10. High grazing pressure
11. High local dependency on wood cutting
12. Loss of traditional crops to introduced high-yielding varieties
13. Water pollution
14. Hydropower development
15. Increasing incidence of forest fires
16. Reduced photosynthesis due to dust and pollution
17. Habitat disturbance due to development activities
18. Unsustainable fodder collection practices
19. Muck dumping
20. Stone quarrying
21. Trash dumping
22. Road tunneling
23. Natural flow diversions
24. Insufficient environmental flows

Natural Climate Variability
25. Melting of glaciers
26. Upward shift in snow line
27. Increase in size and number of potential GLOF lakes
28. Increasing temperature
29. Upward shift of vegetation species
30. Increasing incidence of landslides and debris flows
31. Increasing incidence of avalanches
32. Increasing incidence of flash floods and GLOFs
33. Reduced recharge capacity due to forest degradation

Refuge Capacity
34. Very fragile ecosystem that is highly vulnerable to climate change impacts
35. Upward shift of treeline
36. Increasing incidence of pest and disease outbreaks
37. Introduction of exotic species
38. Changes in fluvial ecosystems

Habitat Connectivity
39. Increased geomorphic barriers as glaciers melt
40. Increased habitat disturbance due to increasing human activities
41. Dam construction

With respect to human disturbance, participants ranked most ecosystems and key biodiversity elements in North Sikkim as highly vulnerable. Though there are limited studies on glaciers and lakes within the state, enough evidence is available that shows that these are under serious threat from climate change, which is compounded further by anthropogenic activities, such as at Gyamtsona Lake. The primary reasons given by expert workshop participants for the high vulnerability ranking with respect to human disturbance of ecosystems and biodiversity across North Sikkim were poorly planned road construction, increasing vehicular traffic, increasing non-indigenous human population, tourism, loss of traditional knowledge and cultural values, adoption of unsustainable livelihood practices, and failure to follow environmental policy. Border patrol activities that include infrastructure development, heavy vehicular traffic, and waste accumulation in the high-altitude areas were highlighted as key factors in the high vulnerability to human disturbance ranking, as were tourism activities. Notably, both snow leopards and the high-altitude wetlands were ranked as highly vulnerable to human disturbance. The economic activity of harvesting caterpillar fungus, which is becoming unsustainable due to unregulated practices, is both a cause of human disturbance and ranked as highly vulnerable to human disturbance. Another factor for the high vulnerability to human disturbance ranking is the increasing incidence of forest fires.

With respect to natural climate variability, the Middle Mountain and High Mountain ecological zones were ranked as having higher vulnerability to natural climate variability than the High Himalaya ecological zone. This is due to the increasing trend in average and minimum temperatures in these zones that will affect ecosystems, biodiversity, and livelihoods as well as the increased risk of catastrophic GLOF disasters in these zones resulting from expansion and formation of new glacial lakes.

With respect to the vulnerability of ecosystems to be able to act as climate refugia under warming climatic conditions, those ecosystems that already have a low capacity to provide refuge, such as all types of wetlands and agricultural systems, were ranked as highly vulnerable to climate change impacts. At the same time, cold high altitude landscapes were seen as less vulnerable since these will likely serve as climate refugia in the future.

With respect to the vulnerability of ecosystems to serve as migration corridors in the face of a changing climate, areas that were considered to already have lower habitat connectivity were considered to have higher vulnerability to losing remaining connectivity under warming climatic conditions. In general, isolated wetlands were considered to have low connectivity for wetland species and thus had a high vulnerability ranking, as did rivers and streams at lower altitudes. Their connectivity is threatened by hydropower development such as damns. At higher altitude, glaciers were seen to have a high vulnerability with respect to habitat connectivity as they melt and retreat. Another major threat to habitat connectivity was road building.

Overall, wetlands, rivers, streams, and springs in all three ecological zones were thought to have the highest vulnerability to climate change and development impacts. This vulnerability will likely have long term ramifications for North Sikkim residents' livelihoods and well-being.

Figure 17. Snow leopards (*Panthera uncia*) photographed near Gochung, North Sikkim. Photo: ©WWF-India

4.4 Snow Leopard Vulnerability

In the above vulnerability analysis, participating experts thought that the snow leopard is highly vulnerable to both climate change impacts and human disturbance in North Sikkim, which will likely lead to a decline in the total area of suitable habitat as well as in prey species numbers (Fig. 17).

The combination of increased temperature, particularly in winter months, and a wetter and warmer monsoon season could dramatically alter interactions between snow leopards, their prey, and local human populations. Rising temperature may induce changes in local vegetation and cause tree line to shift upslope. Changes in seasonal temperature suggest the possibility of earlier arrival of spring, resulting in earlier snowmelt, and the monsoon season may be longer and wetter. Additionally, warmer temperature means that snow may not accumulate until later in the year. These changes would allow herders to graze livestock at higher elevations earlier in the spring and continue to graze livestock at these elevations later into the autumn season. These changes could cause increased potential disturbance to snow leopards and their prey, as well as create a situation of longer direct competition between livestock and wild snow leopard prey species such as ibex, for limited alpine pasture resources each year. These climatic changes may also create an opportunity for longer interactions between humans and snow leopards each year, and consequently even more potential human-snow leopard conflict.

Figure 18. Agriculture, one sector showing probable changes in response to changing climatic conditions in North Sikkim. Photo: Roshan Rai/DLR PRerna, Darjeeling

Figure 19. *Rhododendron anthopogon* collected from high-altitude pastures is used as incense for ritualistic purposes in homes and monasteries. Photo: ©WWF-India/Partha S. Ghose

4.5 Economic Vulnerability

The main economic sectors that were considered in the above vulnerability assessment exercise were NTFP extraction and the agriculture and animal husbandry sectors, and indirectly the tourism sector also was part of the discussion.

