# Climate Crisis in the Indian Himalayas: An Introduction

**Ashima Sharma and Renu Masiwal**

**Abstract** The Indian Himalayan Region (IHR), known for the stunning beauty and rich biodiversity, is facing an unprecedented climate crisis. The fragile ecosystem, which supports millions of people, is under threat due to human activities such as deforestation, overgrazing, urbanization and industrialization, compounded by the prevailing threat of climate crisis. Unparalleled variations witnessed in weather patterns, and ecological imbalances threatens the ecosystem. The region is exceedingly vulnerable to the implications posed by climate change, such as warming temperatures, melting glaciers, and erratic weather patterns. Moreover, climate-induced extreme weather events have become progressively common, resulting in property damages and life losses. The rising temperatures have resulted in accelerated melting of glaciers, which poses a significant threat to the region's water resources, biodiversity, and local communities' livelihoods. The situation in the Indian Himalayas is alarming, and urgent action is required to mitigate the effects, including sustainable and community-based practices, natural resource management, and concerted efforts to reduce greenhouse gas emissions, addressing both local and regional level pollutants. Failure to address this crisis threatens the future of the region and its inhabitants. In this context, this chapter will introduce the various factors contributing to the climate crisis in the Indian Himalayas and explore potential solutions to address the issue.

**Keywords** Indian Himalayan Region (IHR) · Climate crisis · Fragile ecosystem · Climate change · Extreme weather events · Indian Himalayas

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A. Borthakur and P. Singh (eds.), *Addressing the Climate Crisis in the Indian Himalayas*, https://doi.org/10.1007/978-3-031-50097-8_1

# 1 The Great Indian Himalayas

## *1.1 Introduction*

Himalayas are the youngest mountains on the planet, spread across a length of 3000 km that covers an area of around 3.44 million km$^2$ (Kumar et al., 2018a). These mountains not only support the ecology and the economy, but their diverse geographical features, such as the towering peaks, deep valleys, glaciers, rivers, and alpine meadows, advance diverse cultural and ecological richness. They are also referred to as the "water tower of Asia". This denotes the potential of the complex orography of these mountain ranges and their interaction with the monsoon system that helps generate enormous precipitation leading to richness of water resources in this region (Bandyopadhyay & Modak, 2022). The range encompasses some of the highest peaks in the world, such as the Nanda Devi, Kanchenjunga, as well as the legendary Mount Everest.

The Indian Himalayas are both majestic and breathtaking, and act as a northern natural boundary line to the country. The Indian Himalayan Region (IHR) comprises 0.537 million km$^2$ area of the country, which translates to nearly 16.2% of the total geographical area (Kumar et al., 2018a). The IHR spreads between 21° 57′–37° 5′N and 72° 40′–97° 25′E, and covers a span of 13 Indian states and/Union Territories as shown in Fig. 1 (Babu et al. 2021; Kumar et al., 2018a). The salient characteristics of these Himalayan States and/Union Territories is given in Table 1.

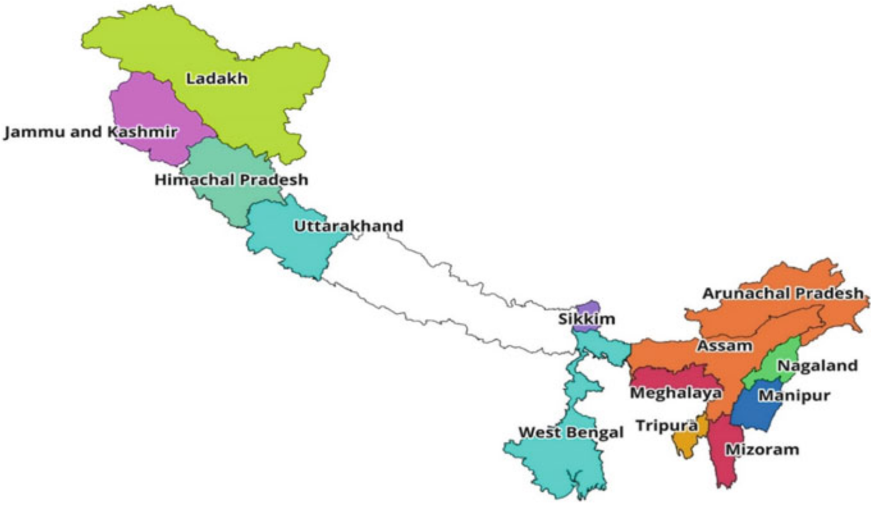


**Fig. 1** The Indian Himalayan Region (IHR). *Source* Authors (Software used: QGIS)

**Table 1** Salient Characteristics of the Indian Himalayan states

| States | Geographical area ($km^2$) | Population (As of 31.12.2020) | Population growth % (2019–2011) | Forest cover 2021 Assessment (area in sq. km) | |
|---|---|---|---|---|---|
| | | | | Total forest | % of geographical area |
| Arunachal Pradesh | 83,743 | 15,70,458 | 13.49 | 66,431 | 79.33 |
| Assam | 78,438 | 3,56,07,039 | 14.10 | 28,312 | 36.09 |
| Himachal Pradesh | 55,673 | 74,51,955 | 8.56 | 15,443 | 27.73 |
| Manipur | 22,327 | 30,91,545 | 8.26 | 16,598 | 74.34 |
| Meghalaya | 22,429 | 33,66,710 | 13.48 | 17,046 | 76.00 |
| Mizoram | 21,081 | 12,39,244 | 12.95 | 17,820 | 84.53 |
| Nagaland | 16,579 | 22,49,695 | 13.71 | 12,251 | 73.90 |
| Sikkim | 7096 | 6,90,251 | 13.05 | 3341 | 47.08 |
| Tripura | 10,486 | 41,69,794 | 13.50 | 7722 | 73.64 |
| Uttarakhand | 53,483 | 1,12,50,858 | 11.55 | 24,305 | 45.44 |
| Jammu & Kashmir | 2,22,236 | 1,36,06,320 | 11.00 | 21,387 | 39.15 |
| Ladakh | | 2,89,023 | −0.51 | 2272 | 1.35 |

*Sources* Adapted and modified from: Kumar et al. (2018a); https://uidai.gov.in/images/state-wise-aadhaar-saturation.pdf; https://statisticstimes.com/demographics/india/indian-states-population.php; https://frienvis.nic.in/Database/Forest-Cover-in-India-2021_3550.aspx

## *1.2 Climate and the Geology*

The Himalayas shows a great climatic variability, including the tropical humid climatic conditions to the cold Alpine tundra (Paudel et al., 2021). These ranges serve as a natural barrier for the summer monsoons, in addition to the winter westerlies (Chalise, 2001). There are evident disparities in rainfall with elevation, mainly due to the orographic nature of the monsoon rainfall (Eriksson et al., 2009). There is also a discernable prevalence of winter accumulation and summer ablation processes within the Himalayan glaciers, and this release of water due to melting eventually serves as a feedstock for numerous rivers downstream (Eriksson et al., 2009).

