Climate Change & Disaster Management: The Adversity of Floods & Landslides in the Himalayan States

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Abstract

Climate change has been a phenomenon in the making for decades and has had a far-reaching impact on the present-day world. Nations worldwide have been embroiled in the disastrous outcomes brought about by this, spending billions of dollars on political, social, economic & technological mechanisms to tackle climate change. India, in particular, has been no exception to this and has suffered from various events such as floods and droughts (read natural disasters), especially in the last decade, as a consequence of intensifying greenhouse emissions, among other factors contributing to climate change. While instances of such events are apparent across the country, the Himalayan states, in particular, have stood out, for the consequences of climate change have resulted in an array of disasters such as floods, landslides, and thunderstorms, causing massive damage over the years. This paper aims to selectively highlight the history of such events across the Himalayas, discuss the situation in vulnerable areas, as well as provide a brief outline of actionable policies & measures that can be adopted to tackle them.

Keywords: glacial retreat, climate change, IPCC, disaster management & response, floods and landslides

Context: Climate Change- A Menace

It is undoubtedly evident that climate change remains one of the most pressing issues in today's world. According to the first part of the 6th Assessment Report released by the Intergovernmental

Panel on Climate Change (IPCC) in August 2021, titled *Climate Change 2021: The Physical Science Basis*, global temperatures are anticipated to rise 1.5-2 degrees (Celsius) above pre-industrial levels in less than the next 20 years. The report's findings indicate that extreme weather events are becoming more common throughout South Asia, including India, describing that in the 21st century, heatwaves will grow more powerful and frequent, and summer and monsoon rains will also increase and become more frequent (Aggarwal & Ghosh, 2022). Data indicates that extreme rainfall occurrences shall increase as much as 20% across the Indian subcontinent, leading to floods and depressions and eventually to severe, more common cyclonic storms along India's 7500-kilometre-long coastline. Evidently, India would certainly face a tragedy as a result of such catastrophic weather events (Lahiri, 2021). A report titled 'Global Climate Risk Index 2021' released by Germanwatch ranks India 7th globally among the most climatically vulnerable countries in the world (Eckstein et al., 2021), thus cementing the previous statement. Further, according to data from the Council on Energy, Environment and Water's (CEEW) report of December 2020 titled *Preparing India for Extreme Climate Events*, more than 75 per cent of the districts in India (with nearly 64 crore people) are extreme climate events hotspots, prone to events such as floods, cyclones, droughts, etc (CEEW, 2020). India has witnessed several recent disasters, such as Kerala flashfloods in 2018 (Chavez & Pokharel, 2018), the cloudburst and the consequent flooding & landslides in Uttarakhand in 2013 (Manzar, 2013), and Cyclone Yaas in Odisha in May 2021 (Singh & Barik, 2021).

These events are concrete examples of how climate change is no longer a stand-alone issue but one that has significantly impacted our lives. Keeping this in mind, it becomes important not to be in the dark about such changes since they have the potential to adversely affect the economy as well as the lives of the common people; otherwise posing a risk to economic growth, social development, and political stability on a widespread scale.

The Himalayan States & The Recipe for Disaster

Arising from the collision between India (the Indo-Australian tectonic plate) & Tibet (the Eurasian tectonic plate), the Himalayan Mountain ranges are the highest and one of the youngest in the world (Sorkhabi, 2009). Spread across the landmass of South Asia, these are often called the Third

Pole, for they are home to the largest deposits of ice & water (read glaciers, more than 15,000) after the North & the South Poles, respectively (WWF, 2020). For this reason, the Himalayas are also home to several river systems (such as the Indus, the Ganga-Brahmaputra, and the Yangtze) that serve as lifelines for water in the adjoining countries. Furthermore, the young mountains also have the sway to influence the air systems in the region (impacting climate & weather) because of their tendency to act as natural barriers against the cold Arctic winds as well as the monsoon winds.

Based on the modern theory of plate tectonics, scientific research points out that this mountain range continues to grow at a pace of 2cm per year, making itself one of the most vulnerable to sudden tectonic movements, often leading to earthquakes, floods & landslides (PBS, 2014). This fragility has only been worsened by climate change as several natural processes such as sedimentation, creation of cracks & fractures in the rocks, and melting of glaciers have only been accelerated in terms of their speed & intensity. As a result, the Himalayas have experienced significant warming in the 1900s, particularly the Hindu Kush Himalayas (HKH), a range that houses the largest ice caps in these mountains (Sabin et al., 2020). A key finding from an annual report of the International Center for Integrated Mountain Development (ICIMOD) in 2019 states that the Himalayan region will warm above the global average of 1.5-degree Celsius (Krishnan et al., 2019)- at least 0.3-degree higher in the HKH and at least 0.7-degree higher in the northwest Himalayas & the Karakoram ranges. Apart from this, glaciers are melting faster than ever before, leading to a loss of volume & mass due to warming (Kulkarni & Karyakarte, 2014) (refer to Table 1); this is evident from a faster rate of warming i.e. 0.2-degree Celsius per decade in the HKH from 1951-2014, as opposed to a mere 0.1-degree Celsius per decade from 1901-2014 (Kulkarni et al., 2013). Another study points out that this region experienced as much as 2.5 degrees Celsius warming during 1950-1999 (Rao et al., 2016) and is expected to reach as high as 9 degrees Celsius by the year 2100, which is a worrying trend. This glacial retreat is the source of many events, such as glacial lake outburst floods (GLOF) and inundation due to sea-level rise (SLR) (CEEW, 2020). Further, there are internal differences within the Himalayan geography (say Eastern & Western ranges) with respect to the overall effects of climate change.