Agricultural production in North Sikkim has seen ebb and flow in recent years, with increased production reported seven to eight years ago with the introduction of greenhouses, seed diversification, and subsidization of chemical inputs from the government. Currently however, a number of reasons are responsible for a drastic decline in agricultural productivity (Fig. 18). While the overall changing climate scenario has created unfavorable climatic conditions, notably increasingly unpredictable rainfall as well as an increase in diseases and pest infestation, increased crop depredation by wild animals is also a problem. Coupled with this is the state's 2015 decision to only allow organic farming practices, which has led to a further decline in crop production as organic manure is not easily available as a substitute for chemical fertilizers. Most of the farming practice in Thangu depended on sheep manure, which has seen a decline over the years with currently only one sheep-owning herder left in North Sikkim. Also, the traditional practice of allowing farm animals to mostly free range does not result in a convenient cow manure stockpile. As a result, farmers in remote locations such as Lachen and Lachung are facing extreme challenges in sustaining their agriculture practices in the absence of chemical inputs.

Most observations show that people are giving up on agriculture to build hotels and homestays, and pursue other tourism-allied activities. Traditional crops like barley and buckwheat that are more tolerant to external stresses are rapidly disappearing due to the introduction of new seed varieties through government programs. However, one interesting insight from Lachung was that winter farming is becoming possible due to warming temperature. Vegetables like cabbages and carrots are now locally grown and available throughout the winter. It appears that the changing climate could also usher in situations that are conducive for farming. Thus the overall vulnerability ranking of agro-ecosystems and agriculture was considered to be medium.

For both communities of Lachen and Lachung, the NTFPs that are collected mainly consist of wild edibles and medicinal plants. These are used for activities such as dye making and making incense. Recently, the dependence on edibles like wild mushrooms, has been considerable reduced. Pradhan and Badola (2008) report that *Aconitum heterophyllum*, *Dactylorhiza hatagirea*, *Nardostachys jatamansi*, *Panax pseudosinseng*, and *Picrorhiza kurrooa* were used as ethno-medicine in the past but are now no longer used. However, the demand for caterpillar fungus (cordyceps), locally known as *Yarsagumba*, has grown over the years and has become a major source of income for the communities. For this sole reason, during the peak seasons villagers in small groups flock to the high-altitude scrublands and meadows above Lachen and Lachung to collecti *Yarsagumba*. This activity has been more popular in Lachen, with recent annual collections exceeding Rs. 1 million (USD 15,400) per family. Under new 2016 Sikkim state regulations on collection and sale of caterpillar fungus, the first auction was carried out in Mangan, North Sikkim District, but there were hardly any bidders, and this process will

Figure 20.
Agropastoralism is one of the sectors showings signs of impact due to variations in climate. Photo:©WWF-India/ Partha S. Ghose.

take time to be streamlined. While the ecological consequence of over extraction, climate change, and ecological stressors on caterpillar fungus are poorly understood, this collection and sale has brought an unprecedented economic boom to the valley. Already a declining trend in the amount of caterpillar fungus harvested is already being is reported by the villagers, which may jeopardize this source of income.

Use of incense (Nepali: *Dhup*) for the purpose of rituals is an age-old practice for Buddhists. Various wild plants collected from the high-altitude pastures are used as incense for ritualistic purposes in home and monasteries. Commonly, juniper (*Juniperus* sp.) and two species of rhododendrons (*Rhododendron anthopogon* and *Rhododendron setosum*) are used as incense in Sikkim (Fig. 19). In recent times, the demand for incense has increased in markets outside North Sikkim, especially from other parts of Sikkim, and the nearby hill cities of Darjeeling and Kalimpong in West Bengal. This in turn has increased collection of plants used for incense in the highland areas of Sikkim. Juniper is known to be particularly sensitive to climatic and ecological changes, although this hasn't been well-documented in North Sikkim.

Unusual and untimely snowfall has severely impacted the life and livelihood of high-altitude pastoralists known as Dokpas, who traditionally follow rotational grazing practices, particularly pasture productivity in high-altitude areas (Fig. 20). Rangeland degradation, frequent land and mud slides, flooding, avalanches, and reduction in area of usable pastures are commonly observed in the alpine areas of North Sikkim. Parasitic diseases in yaks, hoof and mouth disease in yaks and cattle, and skin diseases in both yak and sheep have been observed recently. Further, because of increasing temperature, water quality degradation, and the degradation of grazing lands, yaks are no longer moved to lower altitudes in winter. Livestock depredation by Tibetan wolves have been observed, but feral dog packs kill far more livestock. Possibly more than 200–300 feral dogs live in the high-altitude cold desert areas of North Sikkm, according to locals. All these recent developments are a threat to yaks, goats, and sheep and also to herding livelihoods. The number of yaks has decreased drastically, attributed also to the younger generation's lifestyle changes. Many are not willing to take up the harsh herding life that offers inadequate incentives for such practices. In recent times, the number of migrant-herders coming from northern West Bengal and Nepal has increased. At the same time, a recent government initiative is attempting to revive traditional sheep herding in the area.

Tourism has become one of the most important contributors to the local economy in the Lachen and Lachung areas. About 60% of households in these villages are involved in tourism or its allied activities, shifting from agriculture in the primary sector. However, with increasing vulnerability to disasters and many scenic areas being rapidly developed, the tourism sector in North Sikkim is highly vulnerable to climate-related natural disasters, decreasing appeal due to development activities and changing trends in domestic Indian tourism.