The Himalayas are broadly divided into: (1) The Greater Himalayas (or the Himadri), (2) the Lesser Himalayas (or the Himachal), and (3) the Outer Himalayas or the foothills (or the Shivalik hills) (Eriksson et al., 2009; Sorkhabi, 2010). Roy (2014) reports that the Himadri is made up of thick metamorphic rocks (schist and gneiss) and granites, the Himachal consists of metamorphosed sedimentary rocks (quartzite, marble, slate, etc.) and minor volcanic and granitic rocks while the Shivalik range is made up of sandstone and mudstone shed from the Himalayan mountains, and carried, deposited by the rivers.

The reason that the Himalayan mountains are considered geologically young is that they are still growing due to movement of tectonic plates and henceforth experiencing upliftment rates between 0.5–4 mm/year (Godard et al., 2014). This is also one of the reasons behind the vulnerability of this region to natural disasters.

## *1.3 Rivers, Forests and the Biodiversity*

One of the defining features of the Indian Himalayas is its glacial landscape. Nearly 17% region of Indian Himalayas are under the permanent snow cover and glaciers (Kumar et al., 2018a, 2018b; Singh, 2006), including the Gangotri, Yamunotri, and Siachen glaciers etc. Several rivers also originate from these mountain ranges, including the mighty Ganges, the vast Yamuna, the massive Brahmaputra etc. Around 30–40% glaciers are under seasonal snow cover and feed these rivers (Kumar et al., 2018a, 2018b; Singh, 2006). Every year around 12,00,000 million $m^3$ water flow through Himalayan rivers (Kumar et al., 2018a, 2018b; Singh, 2006). These rivers not only provide water for irrigation and domestic use but also hold immense cultural and spiritual significance for millions of people who consider them sacred. These water bodies also support a great range of species diversity.

The one-third of India's undisturbed forests are located in the IHR. Around 41.5% land of IHR are under forest cover (Kumar et al., 2018a, 2018b; Singh, 2002). The IHR supports a number of diverse ecosystems including alpine meadows, temperate forests, and high-altitude wetlands. These serve to sustain a wide variety of endemic and endangered flora and fauna.

Based on ecological diversity, this region is divided into three ecological zones: (1) the subtropical foothill zone (altitude < 800 masl), (2) the temperate forest zone located between the foothill zone and timber line (altitude around 2800 masl) and, (3) the alpine and sub alpine zone, located above the timber line, rich in bushes, grasses and herbs (Negi et al., 2022). This region is one of the 36 global biodiversity hotspots, meaning areas that supports high degree of endemic species and are under high anthropogenic risks (Hamid et al., 2019).

Several studies have reported the abundant biodiversity that the IHR is enriched with. Butola et al., 2007 reports that the region is home to 21 forest types, 18,440 plant species; 816 tree species; 1748 species of medicinal plants; 675 species of wild edibles; 279 species of fodder; 155 species of sacred plants and 118 species of essential oil yielding medicinal plants. This region is also home to nearly 50% of the flowering plant population in India. Another interesting fact is that nearly 30% of these flowers are endemic to the region (Kumar et al., 2018a, 2018b; Negi et al., 2022). Table 2 reports the different categories of species and their numbers in the region.

**Table 2** Species richness in Indian Himalayas. *Source* Adapted from the data of Kumar et al. (2018a)

| Category | Number of species | Endemism (%) |
|---|---|---|
| Angiosperms | 8000 | 40 |
| Gymnosperms | 44 | 16 |
| Pteridophytes | 1737 | 25 |
| Lichens | 1159 | 11 |
| Fungi | 6900 | 27 |

## *1.4 Ecosystem Services*

The Indian Himalayas provides a range of goods and services (Fig. 2), which not only support the livelihood of the local communities but also contributes enormously to the nation's GDP (Bahuguna & Bisht, 2013; Badola et al., 2010; Negi et al., 2022;). A few ecosystem services associated with forests of the Indian Himalayas are climatic and hydrologic regulation, sequestration of carbon, formation of soil, decreasing soil erosion, improving water quality, filtering pollutants from water, recreational services etc. (Bahuguna & Bisht, 2013; Badola et al., 2010; Kumar et al., 2018a, 2018b; Negi et al., 2022).

The total financial value of these ecosystem services is too high and at present, we as consumers do not pay for these services. Many ecologists and economists have attempted to calculate this and the minimum estimated value is around $ 33 trillion/


**Fig. 2** Ecosystem services provided by Indian Himalayan Region. *Source* "Authors"

year (Costanza et al., 1997). As per an article in Down to Earth by Mapahaptra (2019), the total estimated monetary value of the forest ecosystem services provided by the Indian Himalayan region is around Rs 94,300 crore/year, wherein the forests of the Uttarakhand alone provide services estimated at Rs 10,700 crore / year.

The IHR states are also recognized as India's water reservoir. The watershed services of Himachal Pradesh are assumed to be of nearly Rs 1.06 lakh crore per year (Mahapatra, 2019). Studies reported that the undisturbed forests of Sal, pine and oaks of Uttarakhand, sequester around 4–5 t C $ha^{-1}$ $yr^{-1}$ (Singh, 2007). Further estimations also suggest that the total forest biomass of Uttarakhand to be around 6.61 M t/year, which translates into a net worth of Rs. 3.82 billion (Singh, 2007). Another example is of a study where Badola et al. (2010) estimated the monetary value of forests of the Corbett National Park, observing carbon mitigation worth nearly $64 million/year, while the recreational value estimated at $167,000/year.

Besides timber, the forests also provide other plentiful forest products such as seeds, medicine, flowers, etc. These are further useful as edible products, used in cooking or lighting, providing employment to thousands of people, medicinal purposes, etc. (Negi et al., 2022; Pant, 2015; Singh, 2007).

## *1.5 Cultural and Spiritual Services*

The Indian Himalayas are also a cultural and spiritual hub. It is one of the most commonly visited places as far as religious tourism is concerned, as it is the home to many religious shrines, sacred and naturally scenic places. Some famous destinations frequented by travelers across the world include the Badrinath, Kedarnath, Gangotri, Yamunotri, Hemkund Sahib, etc. in Uttarakhand, Manimahesh, Jwala Devi and Chintpurni in Himachal Pradesh, Vaishno Devi and Amarnath in Jammu and Kashmir, Khecheopalri and Gurudongmar lakes and the Buddhist monasteries in Sikkim, etc. (Kumar et al., 2018a, 2018b). The region is dotted with ancient temples, monasteries, and pilgrimage sites. The Himalayas have also inspired generations of poets, writers, and artists, who have depicted its grandeur and mystique in their works. Tourism here, is both in the form of pilgrimage trips to religious sites, or to the cooler hill stations such as Darjeeling, Nainital, Mussoorie, and Shimla, and the river sources located high up in the mountains (Kumar et al., 2018a, 2018b). The IHR receives both domestic and international tourists who play a vital role in its economy. Activities like trekking, mountaineering, river rafting, and wildlife exploration, contribute to the local economy and provide employment opportunities to the local communities. The tourism business is highly lucrative in the IHR, for the government as well as for the private investors, providing them with a source of income, business opportunity and work. According to Report of Working Group II Sustainable Tourism in the Indian Himalayan Region released by the NITI Aayog the tourism sector contributes around US$ 71.5 billion/year to the national GDP (Fig. 3).