Name of glacier	**Period (years)**	**Average retreat (m/year)**
Bandar Punch	1960–1999 (39)	25.5
Jaundar Bamak	1960–1999 (39)	37.3
Jhajju Bamak	1960–1999 (39)	27.6
Tilku	1960–1999 (39)	21.9
Gangotri	1935–1999 (64)	19.0a
Bhrigupanth	1962-1995 (33)	16.5
Bhagirathi Kharak	1962–2001(39)	16.7
Chaurabari	1960–2010 (50)	6.5
Pindari	1906-2001 (95)	15.2
Chipa	1961–2000 (94)	26.9
Meola	1912–2000 (88)	19.3
Jhulang	1962–2000 (38)	10.5
Nikarchu	1962–2002 (40)	9.2
Adikailash	1962–2002 (40)	12.8
Milam	1848–1997 (149)	16.7
Bhurpu	1966–1997 (31)	4.8
Mean	**57 years**	**17.8**

Table 1: Average annual retreat of major glaciers in Central Himalayas (as per Study Group Report, Government of India 2011) (Patwardhan, 2011)

The Indian Himalayan Region

Like other parts of the Himalayas, the Indian Himalayan Region (IHR) is also facing the cascading effects of climatic changes- visible in its ecology, geology, weather patterns, political & social lives, and local economy. A Census report from 2011 reveals that the Indian Himalayan Region is home to nearly 50 million people in over 13 States/Union Territories- the largest among all mountain ranges in the world, and also spans around 2500 square km (around 16% of India's total geographical area). It is characterized by its diverse demography and socioeconomic & environmental systems. *The Hindu Kush Himalaya Assessment* report, published in 2019, explains the consequences of the accelerated pace of warming in the Himalayas- including loss of biodiversity, faster melting of glaciers, and lower availability of freshwater, among other aspects (Krishnan et al., 2019).

A significant finding by experts is the withdrawal in the number of snow days in the HKH (Sabin et al., 2020) (Krishnan et al., 2019), which affects the availability of freshwater downstream. In line with the previous study on glacial retreat in the Central Himalayas, another study in Himachal Pradesh in 2020 notes the area under snow cover in 2019 as being ~23,540 sq km, which significantly dropped down to ~19,100 sq km in 2020, confirming the loss of area under snow cover and the rapid melting of glaciers (Randhawa & Gautam, 2021). Similarly, 1) in Jammu & Kashmir and Ladakh, nearly 1200 glaciers decreased by as much as 35cm/year on average between 2000 and 2012 (Romshoo et al., 2020); 2) in Uttarakhand, there was an overall decrease of 27 sq km of snow cover in the Gangotri & surrounding glaciers between 2020 & 2021 (Nath, 2021). As per a study titled *Glaciohydrology of the Himalaya-Karakoram*, the Himalayan rivers cover an area of 2.75 million sq km, have the largest irrigated area of 577,000 sq km, the world's largest hydropower capacity of 26,432 megawatts, and cater to the water-needs of a billion people in the region (the entire population of Nepal, and half the populations of India & Bangladesh) (Sabin et al., 2020). This although, for India, has serious implications since freshwater from the Himalayas supports the lifelines of nearly 500 million people in the Indo-Gangetic plains and is also the principal constituent for the production of almost 1/3rd of the country's total energy capacity.

Another aspect of climate change's ill effects- is shorter, more intense spells of rainfall across India (as per IPCC-AR6, 2021), which coupled with irregular variations in monsoon winds have led to an overall increase in the extreme rainfall trends across the Himalayan region (Guhathakurta et al., 2011). For instance, a study conducted in the state of Himachal Pradesh, using data from the Indian Meteorological Department suggests that while the average annual rainfall between 1989-2018 remains the same, the average frequency of dry days has increased- meaning lesser days of precipitation (rain/snow) (Guhathakurta et al., 2020). Another study on the Gangotri glacier (the largest in the region) of Uttarakhand points out the increased rainfall & decreased snowfall in the region, prompting faster melting of the glacier, which has eventually led to GLOFs & flash floods in Uttarakhand, such as the Chamoli glacial burst in 2021 as well as the infamous Kedarnath tragedy in 2013 (Santoshi, 2022). Therefore, from these instances, it can be inferred that trends in extreme rainfall and the rapid glacial retreat are causing most of the disasters in the Himalayan states. The diverse geography of this region, its fragile ecosystem, and its high vulnerability to active tectonic movements, further exacerbated by anthropogenic factors like human interference & climate change, have made it into a hotspot for natural disasters like earthquakes, cloudbursts, forest fires, floods, and landslides, many of which are induced at a faster pace by climate change & associated phenomena.