4.6 Social adaptive capacity

For assessing the social adaptive capacity in Lachen and Lachung Villages, a review of institutions and government policies was conducted with expert workshop participants. For any future adaptation interventions, it is important to consider the human capacity and institutional presence in the landscape to address and mitigate the impacts of climate change. While the vulnerability analysis assessed the resilience of ecosystems and biodiversity elements with respect to climate change impacts, what follows is an assessment of human factors relevant to implementing effective climate adaptation actions.

4.6.1 Institutional support

Local, state, and national institutions with relevance for implementing climate adaptation interventions in the state are discussed below. The traditional institution of the Dzumsa (village council) exerts a major influence in the lives of the community and is the most important decision making body in the village in all aspects of community development (see Box 1, above). It works on the principles of equality for all and is therefore inherently pro–poor. Natural resource management and environmental protections are embedded in the Dzumsa's functioning, and this is viewed as a strong advantage for bringing positive reforms in practices and for overcoming challenges. Two examples were decisions taken by the Lachen Dzumsa: the regulation on caterpillar fungus harvesting and the ban on the sale of bottled drinking water. The Dzumsa also decides on the agricultural calendar dates that determine activities such as sowing and harvesting in accordance to the Lunar Calendar, and is also the herding calendar for moving livestock to higher summer pastures. Decision making for the community at large on these important issues may be crucial in the long run, if a need arises to adjust certain practices in response to climate change impacts.

The gompa (Buddhist monastery) is another important institution in Lachen. Monastery monks and nuns are represented on the Dzumsa, and they are highly influential in the decision-making process of the village. The gompa plays a very important role in the life of the local Buddhist communities, and Lamas (monks) or Chomo/Ani (nuns) are highly regarded and respected.

Juxtaposed with these two traditional institutions in Lachen are the youth of the village, who are coming together to form their own groups. The Lachen Tourism Development Committee (LTDC) is one such organization formed by youths concerned with the challenges of increasing tourism pressure in the village. LTDC was formed in 2008 by five young village residents, who were committed to securing the traditional culture of Lachen, which was in danger of being lost in the face of increasing tourism. Their main mandate is to promote responsible tourism, and they are involved in preserving and reviving traditional cultural practices, taking biodiversity conservation actions, and working with local communities in promoting ecologically sound traditional lifestyles.

Because Sikkimis a small state, the state government has a large presence in almost all the villages. Many government departments work in varying degrees at the village level. Sikkim has a recorded forest cover of 82.31% of the state's territory, much of which lies in protected and reserve forests (GOI, 2011). The overall administrative control of the forest land and forestry resources comes under the legal jurisdiction of the state Forest, Environment and Wildlife Management Department (FEWMD). However, in Lachen, the two Pipons (village council co-chairmen) usually have extensive control over natural resource management, although technically it comes under the jurisdiction of the forest department. Although there has been some dialogue to involve the local governance mechanisms in the state administration, this will require better understanding and coordination between traditional councils and state level staff. Since 2015, efforts are being led by FEWMD to open up biodiversity management committees in all villages in Sikkim. These committees have already been created in Lachen and Lachung to implement the 2012 Sikkim Biodiversity Action Plan.

Perhaps the most important institution in the study area is the state Rural Management and Development Department which, through the flagship program of the Mahatma Gandhi National Rural Employment Guarantee Scheme, ensures 100 days labor to community members registered under this scheme. In addition, issues of rural water supply and sanitation would also come under the purview of this department.

With the advent of organic farming in the state, the extension work of the state Department of Food Security and Agriculture Development, the Horticulture and Cash Crop Development Department, and the Department of Animal Husbandry have gained much importance. While these departments have a limited presence in the villages, farmers gain access to their services through various schemes and capacity building opportunities. Another potentially important institution is the Indian Council of Agricultural Research Krishi Vigyan Kendra Agricultural Extension Center located in Mangan, North Sikkim District.

The national border patrol has a huge presence in study area, and is a major stakeholder. Cordial relations are usually observed between the border patrol and the local community. While the large border patrol presence has also led to ecological impacts, the border patrol is also the first responder helping these remote communities during times of emergency and natural disasters.

Thus, the success of any climate adaption intervention undertaken in North Sikkim District will require strong institutions with sufficiently high administrative and technical capacity to conduct this work, as well as a high level of coordination between institutions, in particular between state and village-level institutions. Additionally, successful climate adaptation work will require that key institutions involved in adaptation efforts have funding resources allocated for this work in a consistent and predictable manner.