However, the Indian Himalayas have been at the receiving end of the impacts of the climate crisis and human activities, that have posed significant challenges to

**Fig. 3** The Chandak Hills, Pithoragarh, Uttarakhand. *Source* "Authors"

this fragile ecosystem, leading to habitat loss, species extinction, and disruptions in the delicate ecological balance (Kumar et al., 2018a, 2018b; Negi et al., 2022). The region is experiencing the consequences of global warming, leading to glacial retreat and altered precipitation patterns. The retreat of glaciers threatens the stability of the region's water supply, impacting agriculture, hydropower generation, and freshwater availability downstream. Changes in rainfall patterns have resulted in droughts, water scarcity in some areas, and devastating floods and landslides in others (Bandyopadhyay & Modak, 2022; Eriksson et al., 2009).

The Himalayas mean "home of snow" which given the climate crisis we are facing; one day might go obsolete (Bandyopadhyay & Modak, 2022; Eriksson et al., 2009; Masiwal et al., 2022a). The decrease in snow accumulation in the higher peaks would lead to acute water scarcity in near future. Studies report that owing to the changing climate, there might be formation of a large number of glacial lakes, with rapid increase in their water level due to the increased rate of snow and ice melting (Bandyopadhyay & Modak, 2022; Eriksson et al., 2009; Gantayat & Ramsankaran, 2023; Ives et al., 2010) As the Himalayan region fall under active seismic zone, a sudden jerk could lead to tsunami of water, mud and ice which could wash away all the infrastructure, field, livestock, and people (Kumar et al., 2018a, 2018b).

And if we talk about short term impact of climate impact, the melting of glaciers and unpredictable seasonal rainfall may lead to intense floods while the lack of rainfall can cause a drying spell over this region. Studies have predicted a fall in the water flow which would lead to catastrophic consequence as more than a billion people depend on its fresh water system for various purposes such as domestic, industrial, agricultural and power generation.

Henceforth, there is a need to restore balance between economic interests and environmental liabilities. This chapter will introduce the various factors contributing to the climate crisis in the Indian Himalayas and explore potential solutions to address the issue.

## 2 Climate Crisis: One of the Most Sensitive Issues of the Present World

The climate crisis is one of the most urgent and escalating global environmental challenge caused by human-induced climate change. It refers to the profound and wide-ranging impacts of the consequences of climate change (McCarthy, 2001). It poses an unprecedented threat to humanity and the planet as a whole. This crisis is driven by human activities, such as burning of fossil fuels, deforestation, unsustainable agricultural practices (McCarthy, 2001). The consequences are far-reaching, affecting ecosystems, water resources, food security, public health, and socio-economic stability (McCarthy, 2001).

It is evident in the form of rising global temperatures, that is a primary indicator of the climate crisis. Another indicator of climate crisis are the extreme weather events, that tend to occur more frequently and intensely as the climate warms. Heatwaves, droughts, hurricanes, cyclones, and heavy rainfall events are becoming more common, causing widespread damage, displacement of communities, and loss of life. These events also pose significant challenges to food production, water resources, and infrastructure. The warming climate is causing melting of glaciers, ice caps, etc., triggering a rise in the sea levels, and putting low-lying coastal areas and islands at risk of inundation and increased vulnerability to storm surges.

Rising temperatures, changing precipitation patterns, and habitat disruptions also pose significant challenges for species survival. Many ecosystems, including coral reefs, forests, and Arctic and alpine ecosystems, are experiencing rapid shifts, affecting the distribution and abundance of species. This further has far-reaching consequences for ecosystem services, food security, and human well-being, posing substantial risks to human health. Increased heatwaves contribute to heat-related illnesses and deaths, increased tendency of infectious and vector-borne diseases, etc. Air pollution, worsened by climate change, further exacerbates respiratory problems. Disruption of food systems and increased malnutrition are also concerns (Fig. 4).


**Fig. 4** Enhanced Infrastructure development in the Himalayan regions. *Source* "Authors"

The climate crisis has wide-ranging socio-economic implications. Agricultural productivity is affected by changing weather patterns, leading to food insecurity and economic instability for farming communities. Disasters associated with extreme weather events result in significant economic losses and strain on resources for response and recovery. Displacement of communities happen due to sea-level rise and environmental degradation creates social and humanitarian challenges (McCarthy, 2001).

Urgent action is needed to restore ecosystems, and implement resilient adaptation measures. Addressing the climate crisis requires collective efforts from all stakeholders, to ensure a sustainable future.

## 3 Factors Contributing to the Climate Crisis Over the Indian Himalayan Region

The sensitive and fragile Himalayan ecosystem is facing a threat of unscientific development and consequential climate change. There are several factors contributing to the climate crisis, exacerbating the environmental challenges already present in the region. These factors include:

### *3.1 Deforestation*

Agriculture, logging, and infrastructure development are the key reasons that contribute to deforestation, leading to climate crisis in the Indian Himalayas (Fig. 5). Between 1976 and 2014, Batar et al (2017) reported a decrease in forest cover area in the Rudraprayag district of Garhwal Himalaya due to an increase in agricultural land. Forests are of vital importance in capturing and storing carbon dioxide, functioning as carbon reservoirs. With deforestation happening, this carbon storage mechanism is disrupted, releasing previously stored carbon into the atmosphere and diminishing the region's capacity to counteract greenhouse gas emissions (Pant, 2015; Negi et al., 2022; Singh, 2007). According to the State of Forest Report, 2021, a loss of around 902 $km^2$ forest cover since 2019, has been observed, more evidently in the Himalayan states, wherein a cumulative forest area reduction in the 13 states, reducing down to 219,866 $km^2$ from 222,534 $km^2$.

### *3.2 Change in Land Use and Land Cover*

The soil is a great sink of carbon; however, the rate of accumulation varies significantly from one ecosystem to another (Negi et al., 2022; Pant, 2015; Singh, 2007).