Case study 1: The State of Himachal Pradesh

The northern Himalayan states of Himachal Pradesh & Uttarakhand and the Union Territories of Jammu & Kashmir and Ladakh are constituents of the Hindu-Kush Himalayan range. This part of the Himalayas is home to many glaciers, the origin of several perennial rivers, a global hotspot of biodiversity & culture, a hub of natural resources such as minerals, and a coveted prize in terms of its strategic location. As fascinating as this sounds, these Himalayas are young & fragile in nature and, thus perhaps the most vulnerable to climate change as well. It is already established that glaciers are melting at faster-than-ever rates, yet westerly winds have accelerated this process, impacting most of the westernmost parts of the Himalayas (northern India) than the eastern Indian Himalayan Region (Tayal, 2019). Again, despite there being internal differences within the Himalayas as to the effects of climate change, it is interesting to note that the IHR territories of Himachal Pradesh and Jammu & Kashmir (J&K) still display different trends in rainfall, mean temperatures, etc, indicating how ecologically & geographically diverse (and sensitive) this region is (Tayal, 2019). Based on the data from the Indian Meteorological Department (IMD) from 1951-2010, while J&K shows a decrease in annual mean temperatures (-0.01 degree Celsius each year) and an increase in annual average rainfall (+2.13mm each year), Himachal Pradesh surprisingly shows contrasting trends- a decrease in annual average rainfall (-3.26mm each year) but a larger increase in annual mean temperatures (+0.02 degree Celsius each year), in what can be argued as the primary reason behind the triggering of GLOFs (refer to Figure 1) (IMD, 2013). In terms of pure vulnerability rankings (as per a study by the Department of Science & Technology titled *Climate Vulnerability Assessment for Adaptation Planning in India Using a Common Framework*), J&K is a "relatively moderately vulnerable state" with an index of 0.55 (due to its low road density, lack of proper railway network, high incidence of water-borne diseases), which is higher than that of Himachal Pradesh (HP) i.e., 0.49, which is classified as a "relatively low vulnerable state" (Indian Institute of Technology Mandi et al., 2019). Yet, the same assessment points out HP's case to be an interesting one i.e., *"it is one of the rare states that is neither the best nor the worst"* in terms of the vulnerability assessment criteria (Aggarwal, 2018). The author finds the selection of HP to be more pragmatic for this study due to its (more) diverse topography vis-à-vis J&K, positioning in a high seismic zone (Seismic Zone IV and V i.e., highly prone to earthquakes), and relatively (more) fragile ecology. In the domain of disaster management, the state of HP is notorious for the variety of disasters it experiences each year- floods, landslides, earthquakes, cloudbursts, forest fires, etc. For instance, there were estimated damages of 20 billion INR from incessant intense rains and flooding, in the recent month of August 2022 (Dogra, 2022). A report by the state government's Department of Environment, Science and Technology in the same month describes the state as being vulnerable to 25 of 33 identified types of hazards, making it one of the most disaster-prone states across India (Vasudeva, 2022). Increasing glacial retreat has only led to cloudbursts and stronger spells of intense rainfall across the state, which have only increased in the last few years, the report says. According to Sharma (2020), nearly 250 people died till September 2021 due to natural disasters in the same year's monsoon season as compared to 161 in June-September 2020. Further, Himachal Pradesh has seen an average mean increase of 1.6-degree Celsius in the surface temperature in the last century- higher than 1 degree Celsius experienced by the downstream Indo-Gangetic plains & the rest of India (Himachal Pradesh State Disaster Management Authority, 2017). Cloudburst & extreme rainfall events have become so common in the state that a risk assessment report by the state government in 2015 declared all the 77 blocks of the state (with an estimated 18,600 villages) to be prone to landslides (Disaster Management Cell, Govt of Himachal Pradesh, 2015). It should be emphasized that apart from major factors such as glacial retreat & changes in precipitation, many disasters in HP & neighbouring Uttarakhand are induced due to anthropological (human) intervention- construction of buildings, roads, industries, hydropower projects and so on. An expert from the Department of Geology at Uttarakhand's Hemvati Nandan Bahuguna Garhwal University (HNBGU) defines the mountains in these parts to be "climatically & tectonically [highly] sensitive" and goes on to describe the ill role of such (unchecked) human intervention as agents worsening the effects of an already-devastating climate change. This is visible from-

1. The existing length of 2624 km of the National Highways (as of 2018)- with a sanctioned addition of another 4312 km, associated with the 500-km long Chardham highway project (that involves widening of roads up to 30 feet) as well as linking/creating border roads to increase tourism & logistical/strategic capabilities for security along the Chinese border,

2. 813 hydroelectric power plants on various river basins in the state (Himdhara Collective, 2016)- with another 53 to be built soon (that experts say could lead to repetitions of the Kedarnath & Chamoli disasters) amidst India's global move to switch to renewable/green energy and increasing its production to 450 gigawatts by the end of 2030, and

3. Higher-than-ever rate of deforestation- with forest cover dropping to 27% as opposed to the mandated 50% in HP (FSI, 2019), in what is said to be a push for private investment in the region at the cost of local environmental concerns.