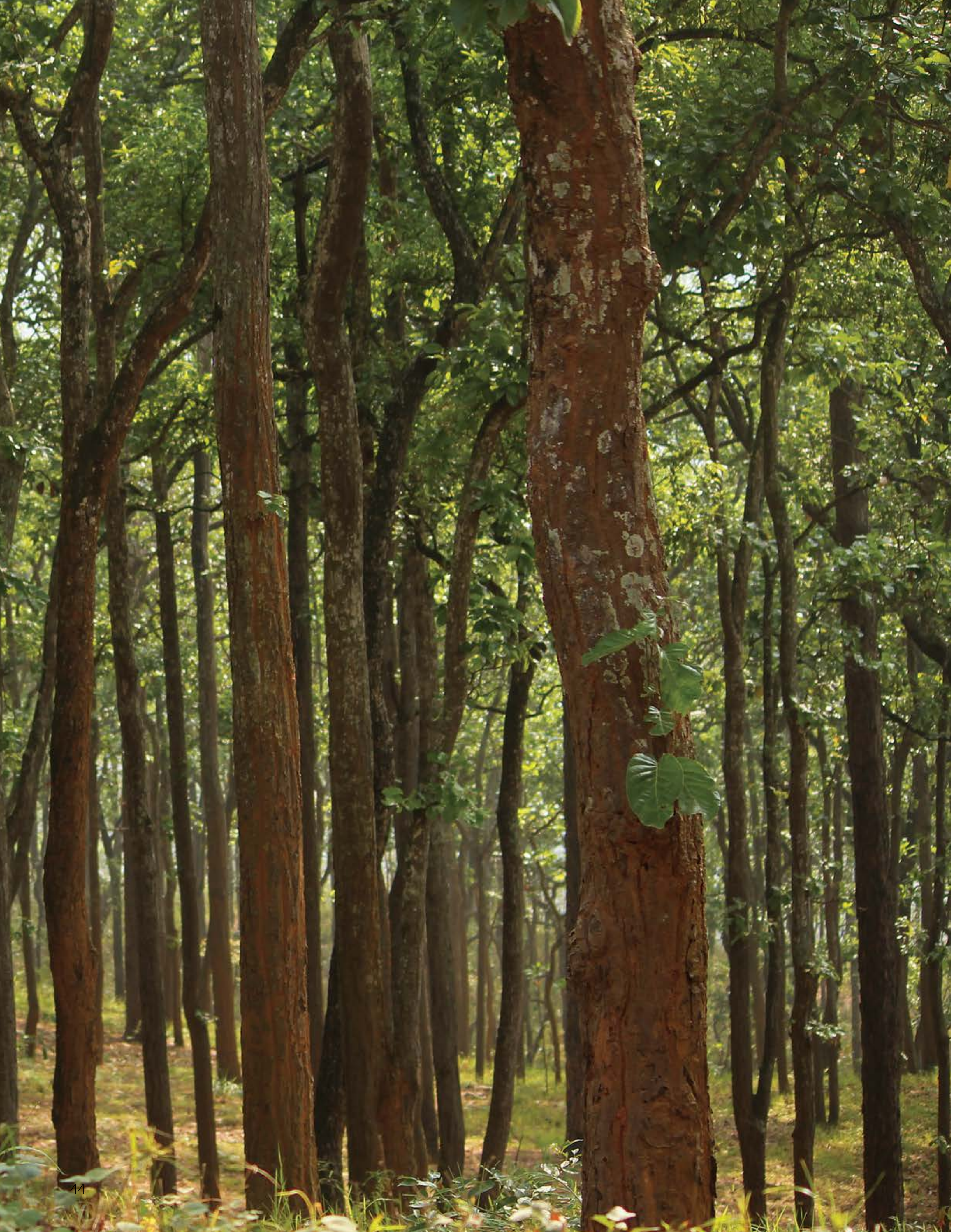
4.6.2 Policy support

Local, state, and national policies with relevance for implementing climate adaptation interventions in the state are discussed below. At the local level, both the Lachen and Lachung dzumsas have a number of regulations in place that facilitate better environmental practices to minimize anthropogenic impacts on local landscapes. The Lachen and Lachung dzumsas have a system of restricting tree felling from certain forest areas in an effort to preserve local forest cover. Lachen and Lachung yak herders are required to follow a system of rotational grazing adopted by the Lachen and Lazhung dzumsas to minimize pastureland degradation. In 2016, the Lachen Dzumsa also announced new regulations on extraction of caterpillar fungus. These new regulations included a limit on the number of people per household allowed to participate in the caterpillar fungus harvest. A ban on burning rhododendrons in fungus collection areas was also instituted and collectors are now required to use gas stoves while in collection areas. Fungus collectors are also now required to carry all trash generated in collection areas back to Lachen.

Sikkim state has built a green image for itself through a number of policies that address environmental protection and climate change.

Sikkim state has built a green image for itself through a number of policies that address environmental protection and climate change. The 2011 State Action Plan on Climate Change prepared by the state Water Security and Public Health Engineering Department addresses climate change impacts on the state and propose adaptation strategies for the site, particularly with respect to agriculture, water, and soil conservation. In January 2016, after an over 12-year effort initiated by the state's chief minister in 2003, Sikkim was declared a fully organic state following implementation of a ban on use of chemical fertilizers and pesticides in the state, a bold and important policy decision. Along with these strategies came a number of initiatives for increasing the green cover of the state that includes afforestation and the Ten Minutes to Earth program by FEWMD. In 2016, the state Forest, Environment and Wildlife Management Department also issued regulations on the collection and sale of caterpillar fungus that are complemented by the local regulations of the Lachen Dzumsa, discussed above. In addition, the Sikkim state Department of Science and Technology and Climate Change is responsible for glacier and climate studies, local vulnerability and risk assessment, institutional capacity with respect to addressing climate impacts, climate data base compilation and management, climate training programs for relevant stakeholders, and public awareness programs on climate change in Sikkim. Notably, both the Tourism and Civil Aviation Department (TCAD), the Sikkim Tourism Development Corporation (STDC), and a state-level NGO, the Eco-Conservation Society of Sikkim (ECOSS) will need to be involved in climate-smart tourism practices in the state's booming tourism industry.

At the national level, policies in India find implementation at the lowest level of governance and several have immediate relevance for climate adaptation work. The 1972 Wildlife Protection Act seeks to protect wild animal and plant species and delineates strict penalties for killing rare animal species. The 1974 Water (Prevention and Control of Pollution) Act seeks to prevent water pollution and maintain or restore adequate water quality. The 1986 Environment Protection Act seeks to protect the environment for the benefit of both humans and wildlife. The 2002 Biological Diversity Act seeks to conserve biodiversity in India with equitable sharing of benefits from the use of traditional biological resources and knowledge. India's National Wetland Conservation Programme was launched in 1985 for the conservation and protection of the nation's wetlands.