**Fig. 5** City of Pithoragarh, Uttarakhand. *Source* "Authors"

Clearing of even a small patch of forest can cause a potential loss of soil carbon. Singh (2007), reports that forest degradation in the Lamgarha block of Uttarakhand's Almora District, could lead to an annual loss of ~ 3-ton carbon per hectare. Moreover, the alpine meadows possess a substantial soil carbon reservoir, owing to their significant root-to-shoot ratio, which enables greater carbon capture compared to grasslands. Due to climate change and enhanced warming, people are shifting towards higher altitude and this migration of people to these regions means more conversion into agricultural land, and consequent release of soil carbon into the atmosphere in the form of $CO_2$ (Pant, 2015; Negi et al., 2022; Singh, 2007).

### *3.3 Overexploitation for Timber and Non-timber Based Forest Products*

Sal (*S. robusta*), teak (*Tectona grandis*) and deodar (*Cedrus deodara*) are considered as one of the best timber woods in India, costing around Rs. 13,000–51,000 per $m^3$ (Pant, 2015; Negi et al., 2022). Due to their high economical and commercial value, illegal logging is very common. Many times, forest mafias or timber smugglers start fires, to wipe away the evidence of tree felling and these practices pose a threat to the Indian Himalayan system.

Wild edible fruit plants have traditionally occupied an important position in the socio-cultural, spiritual and health care of rural and tribal lives, due to their nutritional efficiency, and also as a source of income (Joshi & Negi, 2011; Kapkoti et al., 2016).

Other non-timber-based forest products are also the reason behind the incessant logging and felling of trees. For instance, the Sal tree yields an oleoresin named Sal Dammar, used in incense and also in paints and varnishes, shoe polishes and as an astringent in diarrhoea and dysentery (Negi et al., 2022). Sal seeds are an important livelihood resource for poor people. A review of literature of a Central Himalayan state Himachal Pradesh (Masoodi & Sundriyal, 2020) screened 811 non-timber-based forest products (belonging to 495 genera) and found that maximum species were used for medicinal purpose (61.4%) followed by edibles (11.7%) and about 10% for fuel wood, fodder, essential oil, dyes, spices, tannins, resin, perfumes, religious purposes etc. High dependence on these products by the poor and marginal communities for domestic needs and excessive demand of these species creates an excessive pressure, resulting in an ecological disbalance.

### *3.4 Unsustainable Grazing*

An increase in population and growing demand of milk-based products has resulted in an increase in the livestock population. A study published by Sati (2016) the main livestock reared in the Himalayan state Uttarakhand include cow, buffalo, oxen, hen, goat, sheep and lamb. Also, shifts in cultivation pattern from crops to vegetable has reduced the fodder production and to meet this demand of fodder, forests were exploited (Tiwari et al., 2020).

### *3.5 Agriculture*

Agricultural practices (Fig. 6), including shifting cultivation, intensive farming, and livestock grazing, have a significant impact on the climate crisis in the Indian Himalayas. These agricultural practices result in soil erosion, loss of top soil and soil nutrients (Singh, 2007). Deforestation for agricultural expansion releases carbon stored in trees and contributes to greenhouse gas emissions. Furthermore, unsustainable agricultural practices, such as an incessant usage of chemical fertilizers, wasteful irrigation, can lead to soil degradation, reduction in carbon sequestration, and increased emissions of the greenhouse gases.

Apart from this, the Himalayas has smallholder farming and these farmers has experienced increasingly erratic rainfall, drought and floods, higher temperatures,

**Fig. 6** Infrastructure development in Himalayas. *Source* "Authors"

and a rise in crop pests and diseases, leading to lower yields. In the central Himalayas, the drop in rainfall is thought to have exacerbated forest degradation, leading to more crops being devastated by wild animals, especially wild boars. As a result, income from and interest in farming have declined and many young people are moving to urban areas for work (Mukerjee et al., 2018).

### *3.6 Illegal Hunting*

Over exploitation of natural resources and augmented developmental activities in this region has given rise to human-wildlife conflicts in the form of habitat loss or fragmentation or even degradation, triggered by activities like poaching, illegal trade, etc. These human activities have led to the continuous decrease in wildlife population and reduction in distribution range and also in some cases local extinction of species (Rana & Kumar, 2023). The endangered tiger (*Panthera tigris*) and vulnerable great one-horned rhinoceros (*Rhinoceros unicornis*) hunted for their body parts for their apparent usage in the traditional Chinese medicines, and the vulnerable snow leopard (*Panthera uncia*) and endangered red panda (*Ailurus fulgens*) that are sought for their beautiful pelts, while the Himalayan brown bear hunted for its gall bladder which is believed to be highly valuable for the traditional medicines whereas, bear skin claw and meat has commercial value. The poachers are quite active in this region and as per the forest department, they take advantage of forest fires to catch the animals. Sometimes they set intentional fires to bring out the wild animals from their hiding place. For instance, the state of Uttarakhand witnessed forest fires even during the month of winters under sub-zero temperature conditions (BSMS, 2023).

### *3.7 Mining*

Himalayas are the store house of minerals. Essential minerals like talc, limestone, magnesite is found in Uttarakhand, whereas mining of limestone, silica boulder and barite is underway in Himachal Pradesh. There are important mineral deposits in Jammu and Kashmir, including that of limestone, gypsum, magnesite, sapphire or Paddar (DST, 2019). In February 2023, the Geological Survey of India discovered 5.9 million tonnes of lithium resources in Jammu & Kashmir. Mining not only damages the Himalayan ecosystem but also slow down its regeneration process.

### *3.8 Alien Species*

These are the non-native species of a region. The Indian Himalayan region has abundance of nearly 190 alien species, falling under 112 genera and belonging to


**Fig. 7** Bushes of Lantana and Parthenium recorded in a Himalayan city (Pithoragarh, Uttarakhand). *Source* Authors

47 families (Hussain et al., 2016). The most aggressive of them are *Parthenium hysterophorus, Lantana camara, Ageratina eupatoriaare* (Fig. 7). These species have encroached a large area of Indian Himalayas, and also, due to their invasive nature, replaced a number of native Himalayan species (Pathak et al., 2019). As per studies, these species have replaced the forest floor vegetation and led to reduction in growth of forest trees. The invasive plants hinder the regeneration of the tree saplings, and may lead to an enhanced frequency of fires.

The rise in temperature due to climate change in the Himalayan region is not only a threat to the local species but also help to thrive these kinds of invasive species, that can survive such changes, and eventually may cause significant species loss. For instance, *Lantana camara*, is native to the tropical region of Africa and America and was brought in India as an ornamental plant in 1807 and placed in Botanical Garden of Calcutta, but later spread across road side, railway track and even reached to Himalayas (Negi et al., 2019). *Lantana* is a noxious weed, that invades the pasture land as well as the forests. It is a threat to wildlife habitat leading to rise in wild life conflicts. In Himalayan foot hills, the *Lantana* bushland provide shelters to wild boars which not only damage the crops, but also harms the local communities. It has caused major ecological problem in Garhwal and Kumaon region of Uttarakhand (Negi et al., 2019). The natural or intentional fires favours the growth of Lantana, as after fire, it shows a more vigorous growth.