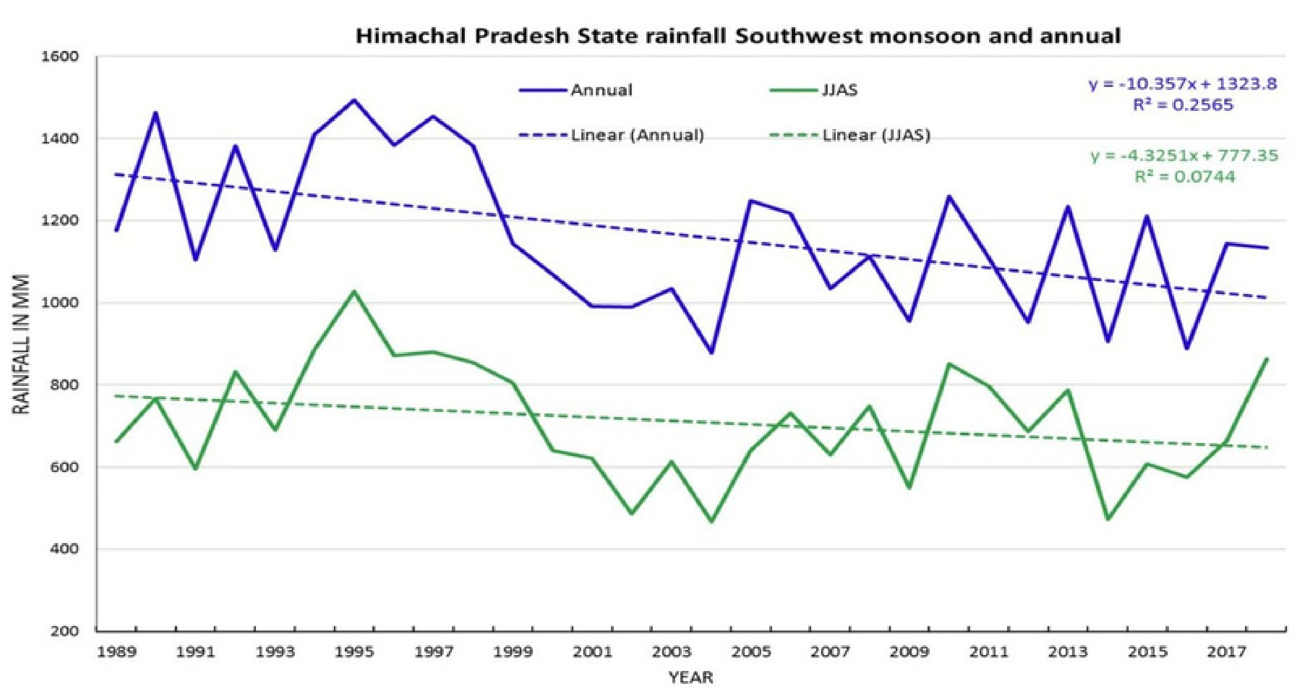

Figure 1: Time series of rainfall in mm for the southwest monsoon season and annual trends; Source: IMD Pune (Guhathakurta et al., 2020)

Further, quoting IMD's data on rainfall in HP from 1989-2018, not only have there been shorter, intense spells of rain leading to higher surface runoffs, floods, and landslides, but this change in precipitation has also meant a rise in the number of natural water springs- as much as 50% of them (Bhardwaj, 2013), drying up across the state (Gupta & Kulkarni, 2018), which is detrimental to the 90% population of the state dependent on agriculture (now forcing them to alternate other means of livelihood or migrate to cities/towns downstream) (Indian Institute of Technology (IIT) Mandi, 2019) and also to the *"hydrological role in generating streamflow for non-glaciated catchments and in maintaining winter and dry-season flows across numerous Hindu Kush Himalaya basins."* (Scott et al., 2019) A cumulative result of all such factors is the ever-rising number of landslides, which is the most common natural disaster in the state. Between the years 1800 and 2011, an assessment of the geographical distribution of landslides across India found the western & northwestern Himalayas (in northern India) to be the most vulnerable to landslides, followed by Northeast India's Himalayas (Prakash, 2011). Such a nexus of floods & landslides has been wreaking havoc in HP, and has the potential to jeopardise the hydropower-generation systems if such events increase in the future (Eriksson et al., 2009).

Case study 2: The Northeast of India

Like the Himalayan states in the northern part, the states in Northeast India (NEI) are equally, if not more, prone to the effects of climate change- including natural disasters. The *National Landslide Risk Management Strategy* published in 2019 by the National Disaster Management Authority (NDMA) under the Ministry of Home Affairs (MHA) describes the Northeast as particularly prone to landslides (and other natural disasters like floods) due to active tectonic movements, intense rainfall and fragile geology in the region.

For ease of understanding, this study considers 1) the flooding problem in Assam, and 2) the landslides in Meghalaya.

A popular & an apt example is the state of Assam, which is notorious for its devastating floods & landslides every year, such as the Silchar floods in June & July 2022 that drowned ~95% of the town & affected nearly 5.5 million people in the state. To this end, a vulnerability assessment of Indian states with respect to natural disasters under the aegis of the Department of Science & Technology, Government of India (Indian Institute of Technology Mandi et al., 2019) found Assam to be among the most vulnerable states in India (an index of 0.62 out of 1, with a higher index meaning a higher rate of vulnerability) - 5th out of all states & Union Territories, the 2nd most vulnerable state in the Northeast (after Mizoram) as well as the most vulnerable in the IHR; so much so that 15 districts of the state are among the most vulnerable 25 districts (to climate change) across the country, as per a study by Council on Energy, Environment and Water (or CEEW) (CEEW, 2020). The Water Resources Ministry of the Government of Assam lists out the vast network of river systems, erosion of river banks by deforestation, illegal encroachments and GLOFs/cloudbursts to be the primary reasons for flooding & landslides in the state, describing it as "different from other states w.r.t extent & duration of flooding and the magnitude of erosion" as well as the "most unique problem [of flooding] in the country"; it further affirms nearly 40% of the state's total area (amounting to 31 lakh hectares) to be flood-prone, which is 4 times higher than the national average (~9.40%) as assessed by the Rashtriya Barh Ayog (RBA). The Brahmaputra River basin, which covers most of the area of Assam, Meghalaya, Nagaland, Sikkim, and Arunachal Pradesh has only seen abnormal monsoon rains in the last 30 years, with an exponential increase in extreme flood events since 2010, the CEEW study cites (CEEW, 2020).