5. Adaptation Interventions

Experts felt that some of the most important adaptation actions required improving knowledge and protecting critical water resources in North Sikkim.

According to the IPCC, climate adaptation is the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC 2007[a]). At the final session of the December 17, 2016 expert workshop, participants were asked to devise possible adaptation actions and identify the corresponding government agencies that would likely be responsible for implementing these actions. Participants were guided by three important considerations in proposing adaptation interventions: 1) feasibility, 2) need, and 3) addressing each type of major climate change impact compiled during the session on impacts. The proposed adaptation actions were then compiled into a list of recommendations for developing adaptation strategies for the study region of North Sikkim (Table 8).

A discussion of the experts' proposed adaptation actions highlighted several areas where more work is needed. First, participants agreed that due to the very minimal amount of research that has been conducted on the impacts of climate change and development in the North Sikkim District, more research in these areas is needed in order to devise the best adaptation interventions possible. Second, it was agreed that awareness needs to be raised among both locals and implementing government agency staff concerning the impacts of climate change and development on the local environment, particularly with respect to forests, biodiversity, water resources, NTFPs, and traditional livelihoods. Third, it was agreed that there is a need to conduct regular and standardized monitoring on implementation of existing policies with relevance for climate adaptation and to revise and formulate new policies as needed for the purpose of implementing adaptation interventions. Fourth, it was agreed that it is important to identify, strengthen, and incentivize practices that are agreed to be good adaptation options with respect to various categories of climate change impacts. Fifth, among the 19 types of ecosystems and biodiversity elements analyzed in the above vulnerability assessment exercise, wetlands and water resources in all three ecological zones were viewed as being highly vulnerable to climate change and development impacts.

Thus experts felt that some of the most important adaptation actions required improving knowledge and protecting critical water resources in North Sikkim. These adaption actions included mapping of critical recharge

Forests in Sikkim, WWF India

areas for springs, afforestation and improving protection of these areas, strengthening mechanisms for monitoring impacts of hydropower development and operations on the local environment, particularly with respect to environmental flows at these sites, improving management of ground water extraction and recharge, and improving water governance in North Sikkim District in general.

The climate adaptation interventions recommended by participants of the expert workshop are summarized in Table 8, below, organized according to 12 key impacts of climate change and poorly-managed on-site human activities identified by workshop participants. As is frequently the case, for many of these impacts it is difficult to clearly separate climate change impacts from impacts caused by on-site human activities, with climate change impacts often exacerbating direct human impacts and vice versa. However, in Table 8, impacts 1–5 are considered to be primarily a result of climate change, impacts 6–9 appear to be the result of a mix of both climate change and on-site human activities, while impacts 10–12 are the result of on-site human activities, although these final three categories of impacts will inevitably be exacerbated by climate change impacts.

Table 8. **Possible adaptation actions for North Sikkim District proposed by expert participants of the December 17, 2016 climate vulnerability workshop in Gangtok, Sikkim**

Impact	Possible Adaptation Actions	Responsible Agencies
	Climate Change Impacts	
1. Changes in hydrology and water resource availability due to increasing frequency of drought and shifting precipitation patterns	• Map spring recharge areas followed by afforestation and safeguarding of recharge areas from external stressors. • Strengthen mechanisms for monitoring of environmental flows at hydropower sites. • Conduct studies on glacial lakes and methods for prevention and mitigation of GLOF events.	Forest, Environment and Wildlife Management Department (FEWMD), Department of Science and Technology and Climate Change (DSTCC), Rural Management and Development Department (RMDD), State Pollution Control Board (SPCB), village dzumsas
2. Decreased agricultural productivity due to increasing temperature, increasing frequency of drought, and more erratic precipitation patterns	• Promote climate-smart agricultural practices, particularly with respect to pest management, disease control, irrigation, and soil conservation. • Select suitable crops, particularly traditional varieties, especially those that appeal to tourists interested in local food. • Explore the possibility of winter farming as an opportunity. • Build capacity of local farmers with respect to climate-smart agricultural practices through study tours. • Conduct value chain studies for local organic produce.	Department of Food Security and Agriculture Development (DFSAD), the Horticulture and Cash Crop Development Department (HCCDD), WWF in partnership with DLR-Prerna, Indian Council of Agricultural Research, Krishi Vigyan Kendra Agricultural Extension Center (KVK), and village dzumsas
3. Increased incidence of yak disease believed to be due to increasing temperature	• Conduct research on the extent of this problem and the types of diseases involved, beginning with a survey of livestock owners in the survey area. • Build local capacity for identifying and controlling yak disease outbreaks, particularly through relevant government agencies. • Establish mobile veterinary clinics for vaccinating and treating affected livestock in North Sikkim.	Department of Animal Husbandry (DAH), FEWMD, WWF, village dzumsas, Lachen Tourism Development Committee (LTDC), KVK
4. Increasing incidence of forest fires due to increasing temperature and increasing incidence of drought	• Install wildfire early warning systems in fire prone areas. • Conduct a public awareness campaign about how to prevent forest fires. • Train FEWMD community members on forest fire prevention and control.	FEWMD, WWF, District Collector Office, Sub-divisional Magistrate, State Police
5. Increased proliferation of invasive species at higher elevations due to increasing temperature	• Start a program of active forest management that includes control of undesirable invasive species	FEWMD, WWF, State Biodiversity Board

Table 8. Possible adaptation actions for North Sikkim District proposed by expert participants of the December 17, 2016 climate vulnerability workshop in Gangtok, Sikkim (Continued)