### 3.9 *Infrastructure Development in the Eco-Sensitive Zone*

Himalayas are geologically fragile, vulnerable to hazards and disasters (Sinha & Upadhyay, 1995). The unscientific development in this region linked with urbanization, growth of infrastructure, development of road networks, implementation of hydropower projects, etc. are the major anthropogenic threats that have intensified the vulnerability of the region (Fig. 8).

**Fig. 8** Infrastructure development in the Indian Himalayan Region. *Source* Authors

The Himalayan states are quite eco-sensitive, and vulnerable to natural calamities especially the state of Uttarakhand and Himachal Pradesh. Majority of Himalayan states fall in zone IV and V of seismic zone classification, referring to the high-damage risk and very high-damage-risk areas, respectively.

Rapid infrastructure development are major factors contributing to the climate crisis in the Indian Himalayas (Grumbine & Pandit, 2013; Rao et al., 2016; Sabin et al., 2020). These activities often encompass deforestation, habitat destruction, and alteration of natural drainage patterns. Such changes exacerbate the impacts of climate change by intensifying water runoff, altering ecosystems, and increasing vulnerability to natural disasters. Activities like construction of multiple dams on a single river for optimum utilization of its energy potential has also been done. Grumbine and Pandit (2013) reported that the IH region will have the highest dam density in the world, with one dam in every 32 km of river channel. These dam constructions could lead to loss of direct submergence of forest land, and a consequent loss to the biodiversity. Studies hypothesize that the Joshimath disaster was caused by an ongoing hydroelectrical project. Bisht and Rautela (2010) reported that Joshimath is situated at an old landslide zone which is why, heavy construction is banned around it, however, the construction of hydroelectrical projects in these vulnerable regions cause havoc, including an increase in landslide incidents near the infrastructure development project sites (Fig. 8).

## 3.10 High Energy Demand

Due to the harsh topography and cold weather, majority of the households in the Indian Himalayan region depend upon traditional fuels such as wood, cow dung, agricultural residue for cooking and space heating (Fig. 9). The per household consumption of traditional fuel varies depending on size of the family, economical conditions, month of the year, and the region where household is located (Masiwal et al., 2021). Although, there has been a gradual shift towards cleaner fuels such as LPG, but with issues such as remote area accessibility, budget, etc., still a large population

**Fig. 9** Traditional Chullah, wood is used as a dominant source of fuel. *Source* "Authors"

**Fig. 10** Vehicular emissions and open-waste burning lead to air pollution over the Indian Himalayan Region. *Source* Authors

of rural households depend upon fuel wood for their daily requirements. These are mainly sourced from the forests, and on burning emits ample gaseous and particulate pollutants.

## *3.11 Tourism*

The Indian Himalayas attract millions of tourists each year from across the world, who come to visit religious shrines, sacred places and beautiful scenic places, perform adventure activities, attain spiritual experiences, and to explore nature. Apart from this there are many thick forested and biodiversity rich regions which are used for commercial tourism. Unfortunately, these regions lack basic facilities of accommodation, transport, waste disposal and other amenities.

As per Niti Aayog report (2018), the tourism industry contributes significantly to the climate crisis through increased energy consumption, waste generation, and ecosystem degradation. Additionally, the infrastructure demands associated with tourism development has grave environmental impacts. The unregulated movement of tourists causes exploitation, disturbance and misuse of the fragile ecosystem of the Himalayas (Apollo et al., 2022). Inappropriate waste management in the ecologically sensitive areas of the IHR, adds to the growing impacts of climate change, that ultimately impacts human well-being (Aayog, 2018a, 2018b).

## *3.12 Air Pollution*

The Indian Himalayas are affected by air pollution, primarily owing to industrial activities, vehicle emissions, open burning of biomass and waste, mining and infrastructure development activities (2022b; Masiwal et al., 2021) (Figs.10 and 11). Himalayas are prone to forest fires during the summer season, which earlier used to be either seasonal or natural processes, but in recent years have transformed into an intentionally induced event meant for illegal hunting and logging. This destroys the forest ecosystems and releases a large amount of air pollutants. Moreover, the air pollutants over the Himalayas have both local as well as regional and transboundary sources. Air pollutants, such as the black carbon and particulate matter, can settle on snow and ice surfaces, leading to accelerated melting. This exacerbates glacier retreat and contributes to the climate crisis in the region (Hassan et al., 2022; Saikawa et al., 2019; Sabin et al., 2020).

**Fig. 11** Unsustainable waste management in Pithoragarh city, Uttarakhand. *Source* Authors

**Fig. 12** Landslide prone route from Tanakpur to Pithoragarh, Uttarakhand. *Source* Authors

### *3.13 Lack of Solid Waste Management*

A careless dumping of solid waste, including the municipal solid waste, e-waste, plastic waste etc., is happening due to anthropogenic activities, including tourism, urbanization, infrastructure development etc. in the IHR, (Aayog, 2018a, 2018b; Dame et al., 2019). The IHR receives around 100 million tourists yearly (Thakur et al., 2021), and this number is growing every year. Unmonitored activities and inconsiderate dumping resulted in unchecked solid waste generation Fig. 11 (Kumar et al., 2016). Estimates suggest an annual generation of around 8.3 million tonnes solid waste from the tourism activities like trekking and expedition, etc. (Thakur et al., 2021).

Key issues for waste management comprises of inconsistency in waste generation that normally varies with seasonal influx of tourists, which affects the solid waste collection, transportation and disposal processes, a harsh terrain, unregulated management, etc. (Kuniyal, 2005). The IHR generates around an annual solid waste of nearly 1.9 MT. Out of this, only 1.6 MT is collected, only 0.41 MT is processed and around 0.2 MT is dumped in the landfills (Aayog, 2018a, 2018b; CPCB, 2019). The untreated waste mostly ends up in water bodies and causes water pollution. Due to this inefficient collection, segregation and waste disposal system, locals prefer to burn their waste, which is a significant source of air pollutants such as dioxin, carbon monoxide, toluene, benzene, aerosols, oxides of nitrogen, etc. (Thakur et al., 2021).

### *3.14 Lack of Data*

As per a report by the Intergovernmental Panel on Climate Change (IPCC), the entire Himalayan region, is described as a 'data deficient' area as far as climate monitoring is concerned (Solomon, 2007). It is evident that careful and regular monitoring is necessary to ascertain the changes occurring over time. Henceforth, long term weather, air and glacier monitoring is required across the Himalayan region (Tewari et al., 2017).