The problem of flooding in Assam is so severe that the state incurs an expected average annual loss of 200 crores, apart from the economic, environmental and socio-cultural loss resulting from associated phenomena such as soil erosion and landslides. A glance at a typical flood in Assam- the floods of 26 June 2019 in the Brahmaputra River, includes the following data (refer to Figure 2).

Name of district	No. of village affected	Crop area affected (ha.)	Population affected	Relief camps	Distribution centre	Population in camps
Dhemaji	419	8,830	128,853	1	7	49
Barpeta	502	3,243.50	735,450	-	28	-
Lakhimpur	130	3,968.70	65,969	1	13	177
Jorhat	77	1,463	47,690	2	-	197
Biswanath	133	1,585	75,988	1	-	229
Golaghat	109	5,070.23	119,179	15	38	2,413
Baksa	14	650	4,050	10	-	3,394
Nalbari	90	4,198	72,600	2	22	284
Chirang	12	2,314.70	7,024	7	-	1,249
Majuli	90	2,367	78,547	5	29	442
Darrang	119	1,312.50	69,865	-	5	-
Sonitpur	48	2,324.16	40,350	8	3	2,246
Bongaigaon	42	1,899.50	83,338	1	40	334
Nagaon	107	3,012.71	19,428	-	-	-
Kokrajhar	1	-	144	1	-	144
Morigaon	296	25,291	349,703	6	3	601
Dibrugrah	91	4,809.22	51,186	6	8	872
Dhubri	323	3,182	337,799	3	-	1,246
South Salmara	53	832	1,0,849	-	-	-
Goalpara	148	4,172	99,290	-	-	-
Kamrup	100	4,035	36,855	-	3	-
Hojai	62	1,225.20	9,228	-	5	-
Sivsagar	33	235	1,170	-	14	-
Tinsukia	60	1,095	38,001	8	17	911
Cachar	40	-	9,732	5	-	1,354
Karbi-Anglong	1	-	937	3	-	445
West Karbi-Anglong	22	6	10,158	-	7	-
Hailakandi	56	486	2,150	-	-	-
Total	**3,181**	**87,607.43**	**26,45,533**	**85**	**242**	**16,596**

Figure 2: Analysis of the damage by floods in Assam (June-July 2019)

Source: Information Bulletin: 20 July 2019; 1) International Federation of Red Cross and Red Crescent Societies, and 2) State Disaster Management Authority (SDMA), Assam

A few more key findings from the June 2019 floods in Assam:

- Nearly 43 lakh people in the state affected, across 31 of total 33 districts
- 4000 villages inundated
- Brahmaputra river flowing 110 cm above the danger level (in Guwahati)
- National Highway 37- connecting the upper & lower halves of Assam, closed for a few days
- Flooding of 90% of Kaziranga National Park, death of ~2000 animals, including 4 rhinos (including 2 endangered One-Horned Indian Rhinoceros) and 1 tiger
- More than 183 relief camps organised by the state by the end of July 2019; rescue efforts (including humanitarian aid) led by the National Disaster Response Force (NDRF), Assam State Disaster Response Force (SDRF) and the Indian Army

The extent of such destruction is such that the state experiences it every year in the months of June, July & August (Karmakar, 2020), so much so that the lower parts of Assam have historically been called the "floodplains" as they get flooded due to the extreme south-western monsoon rain. Further, the SDMA states that 85% of the average annual rainfall is received in these 3 months, amounting to nearly 2900 mm. Another key statistic from the Assam Government highlights the loss of nearly 8000 hectares of land per year due to riverbank erosion along the Brahmaputra, on which an estimated 30,000 crore INR has been spent in the last 60 years by successive governments in Assam (Sumeda, 2022). In light of such destruction, the Assam Government enacted an Assam State Climate Change Action Plan in 2015, and revamped its Assam State Disaster Management Plan (SDMP), among other efforts to build climate resilience & encourage disaster preparedness; all of these efforts backed by scientific studies led by governmental and/or private expert bodies, which time & again have emphasised 1) the expected increase in extreme rainfall between 5-40% and 2) the expected increase in floods by 25% in Assam by 2050 (IANS, 2022).