Impact	Possible Adaptation Actions	Responsible Agencies
Mixed Climate Change and On-site Human Impacts		
6. Habitat fragmentation resulting from increasing temperature that leads to an upslope shift of low elevation species as well as poorly-planned development activities such as road building	• Conduct a study on distribution of rare species in North Sikkim and delineate areas of critical habitat that need to be safeguarded. • Establish new and maintain existing biological corridors between both current habitat patches and potential climate refuge areas.	FEWMD, WWF
7. Increasing human wildlife conflict due to rising temperature that may be shortening bear hibernation periods and preventing yak herders from moving to lower elevations in winter. Also, opening of remote areas to increasing human occupation through road construction and other infrastructure development	• Perform a comprehensive study on why human-wildlife conflict of all types is increasing in North Sikkim. • Construction of bear-proof corrals where needed. • Develop a state policy on human-wildlife conflict, including compensation mechanisms, to address the issue.	FEWMD, WWF, other North Sikkim District Line Agencies, State Police
8. Unsustainable non-timber forest product (NTFP) harvesting practices by local residents, the impacts of which will likely be exacerbated by climate change	• Systematically implement the existing state policy on harvesting caterpillar fungus. • Educate collectors and relevant agencies about sustainable NTFP practices. • When possible, promote home cultivation of NTFPs, such as satwa (*Paris polyphyla*) to preserve this resource in the wild. • Conduct distribution mapping of economically important NTFPs to better understand their ecology and improve policy on their collection. • Develop adaptation strategies for improving the resilience of NTFP collection areas to climate change impacts.	FEWMD, WWF, village dzumsas
9. Decline in herding of yaks and sheep among the younger generation, leading to loss of traditional knowledge of these practices that might otherwise be used to develop effective livelihood adaptation strategies for highland residents of North Sikkim.	• Conduct a study to document traditional knowledge of livestock herding practices in North Sikkim. • Diversify livelihood options by introducing yak wool processing and craft making techniques to North Sikkim. • Provide incentives for herding yaks and sheep following traditional rotational grazing practices.	DAH, village dzumsas

Table 8. Possible adaptation actions for North Sikkim District proposed by expert participants of the December 17, 2016 climate vulnerability workshop in Gangtok, Sikkim (Continued)

Impact	Possible Adaptation Actions	Responsible Agencies
On-site Human Impacts		
10. Improper road design and construction that combined with climate change impacts, such as increasingly intense rainfalls, can trigger catastrophic landslides and strand locals and tourists when poorly-designed roads and bridges are washed away by floods	• Educate agencies responsible for road building about the adverse impacts of road construction on ecosystems, biodiversity, and slope stability. • Improve the Environment Impact Assessment (EIA) process for road and infrastructure development to make it more rigorous. • Develop climate-smart best environmental practices for road and infrastructure development to improve resiliency of landscapes affected by both development and climate impacts	FEWMD, State Roads and Bridges Department, RMDD,
11. Impacts of tourism, particularly on high-altitude alpine scenic areas that are already being severely impacted by climate change, including increased cutting of fuel wood, transmission of livestock disease by tourists carrying their own meat supplies from lowland areas, contamination of water sources, increased black carbon emissions from vehicles, and increased volumes of trash in remote areas	• Conduct a study to determine the carrying capacity of tourist destinations in North Sikkim with respect to tourist numbers. • Promote use of clean fuel vehicles in North Sikkim to reduce black carbon emissions that may be contributing to acceleration of melt rates of snow and glacier ice. • Promote responsible and sustainable tourism practices amongst tourism industry workers and tourists themselves. • Identify critically important areas with respect to ecology and biodiversity in North Sikkim, such as blue sheep lambing grounds, and restrict or prohibit tourists from entering these areas.	village dzumsas, WWF
12. Increase in feral dog populations that survive by following road construction and border patrol camps as well as by killing livestock and wildlife. Their survival rate may be increasing due to increasing temperature.	• Conduct a study on the cause of the feral dog population increase. • Start a feral dog sterilization program in high-altitude areas of North Sikkim and provide incentives for capture of feral dogs for sterilization in these areas. • Launch an awareness campaign on the negative ecological impacts of the local feral dog population and methods for reducing the feral dog population.	TCAD, Sikkim Tourism Development Corporation (STDC), FEWMD, Eco-Conservation Society of Sikkim (ECOSS), LTDC, WWF, village dzumsas

6. Overall Recommendations

6.1 Mainstream climate adaptation into planning processes

Integrating climate change considerations into government planning processes at the village (gram panchayat development plans), district, and state levels is essential. This includes integrating the identification of climate related risks, impacts, and vulnerabilities into all biodiversity conservation and developmental planning activities. Such efforts need to be promoted at both the state and district level to ensure local adaptation planning is reflected in state-wide plans.

New climate change-related impacts will continue to arise in coming decades. However, present climate variability and consistent climatic trends of increasing temperatures, erratic rainfall, and decreasing snowfall in the region will have severe consequences for life in North Sikkim in the short to medium term. Therefore, it is crucial to ensure future risks are embedded into planning of all conservation and development activities.

6.2 Revisit the State Action Plan on Climate change (SAPCC)

The State Action Plan on Climate Change (SAPCC) was drafted in 2011 by the Sikkim government in consultation with various line departments, civil society organizations, and academic institutions (SAPCC 2011). The adaptation strategies outlined in this plan take into account the likely vulnerabilities that will result from projected climate change scenarios for the state in the following sectors: water security; agriculture and livestock; biodiversity, forests, wildlife and ecotourism; urban and rural habitats; and urban transport.

The strategies laid out in the SAPCC six years ago should be revisited for relevance in the present context and measures put in place for large scale implementation of the plan. Further detailed research will have to be pursued vigorously given that existing information is limited, particularly in the North Sikkim District, and the understanding of climate change impacts on certain species is poor. Such an effort will greatly help in synergizing local efforts to both climate-smart state development plans and streamlining action on climate change among various state departments.