# 4 Consequences of the Climate Crisis in the Indian Himalayan Region

The Himalayas literally translate to mean a "home of snow". However, this, might one day go obsolete, because the region is a sensitive hot spot to climate change. There are several consequences of the climate crisis in the Indian Himalayas. These are categorized into two broad categories, namely the environmental-ecological, and socio-economic impacts, which are discussed below:

## *4.1 Environmental-Ecological Impacts*

### 4.1.1 Rising Temperature

Several studies have hinted that the mean temperature over Himalayas is rising rapidly, even faster than the global mean temperature. (Pepin et al., 2015). The western Himalayas has recorded a significant rise in temperature since 1975 (Sabin et al., 2020) and studied the alteration of the annual mean temperature over Hindu Kush Himalayas and Indian landmass, and observed that the Himalayan region is warmer compared to Indian landmass, but the warming rates were not same over the Himalayan ranges and alters with altitude (Liu et al., 2009; Ren et al., 2017). However, because of the extreme topography and complex reactions to the greenhouse effect, even high-resolution climatic models cannot give reliable projections of climate change in the Himalayas (Hasson et al., 2014; Sabin et al., 2020). As per the State of Forest Report, 2021 that Himalayan states and UTs like Ladakh, Jammu and Kashmir, Himachal Pradesh and Uttarakhand will record the maximum increase in temperature and also a possible decrease in rainfall (Mishra, 2022).

### 4.1.2 Glacier Retreat

The Indian Himalayas are home to numerous glaciers. There are around 9575 big or small glaciers in the IHR with an estimated ice cover of about 36,000 $km^2$ and overall ice volume of about 2000 $km^3$ (Singh et al., 2018). Most of the glaciers in the region are retreating at varying rates. It is estimated that since the 1960s, there has been 16% recession in the glaciers in IHR, which are experiencing rapid retreat due to global warming (DST, 2019).

Glacier retreat in the Himalayas results from precipitation decrease accompanied with an increase in temperature and studies suggest this glacier shrinkage will speed up if the climatic warming and drying continues (Ren et al., 2004). This also contributes to an increased water runoff, altered river systems, and the loss of freshwater storage. This has significant implications for water availability for millions of people, hydropower generation, and downstream communities that rely on these water sources (Hasnain, 2009). Excessive meltwaters, often in combination with liquid precipitation, may trigger flash floods or debris flows. It may also destabilise surrounding slopes and give rise to catastrophic landslides and sometimes floods (Eriksson et al., 2009; Kumar et al., 2018a, 2018b).

### 4.1.3 Changing Precipitation Patterns and Hydrological Patterns

Climate change is altering precipitation patterns in the Indian Himalayas, resulting in shifts in rainfall timing, intensity, and distribution. This has effects on agriculture, water availability, and ecosystem dynamics (Das & Meher, 2019; Saini et al., 2023; Tewari et al., 2017) and can lead to increased frequency and intensity of floods and droughts, causing extensive damage to infrastructure, agriculture, and human settlements (Eriksson et al., 2009).

### 4.1.4 Landslides and Avalanches

Increased extreme climatic/rainfall events, or more rainfall in areas which were otherwise dry, or an increased frequency of cloudbursts, contribute towards an increased occurrence of landslides in the Himalayan region (Dimri et al., 2017). Warmer temperatures destabilize slopes, leading to an increased risk of landslides and avalanches (Huggel et al., 2021). The frequency and severity of such events have already increased in recent years, endangering human lives and infrastructure (Chalise, 2001). These natural disasters pose significant challenges to transportation networks, communication systems, and mountain communities (Fig. 12).

Observations suggest that landslides are generally concentrated along the river valleys, mainly because of the high discharge in the rivers (Dikshit et al., 2020). This may also be correlated with the shift in rainfall pattern in IHR and the higher intensity of rainfall that has been noted particularly after 2010 (Kumar et al., 2018a, 2018b; Vardhan, 2019). There is now a higher occurrence of incidences of extreme

**Fig. 13** Rāmgangā River, Village Masi, Uttarakhand. *Source* Authors

climatic events during recent past, like the one observed in 2013, causing havoc mainly in the Kedarnath Township, Mandakini valley and further downstream in the Alaknanda valley or in the year 2017, that witnessed high concentrated rainfall in many parts of the northwestern Himalayas causing numerous disastrous landslides in the Himalayan terrain (Eriksson et al., 2009).

### 4.1.5 Loss of Carbon

Deforestation leads to loss of soil carbon. This happening over the Himalayas is a distinct possibility, because of steep and immature slopes, which are subjected to heavy rainfall (Singh, 2007).

### 4.1.6 Biodiversity Loss

The Indian Himalayas are home to rich biodiversity, including many endemic species. The changing climate disrupts ecosystems, causing shifts in vegetation zones and altering habitats (Malhi et al., 2020). With increasing temperatures, numerous plant and animal species may encounter difficulties in adjusting or relocating to suitable habitats (Weiskopf et al., 2020). This could lead to the loss of habitats, decreased species populations, and heightened risks of extinction. In the regions of Uttarakhand and Himachal Pradesh, excess overburden and mining waste are disposed of in nearby agricultural or forested areas. This impedes prospect of any future agricultural and forestry activity there. Infrastructure projects such as dams tend to disrupt the natural flow patterns of the Himalayan rivers, causing detrimental impacts on their ecological functions and on the social, economic, cultural, and religious importance attributed to these waterways (Grumbine & Pandit, 2013; Rao et al., 2016; Sabin et al., 2020).

### 4.1.7 Human Wild-Life Conflicts

The frequency of human-wildlife conflicts rises as human population expands and land clearance augments (Sathyakumar et al., 2016). The clearing down of forest land into agricultural land and the exploitation of timber, fodder, and fuelwood pose significant threats to the biodiversity of the Indian Himalayan Region (IHR) (Singh, 2012). Other practices such as charcoal production in lower elevation areas, intensive grazing at higher elevations, demand for firewood, grazing domestic animals etc. put further strain on the forests, as well as on the local population, particularly women who often spend hours collecting firewood in the forest, increasing their chances of encountering wildlife conflicts. Likewise, forests can only support a limited number of grazers sustainably, as overgrazing frequently results in the consumption of saplings and the destruction of future forest regeneration.

## 4.2 Socio-economic Impacts

### 4.2.1 Water Security

Several Himalayan rivers and their tributaries feed the local and regional populace residing in the Himalayan region as well as downstream of this region (Fig. 13). Alterations in precipitation patterns, directly impact river runoff and have the potential to shift water availability away from meeting agricultural and dry season demands and toward the risk of monsoon-induced flash floods. Simultaneously, as the region's glaciers continue to melt, there is an elevated risk of encountering both short-term glacial lake outburst floods (GLOFs) and long-term water scarcity issues. GLOFs transpire when glacier meltwater accumulates in glacial lakes, breaching natural barriers and causing destructive floods downstream (Eriksson et al., 2009). All of this could worsen water scarcity concerns, impacting local communities, agriculture, and the generation of hydroelectric power.