Second, the State of Meghalaya. While Meghalaya may not be the most vulnerable state in the IHR (as per the DST Vulnerability Assessment report, 2019) with an index of 0.56, it is among the "relatively moderately-vulnerable states" in India, meaning that it still faces a high threat of natural disasters in the absolute sense. Two crucial factors behind considering this state for the study are 1) its average annual rainfall of 11,500 mm, which is the highest in the country, and 2) its presence in Seismic Zone-V, being prone to severe earthquakes & earthquake-induced landslides (Amateur Seismic Centre Pune, 2022). As for landslides, while it might seem more feasible to view them as pure consequences of flooding events, landslides are induced not only by natural events (like earthquakes & floods) but also by other (human) factors such as ill planning, induced soil erosion, use of cheap construction materials, etc. The severity of landslides as events of destruction can be gauged from the mere fact that Asia recorded the most landslide fatalities between 2004-16, and India was one of the worst affected with nearly 18% of global casualties (Froude & Petley, 2018). In light of climate change, intense rainfall has indeed caused higher surface runoffs and, thus, landslides, which are equally disastrous and ubiquitous as floods. Nearly 12% of India's total area (0.42 million sq km) is prone to landslides (Geological Survey of India, 2020), with as much as 30% of the global landslides occurring in the IHR (Ministry of Home Affairs, 2011). Once again, the Northeast's vulnerability (which houses 0.18 million sq km of the total landslide-vulnerable areas) to landslides is highlighted in the NDMA's *National Landslide Risk Management Strategy 2019* (National Institute of Disaster Management, 2019) (refer to Figure 3). Frequent occurrences of landslides across this region (particularly Meghalaya) have impeded economic growth & created hindrances to development- across the public & private sectors. Data from the Geological Survey of India (GSI) points out that landslides cause as much as 1-2% loss of the Gross National Product (GNP) annually in many developing countries, including India (Geological Survey of India, 2020). A study in 2011 estimates this figure to be 150-200 crore INR each year for India (Prakash, 2011). Further, the states in the IHR lose up to 1 billion USD per year due to landslide-inflicted damages, which amounts to a staggering 30% of the global economic damages due to landslides (Himalayan Landslide Society, 2021). Apart from these economic costs, the damage caused by landslides in Northeast India (NEI) includes loss of cattle & biodiversity, decreased tourist inflow, reduced real-estate values, decreased tax revenues, loss of industrial/agricultural revenue, and loss of productivity (Sujatha & Sridhar, 2021).

An underlooked aspect of the damage is the loss of connectivity in the Northeast, wherein major bridges & roads including the National Highways have been known to be blocked/shut down due to landslides & accumulation of debris. Such events are concerning since they not only disrupt the local economy but also hinder economic development- a phenomenon that has caused NEI to suffer from historical neglect in politics, economy & culture, as well as promote threats to the strategic security of the nation. It is however important to point out the lack of adequate data on the damages caused by landslides in the state of Meghalaya (as well as the rest of NEI and the HKH region), which has also been pointed out (Eriksson et al., 2009) in ICIMOD's *The Changing Himalayas: Impact of Climate Change on Water Resources and Livelihoods in the Greater Himalayas* of the year 2009. Efforts, though, are being made since 2007 to create a national statistical database of landslide events across India (Prakash, 2011) by the National Institute for Disaster Management (NIDM), GSI and the Central Statistical Organisation (CSO).

In Meghalaya, though, the Meghalaya State Action Plan on Climate Change (SAPCC) of 2017 has outlined the strategy to deal with the consequences of climate change by identifying key sectors & issues, establishing long-term goals, and building climate resilience through other means such as sustainable agriculture, national water and solar missions, energy efficiency, strategic knowledge on climate change, etc (Meghalaya Climate Change Centre (MCCC), 2019).

Figure 3: Landslide Incidence Map, India, 2019 (Source: Vulnerability Atlas of India, 3rd Edition, 2019); Parts in red represent the landslide hotspots in India

Further, it has also led to changes in the Meghalaya SDMP of 2016 by the inclusion of pragmatic measures to reduce landslides, notably being:

- Strengthening of embankments, buildings and other basic utility infrastructure in the vulnerable areas (refer to Figure 4)
- Arrangement of strong & reliable communication systems in landslide-vulnerable areas
- Setting up of control rooms to monitor landslides
- Removal of illegal dwellings/embankments at the edge/downstream of rivers in vulnerable areas