6.3 Strengthen research, long term monitoring and data collection

For improving understanding of climate change and its impact in North Sikkim as well as to plan necessary adaptation interventions in the district, long term climatic data is essential. These data will be critical for determining current climatic trends and for future climate projections. Currently there are huge data gaps, which is an impediment for any informed decision making and planning to take place. Therefore, it is recommended that community -based hydro-meteorological monitoring systems be set up and that community members be trained to maintain them. There is also an urgent need to generate more knowledge not only of climate change impacts but also of the negative environmental impacts of human activities in North Sikkim.

6.4 Enhance awareness of climate change impacts and the urgency of this issue

Climate change is a complex global issue with local repercussions, most often lacking local awareness of its causes and local capacity to address its impacts. Therefore, there is an urgent need to enhance general awareness of climate change causes and impacts and the capacity to address and adapt to these impacts at a local level. Mobilizing district-level authorities and local communities to address climate change-related impacts and hazards in North Sikkim is a critical need. Therefore, a sustained process for multi-stakeholder engagement to address this need is of utmost importance.

6.5. Integrate Ecosystem Based Adaptation Approaches

While in the short-term it is not possible to halt glacial retreat and the upward shift of treeline that is occurring as a result climate change, it is important to ensure that all ecosystems continue to provide important ecologic, economic, social, and cultural benefits for humans and wildlife long into the future. Thus, it is important that awareness is raised on how healthy ecosystems regulate climatic or natural hazards, increase resilience of landscapes, and support human populations that depend both directly and indirectly on local ecosystems. Therefore, there is an urgent need to promote traditional sustainable natural resource management practices as well as traditional ecosystem restoration and protection strategies. This approach is referred to as Ecosystem Based Adaptation, which is defined as “the use of biodiversity and ecosystem services to help people adapt to the adverse effect of climate change” (CBD, 2009).

7. Conclusion

No matter who the people are, or where they live, human well-being depends on properly functioning ecosystems. Ecosystem services have become a mainstream concept for the expression of values assigned by people to various functions of ecosystems. Most obviously, ecosystems can provide material things that are essential for daily lives, such as food, wood, wool, and medicines. Although other types of benefits from ecosystems are easily overlooked, they can also play an important role in regulating the environments in which people live. They can help ensure the flow of clean water and provide protection from hazardous events. They can even contribute to people’s spiritual well-being, through their cultural or religious significance.

This vulnerability assessment was based on the Flowing Forward methodology and is meant to improve understanding of vulnerability of various aspects of climate change and development activities in the North Sikkim District (Le Quesne et al., 2010). Many of the findings are based on review of available literature, community perceptions, and the findings of the expert workshop on climate vulnerability assessment in North Sikkim, which brought together key resource people from various fields. While the assessment findings with respect to present and future climate change impacts on North Sikkim are fairly broad, it should be kept in mind that in-depth scientific research is urgently needed on potential impacts of climate change on the ecology of high altitude areas of the district, particularly those that will directly or indirectly affect people, livelihoods, cultures, and ecosystems.

The critical ecological importance of the high-altitude areas of the North Sikkim District cannot be overstated. As the water towers of the state, these areas with countless glaciers, fresh water wetlands, streams, and rivers provide ecosystem services to a vast majority of downstream populations in the state. The presence of many important species, chief among these, the snow leopard, also makes this region a biodiversity hotspot within the state. The existence of the nomadic Dokpas in the higher elevations, and the Lachenpas and Lachungpas, who follow age old traditional cultural practices, is largely dependent on the natural resources base that surrounds them. And these people add to the cultural value of the landscape.

As this climate vulnerability assessment shows, all of the above elements that make up the ecologically fragile landscape of North Sikkim are at risk to varying degrees from climate change-related impacts. At the same time, development in these areas is also proceeding at an unprecedented pace, the impacts of which are being severely exacerbated by climate change impacts. Thus, there is an urgent need for better development policy coordination across all sectors to collectively address climate change impacts in this fragile high altitude region. In particular, local-level adaptation plans to build the resilience of local ecosystems and communities to climate change and other stressors, such as development impacts, is the need of the hour.

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Appendices

APPENDIX 1:
Future Temperature and Precipitation Projections

Source: Peters, D., Bader, D., McKenna, Marconi, B., M., Shrestha, R., Bartlett, R., Lesk, C., De Mel, M., and Horton, R. 2017. Climate Change in the Snow Leopard Landscapes of Asia's High Mountains: Technical Report. New York, NY, USA: Center for Climate Systems Research and Columbia University and WWF-US.

Landscape coordinates: [E87.75, N28.25 – E89.50, N26.00]

Figure B.3.1. Model baseline (1980-2005) monthly temperature and precipitation in Sikkim.