At the same time, the degradation of vegetation cover and intensified land utilization can disrupt surface runoff, evapotranspiration, soil storage capacity, and infiltration processes, consequently perturbing the natural hydrological regime of the region (DST, 2019). In recent decades, urbanization and industrialization and the associated deforestation and landscape alterations have led to the deterioration of catchment areas, resulting in reduced seasonal flow and the drying up of rivers and springs (Ives et al., 2010).

### 4.2.2 Agriculture and Livelihoods

The Indian Himalayas are home to numerous agricultural communities that depend on the land for their livelihoods (Mukerjee et al., 2018). The IHR contributes to about 15–18% of agricultural production. However, owing to harsh climatic conditions and limited cultivable area overall yield is much less (1680.58 kg/ha) compared to the national average (2984 kg/ha) (DST, 2019). Overall health of soil in the region is on decline due to erosion and lack of management. Climate change in the Himalayan region poses new challenges to agriculture, animal husbandry and food security. The impacts, including altered precipitation patterns, increased temperature, and pests and diseases, can negatively affect crop productivity, livestock health, and overall agricultural systems, leading to reduced incomes, food insecurity, and migration from rural areas. This will eventually transform the future of indigenous people and their livelihoods more vulnerable and uncertain (Mukerjee et al., 2018).

### 4.2.3 Hazards

Infrastructure that has been built over the decades, including the hydropower plants, roads, bridges, and communication systems, is all the time more at risk due to climate change (Eriksson et al., 2009; Sinha & Upadhyay, 1995). Disastrous events like the earthquake of Sikkim (2011), Kedarnath tragedy and the aftermath (2013), Kashmir floods (2014), and snowballing incidents of cloudbursts are divulging examples of the area's active tectonics, intrinsic fragility and the likely risk to life and property possible. The impacts include both rapid hazards such as flash floods, or slow onset hazards such as melting of glaciers, drying of wetlands and springs, loss of biodiversity, etc. (Eriksson et al., 2009).

### 4.2.4 Permafrost

Ali et al., (2018) defines permafrost as the frozen ground that continues to remain at 0 °C or below for as a minimum of two successive years. Studies suggest that the Hindu Kush Himalaya has an extensive permafrost belt (Gruber et al., 2017). Allen et al., 2016 reports that in many regions, permafrost is warming due to global climate change, and the resulting thawing can have widespread impacts. These include destabilization of steep slopes, subsurface hydrology alterations, augmented sediment load in rivers, etc., all of which can disturb regional livelihoods, infrastructure and economies, and the hydropower sector (Yang et al., 2010).

### 4.2.5 Human Health

Impact of climate change on health can be direct (drought, heat waves, flash floods, etc.), indirect (economic disruptions, social conflicts, crop failure, associated malnutrition and hunger, spread of infectious diseases, etc.). Climate change is unfolding during a time when there are concurrent shifts in the global environment and human population dynamics, which have a subsequent potential, to interact and amplify the health effects (Thomas et al., 2014).

**Case Study: Devastation of Himachal Pradesh: A Man-Made or a Natural Disaster?**

The monsoon season of 2023 brought feelings of sorrow and despair among the inhabitants of the Himalayan region. Despite the susceptibility of Himalayan states to occurrences such as cloud bursts and landslides, this year witnessed an unprecedented level of havoc. Himachal Pradesh, a well-developed state within the Himalayas known for its sturdy mountains, advanced infrastructure, picturesque tea gardens, tourist attractions, mining activities, and more, experienced significant losses. Over 800 state roads, including major highways like Chandigarh-Shimla, Kiratpur-Manali, Pathankot-Mandi, and Dharamshala-Shimla, were lost. Tragedy struck with the loss of around 327 lives during the monsoon season (June–August 2023). Additionally, approximately 1762 houses were completely destroyed, while 8952 houses suffered partial damage.

The torrential rainfall and resulting landslides caused extensive devastation in various areas of Himachal Pradesh, including Summer Hill, Krishna Nagar, and Phagli. The region witnessed a staggering number of incidents, including over 113 landslides and 58 cloudbursts. These numbers could rise further if the rain continues unabated. Chief Minister Sukhwinder Singh Sukhu of Himachal Pradesh stated that the state incurred losses amounting to around Rs. 10,000 crores, primarily in terms of infrastructure (excluding potential losses to natural biodiversity). According to the Chief Minister, the state received an unusually high amount of rainfall compared to previous years, contributing significantly to the destruction. Climate experts have pointed out that the increased rainfall intensity, coupled with elevated temperatures, has led to landslides due to the loosening of strata in areas that have undergone cutting on the foothills downstream. Experts also contend that this disaster is primarily a result of human actions. The prominent causes identified include the expansion of four-lane roads, hydro-power projects, deforestation, cable car initiatives, and the construction of multi-storied buildings. The unregulated urbanization, especially driven by mass tourism, has led to activities such as deforestation, soil erosion, and slope destabilization beyond the environment's capacity to withstand. Himachal Pradesh, nestled amidst the Himalayan mountains, experiences the initial impact through forest clearing, leading to soil erosion. The construction of roads involves mountain excavation using heavy machinery and explosives, disturbing the mountain's equilibrium and contributing to sliding.

Experts also point out vertical cutting of mountains for road construction, often with inadequate retaining walls of just 5–10 feet, in Himachal. They highlight that several human-induced factors contribute to landslides in the region, including ecologically unsound constructions in the fragile Himalayas, diminishing forest cover, and structures obstructing water flow in streams. A report from the National Disaster Management Authority (NDMA) underscores poor urban planning in hilly areas and inadequate enforcement of existing regulations. Population pressures in specific hilly cities have also been identified as concerning. The Geological Survey of India in Himachal Pradesh has identified 17,120 zones prone to landslides, spanning districts like Sirmaur, Lahaul and Spiti, Mandi, Kinnaur, Kangra, Shimla, Solan, Bilaspur, Una, Chamba, Hamirpur, and others. Instances of land subsidence, similar to Joshimath in Uttarakhand, have emerged in various places within Himachal Pradesh.

Experts assert that this disaster is a consequence of policy decisions. Changes in land use for urbanization, inadequate planning, and similar factors have led to what can be described as a "policy induced disaster." Only a combination of technological intervention, effective governance, and sound policies can mitigate such devastating events in the future. Experts emphasize the need for tailored bylaws for different zones, taking into account the diverse topography of the state. In this regard, they propose that each panchayat should have distinct regulations to ensure responsible development and safeguard against such disasters.