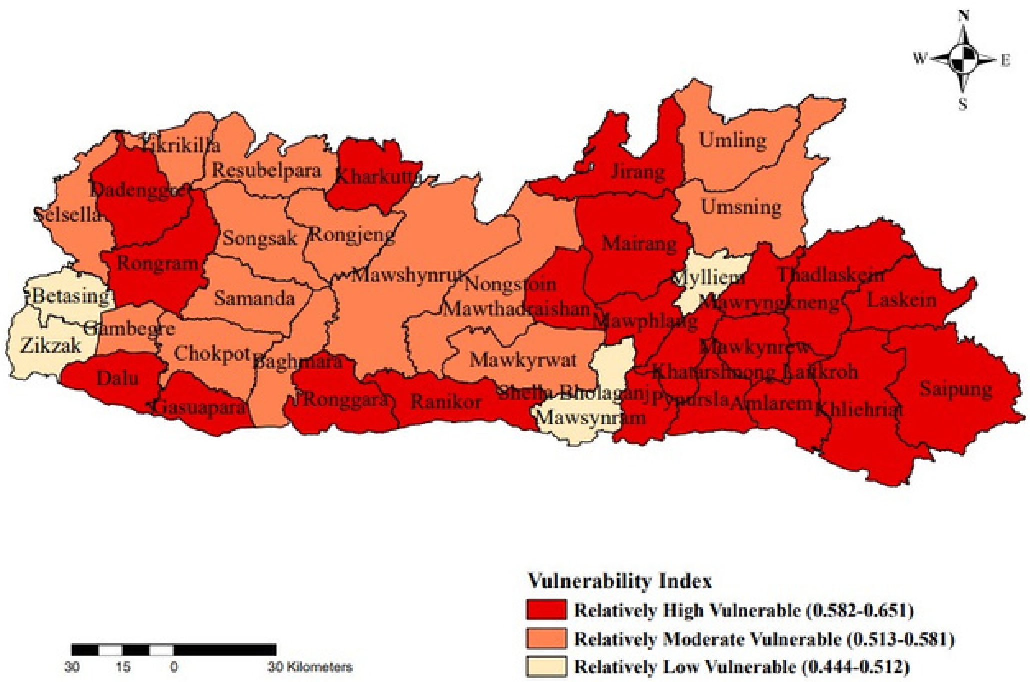

Figure 4: Map showing vulnerability categories of Meghalaya at the block level (Source: Department of Science & Technology Vulnerability Assessment 2019)

These measures in the Meghalaya SDMP are established to ensure minimal loss of lives & property, protect the local economy as well as preserve the ecological stability in the region.

Climate Change & Policy

Overview

Tackling climate change is perhaps one of, if not the most complex issues in the world. From dealing with its diverse consequences such as global warming, natural disasters, and socio-economic inequalities to bringing together all stakeholders for consensus on common issues, it involves a lot of time & calibrated effort. In the context of nations dealing with climate change, there have been several international organisations & summits such as the Kyoto Protocol, the UN Climate Change Conferences (COP), etc that have been trying to garner international support & attention towards climate issues. While it is debatable whether or not they have been immensely successful in achieving their objectives, these entities have, at the least, been helpful in stirring discussions on climate change as a menace of the 21st century. Various international conglomerates/business houses, educational institutions, non-profits, media and other bodies have now become part of such discussions, prompting governments to take necessary action.

In light of India's policy to deal with climate change-induced disasters, the sheer diversity of the geography and the variety of disasters that can happen across states have to be pointed out. The role of agents such as rainfall, surface temperatures, snowfall, pressure zones & wind circulation systems, etc and their constant trends cannot be ignored. As a result, the Ministry of Environment, Forest and Climate Change (MoEFCC) under the Government of India is the apex & nodal agency in the country responsible for the planning, coordination, and implementation of India's environmental policies, as well as the country's representative at forums & agencies like CoP, United Nations Environment Programme, ICIMOD, etc. It has led initiatives in the past that have led to the enactment of key environmental laws such as The Forest (Conservation) Act of 1980, and The Environment (Protection) Act of 1986- formed in the aftermath of the infamous Bhopal Gas Leak Tragedy, The National Environmental Authority Act of 1997- aimed at adjudicating matters concerning environmental clearances for projects and industrial activity, etc (Shaharban V, 2018). While these laws are primarily concerned with the protection of the environment & stability of ecosystems, the technical policies regarding natural disasters are enacted by the Ministry of Home Affairs (MHA) or several of its affiliated agencies at the national level; at the State level, state governments have formed their own bodies to deal with disaster management. By definition, disaster management is concerned with the prevention, preparedness, mitigation, responsiveness, assessment, evacuation/relief and rehabilitation of the concerned stakeholders. As such, the National Disaster Management Act (NDMA) 2005 has provided for the enactment of such strategies by Disaster Management Authorities (DMAs) at the national, state & district levels (DDMAs), apart from the establishment of an expert-led NIDM, creation of response forces (NDRF & SDRFs) and disaster mitigation & response/relief funds at all levels. NDMA has introduced a significant change in India's approach towards disaster management as it has provided greater autonomy to State Governments, paved the way for decentralisation of relief & rescue efforts up to the block & village levels, ensured logistical & financial support to public administrations, and integrated disaster management into more mainstream issues of governance & administration. Further, it has allowed the Central Government (i.e., the Disaster Management Division of the MHA) to formulate & update the disaster management strategy in spirit (while delegating the operational task to the States, as per decentralisation of powers), as well as to play a key role in coordinating efforts & information to-and-from itself and/or among different states in situations of natural disasters.

Way Forward?

In response to the increasing frequency & intensity of climate change-induced natural disasters, there have been growing calls across Indian states for developing policies & strategies to deal with such events. With the introduction of the National Action Plan for Climate Change (NAPCC) of 2008, key areas of climate action have been identified to be addressed along with the agenda of development- national missions undertaken by different ministries on issues such as solar & renewable energy, sustainable water bodies & habitats, preservation of the Himalayan ecosystem, development of agriculture and strategic knowledge, etc. The NAPCC is fundamentally formulated on the basis of the Intended National Determined Contributions (INDCs) of India i.e., climate actions originally agreed upon & ratified by each participating country at the United Nations Framework Convention on Climate Change (UNFCC) of October 2015- popularly known as COP21 or the Paris Agreement. Among others, the INDCs include goals such as reduction in carbon emissions, increase in non-fossil-fuel energy production, the introduction of frameworks for cleaner energy, healthy & sustainable lifestyles, etc, which have been declared after careful consideration of national circumstances as well as the principal of *'common but differentiated responsibilities'* (CBDR). The NDCs are periodically updated by the Government- for instance, as recent as August 2022, the Cabinet chaired by the Prime Minister announced enhanced climate action targets under the 'Panchamrit' promises, as listed below (PIB, 2022):