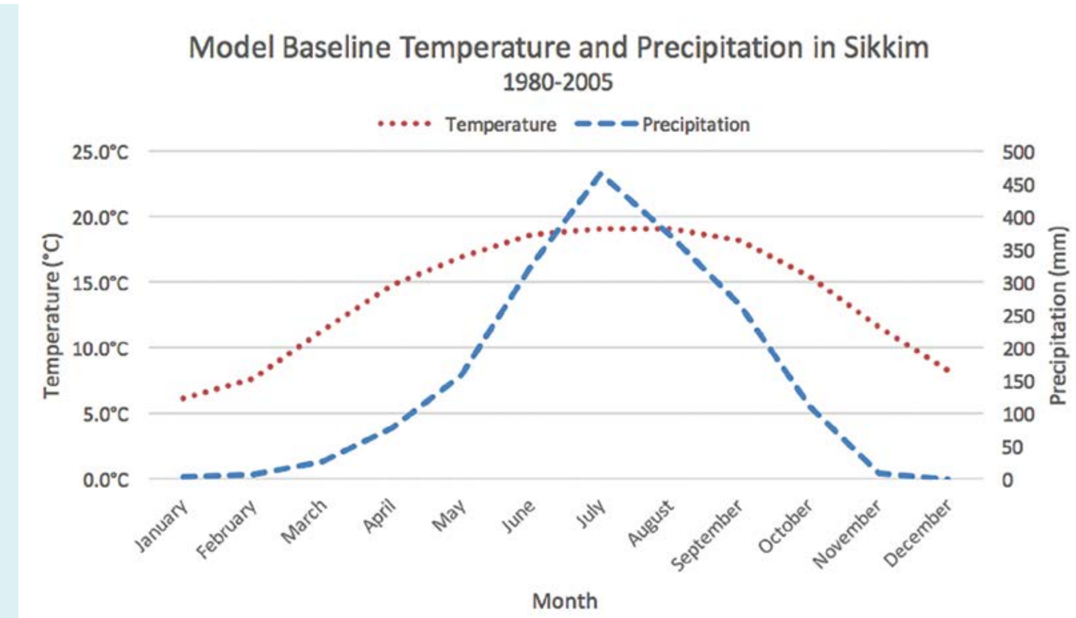

Table B.3.1. **Monthly average baseline temperature (°C) in 1980-2005 and projected change in monthly average temperature (°C) in Sikkim in the 2011-2040 and 2041-2070 time periods compared to the baseline.**

Month	Average Baseline Temperature 1980-2005 (°C)	Projected Average Temperature in 2011-2040 (+°C in relation to baseline)	Projected Average Temperature in 2041-2070 (+°C in relation to baseline)
Annual	13.9°C	+0.8°C to +1.2°C	+1.7°C to +2.5°C
January	6.2°C	+0.9°C to +1.6°C	+2.1°C to +3.1°C
February	7.7°C	+0.9°C to +1.4°C	+2.1°C to +2.9°C
March	11.3°C	+1.1°C to +1.5°C	+2.2°C to +3.0°C
April	14.8°C	+0.9°C to +1.5°C	+1.9°C to +3.0°C
May	17.0°C	+0.8°C to +1.5°C	+1.6°C to +3.0°C
June	18.7°C	+0.6°C to +1.4°C	+1.5°C to +2.7°C
July	19.1°C	+0.5°C to +1.1°C	+1.2°C to +2.2°C
August	19.1°C	+0.6°C to +1.1°C	+1.4°C to +2.2°C
September	18.2°C	+0.6°C to +1.1°C	+1.6°C to +2.3°C
October	15.5°C	+0.7°C to +1.1°C	+1.6°C to +2.3°C
November	11.6°C	+0.8°C to +1.4°C	+1.8°C to +2.7°C
December	8.3°C	+0.8°C to +1.5°C	+2.0°C to +2.9°C

Table B.3.2. **Monthly average baseline precipitation (mm) in 1980-2005 and projected change in monthly average precipitation (%) in Sikkim in the 2011-2040 and 2041-2070 time periods compared to the baseline.**

Month	Average Baseline Precipitation 1980-2005 (mm)	Projected Average Precipitation in 2011-2040 (% change in relation to baseline)	Projected Average Precipitation in 2041-2070 (% change in relation to baseline)
Annual	1820 mm	+5% to +17%	+9% to +29%
January	4 mm	-27% to +18%	-30% to +8%
February	6 mm	-19% to +16%	-25% to +24%
March	27 mm	-18% to +19%	-18% to +30%
April	78 mm	-23% to +21%	-15% to +28%
May	158 mm	+2% to +47%	-4% to +57%
June	327 mm	-5% to +18%	-5% to +29%
July	466 mm	-1% to +24%	-2% to +31%
August	370 mm	+1% to +21%	+10% to +41%
September	265 mm	-7% to +24%	+8% to +40%
October	110 mm	-6% to +17%	-9% to +40%
November	8 mm	-25% to +54%	-22% to +41%
December	0 mm	-54% to +46%	-49% to +61%

APPENDIX 2:
Definition of key terms

Source: Modified from Sherchan R, Bartlett R and Dongol B (2012). Climate Change Vulnerability Assessment: The Tamor River Sub-Basin, Nepal. Workshop report 2012.

Adaptation: The adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderate harm or exploit beneficial opportunities.

Adaptive capacity: The qualities of systems to adjust in response to climate change shocks, conditions or situations is termed as adaptive capacity.

Connectivity: Measures to what extent the system has corridors that allow for key biodiversity to migrate within or across ecosystems to escape climate shocks.

Detrimental non-climatic pressure: The extent to which the ecosystem faces anthropological pressure.

Exposure: Defines the nature and the amount to which the system is exposed to climate change phenomenon.

Natural variability: Measures the extent to which natural disturbance events like floods, drought, or landslides regularly occur.

Refugia: Measure of whether the ecosystem provides a refuge from climate shocks for important biodiversity through microclimatic variation.

Sensitivity: Reflects the system's potential to be affected (adversely or beneficially) by such changes.

Vulnerability to climate change is defined as "the degree to which a system is susceptible or unable to cope with adverse effects of climate change, including climate variability and extremes". Vulnerability is the function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity. Types of Vulnerability:

- Bio-physical vulnerability is dependent upon the characteristics of the natural system itself.
- Socio-economic vulnerability is affected by economic resources, power relationships, institutions or cultural aspects of a social system.

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