## 5 Solutions to the Climate Crisis in the Indian Himalayan Region

The Indian Himalayas face significant challenges due to the climate crisis, and to address these challenges, several solutions can be considered:

1. **Mitigating greenhouse gas emissions**: Efforts to reduce emissions are crucial. India can adopt cleaner energy sources, such as solar, wind, and hydro power, and promote energy efficiency in industries, buildings, and transportation. The use of electric vehicles should be promoted whilst implementing stricter emission standards to reduce carbon emissions.
2. **Sustainable land and water management**: Efficient land use planning and watershed management practices is necessary. Implementing sustainable agricultural practices, by encouraging farmers to cultivate traditional varieties of crops to promote organic farming, agroforestry, and efficient irrigation techniques, can reduce land degradation, improve soil health, and conserve water resources, along with practices such as terracing, contour farming etc. to prevent soil erosion and enhance ground-water recharge.
3. **Climate-resilient infrastructure**: Developing and retrofitting infrastructure to be climate-resilient is essential, including energy efficient buildings. Infrastructure projects and their construction should incorporate the likely impacts of climate change, and be able to withstand them.
4. **Water resource management**: This comprises developing strategies to conserve water, such as rainwater harvesting and efficient irrigation systems. It is also essential to monitor and manage glacial melt. Programmes requiring a combination of interventions to decrease pollution, improve water-use efficiency, enhance flows during the dry periods, etc. are vital.
5. **Awareness of Local communities**: The local communities need to be prepared to cope the climate crisis to help them to build resilience. Strategies such as advising farmers about the crop diversification, best agricultural practices as per the altering climatic conditions, developing early warning systems, implementing standard operating procedures, knowledge of best practices, training in sustainable livelihood options, mock-drills etc. are required (Kumar et al., 2018a, 2018b).
6. **Green Energy**: Better alternatives to biomass burning and traditional fuels can be in the form of green energy sources such as solar, wind, biomass, hydro, and geothermal. This will help in mitigating environmental pollution and forest degradation.

7. **Biodiversity conservation**: Protecting the rich biodiversity of the Himalayas is crucial for ecosystem resilience. This can be done via establishing protected areas, promoting sustainable tourism practices, and regulating activities such as mining and logging that can help conserve fragile ecosystems.
8. **International cooperation**: Addressing the climate crisis in the Himalayas requires international collaboration. India can work with neighbouring countries and engage in regional initiatives to share knowledge, resources, and best practices.
9. **Sustainable tourism**: Creation of appropriate facilities and access to ecological resources, and multi-stakeholder partnerships to enable local communities to gain livelihoods, while leveraging financial, technical, and managerial capacities of investors, taking measures to regulate tourist inflows into mountain regions to ensure these remain within the carrying capacity of the mountain ecology, help drive responsible and sustainable tourism. Such measures help in curtailing the vehicular influx, traffic jams, and noise and air pollution in tourist areas.
10. **Sustainable waste management**: Door-to- Door garbage collection schemes, waste segregation at source, recycling of non-biodegradable waste, e-waste collection and recycling, promoting reuse and refurbishing of items discarded as waste, etc. are strategies that can cater to sustainable waste management in the Indian Himalayan region (Kumar et al., 2018a, 2018b).
11. **Powerful regulatory mechanism**: There is a dearth of regulatory mechanisms for infrastructure creation, management, and for controlling the tourist inflow in Himalayan regions (Kumar et al., 2018a, 2018b). This has resulted in excessive pressure on the sensitive ecosystems and cultural resources of these areas, far beyond their carrying capacities. It is henceforth necessary to develop and implement guidelines for the same, that should keep in view the livelihood interests and the long-term benefit of the local community.
12. **Community participation**: Creation of communicating networks and participatory research linkages between the public sector, NGOs and rural people is an effort to enhance successful implementation of environmental initiatives within the community, such as forest conservation, water conservation, etc. (Arce, 2019; Kumar et al., 2018a, 2018b; Poudyal et al., 2018; Singh, 2007).
13. **Strong monitoring system**: Environmental observation systems in Himalayan regions are very important for weather forecasts and warnings, mountain meteorological services, army operations, agriculture, tourism, power generation, water management, hydro-meteorological hazards preparedness, and risk reduction planning. The Government of India has initiated weather and glacier monitoring programmes such as the Himalayan Glaciology Programme (HGP) and Integrated Himalayan Meteorology Programme (IHMP), yet there is a need to establish more stations in this region (Kumar et al., 2018a, 2018b).
14. **Afforestation**: Forests help absorb atmospheric carbon, and comparatively are a cheaper and easier solution (Singh, 2007). It is always better however to avoid deforestation by conserving forests (Singh, 2007). Reforestation

programs should emphasize on planting indigenous tree species, and involve local communities for the implementation and management.

15. **Green Bonus**: Payments for Ecosystem Services refers to a range of agreements in which individuals or entities who benefit from environmental services, such as conservation of watersheds, forest preservation, capturing carbon, landscape management, etc. offer financial incentives or market-based compensation to those who maintain and provide these services on their lands. So, to incentivise the same, following may be practiced- for instance, farmers, practicing traditional farming including in Himalayan states, should be rewarded for their ecological services as it is considered climate-resistant and pro-environment. This is the green bonus and can serve as a fruitful spur for Himalayan states.

## 6 Conclusion

Undoubtedly, the climate crisis in the Indian Himalayas poses an immense and pressing challenge that demands immediate action and collaborative endeavors. This region, celebrated for its awe-inspiring landscapes, diverse ecosystems, and vibrant communities, now faces a stark reality of environmental deterioration and heightened vulnerability. The evidence of climate change is undeniable, manifesting in the rapid retreat of glaciers, unpredictable weather patterns, and an alarming increase in natural disasters. The repercussions extend beyond the Himalayas, affecting global ecosystems and climate dynamics. At the heart of this crisis lie delicate ecosystems, invaluable biodiversity, and the livelihoods of countless individuals. With rising temperatures and the escalating frequency of extreme weather events, the impact on local communities is profound, and the global implications are increasingly significant.

However, amidst these challenges, there exists an opportunity for building resilience and innovation. Addressing this crisis necessitates a comprehensive approach that encompasses adaptation strategies to bolster community resilience, mitigation efforts to curtail greenhouse gas emissions, and international collaboration to confront common challenges. It is only through sustained dedication, a profound appreciation for the delicate equilibrium of nature, and an unswerving commitment to safeguarding the well-being of present and future generations that we can hope to secure a sustainable future for the majestic Indian Himalayas and the planet as a whole.

By embracing sustainable practices, advocating for climate-conscious policies, and empowering local communities, we can strive towards a future in which the majestic Himalayas stand proudly, rejuvenated, and shielded from harm. It is a collective responsibility to protect this fragile ecosystem and ensure the prosperity of both current and future generations.

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