1. Achieving the long-term goal of net-zero carbon emissions by 2070
2. Reduction in carbon emissions by 1 billion tonnes by 2030
3. Reduction in the carbon intensity of GDP by 45% by 2030
4. Increasing non-fossil-fuel energy capacity to 500 gigawatts by 2030
5. Achieving 50% of energy needs via renewable means by 2030

One significant achievement of the NAPCC has been the introduction of the State Action Plan(s) on Climate Change (SAPCC) since the year 2009. Backed by scientific research & in sync with the NAPCC, the SAPCCs are policy documents of the States/Union Territories highlighting their strategies & policies to mitigate climate change & build climate resilience across key sectors. Over the years, all states & UTs have prepared & published their SAPCCs, and as a result, newer methods & technologies have been adopted such as vulnerability assessments, renewable energy sources, waste management, cleaner technologies, improved infrastructure, etc- all falling in line with India's updated INCs.

As mentioned previously in this study, many vulnerable states have implemented special policies & measures to battle the ill effects of climate change as part of their SAPCCs. For instance, the state of Odisha on the eastern coast of India- receiving erratic & unseasonal rainfall and being highly vulnerable to meteorological hazards like cyclones & storms, was one of the first few states in the country to have developed a comprehensive action plan (Dubash & Jogesh, 2014). The plan with an aim to build climate resilience and simultaneously promote the developmental agenda has outlined a process to identify key stakeholders, map regional vulnerability indices to different disasters, integrate existing policies with climate policies, and allot finances to corresponding climate action via India's 1st climate action budget. Among various key sectors, agriculture- engaging 70% of the state's population & contributing 26% to its GDP, has been suggested the following reforms under the SAPCC:

1. Developing water-efficient micro-irrigation methods via individual & community farm ponds to maximise the efficiency of water-use and help prevent crop failure due to inundation of agricultural fields
2. Introducing dedicated seed banks at the village level to manage climate variability and seeding in the long term
3. Investing in green-energy efficient models for farmers to help improve crop yield and protect the environment, while simultaneously increasing their [scientific] knowledge base and helping them adapt to such innovations
4. Adoption of climate-smart agricultural practices such as the System of Rice Intensification (SRI) i.e., a low-water & low labour-intensive agricultural technique, at the village level to help reduce methane emission and improve crop yields

Looking at the SAPCCs of other states across India, one can easily comprehend the similarities in policies- from identifying key sectors to suggesting policy/technical reforms. Since it is beyond possible to cover all the aspects of SAPCCs in one study, the paper shall focus solely on the policy recommendations that state action plans have come up with over the years. Further, it shall explore the intersection of climate change and natural disasters from a policymaking perspective. Lastly, the author shall list out a few actionable policy recommendations that can be implemented in the concerned state(s), since the prevalence of scientific evidence & the implementation of such practices in different countries across the world has garnered global attention, including that of policymakers & administrations, who now wish to start implementing them in Indian states with local customisations.

Consider the particular case of Meghalaya, as already discussed in the study. The Meghalaya State Disaster Management Plan of 2016 is the nodal document outlining the spirit of the state's Disaster Management (DM). A key feature of Meghalaya's model is the distribution of responsibility, in the form of District Disaster Management Plans (DDMP) tasked with specifying region-specific policies. Each DDMP takes all relevant decisions under the chairmanship of the district's Deputy Commissioner. For instance, the East Khasi Hills district, Shillong has worked in close coordination with the North Eastern Space Applications Centre (NESAC) at Umiam (near Shillong) since 2008 on remote sensing (RS) & satellite imagery (Rajasekar & Dashora, 2017). Shillong has also incorporated various aspects of disaster management in its urban development, under the Shillong City Master Plan (2001). It is also aimed at decongesting urban areas to mitigate the risks of earthquakes & landslides. Studies have also suggested the competent functioning of existing warning systems in Meghalaya to warn vulnerable groups, including the use of modern technology such as vehicle-mounted Public Address Systems (PAS), digital public displays, phone calls, emails & flash warnings (Rajasekar & Dashora, 2017). The Disaster Management Cell (established in 2006) & the State Disaster Response Force (SDRF) also conduct mock drills, awareness & sensitization programmes in partnership with institutes like North Eastern Hill University, National Institute of Disaster Management, etc. Interestingly, Meghalaya is also the 1st state in the Northeast to conduct DM-associated training for female government officials (Meghalaya State Disaster Management Authority, 2021). The state has also created multiple shelter locations in each district for effective utilisation. On a closer look, however, urban expansion has sidelined disaster mitigation as traditional disaster-resilient buildings have been replaced by concrete structures. Despite the presence of urban plans, urban local bodies have not been able to monitor the construction of illegal structures in vulnerable areas. Further, despite decent warning systems in place, night-time warnings have no specific arrangements and the state is mostly dependent on national bodies like the Geological Survey of India (GSI) to issue real-time warnings. Lastly, it is relevant to note that despite extensive awareness programmes by the State, the rate of public participation has not been able to match the expectations.

Since Meghalaya (and the rest of Northeast India) is highly prone to floods & landslides, the SDMPs and the SAPCCs shall be promptly revamped to meet any challenges. Some states have been prompt in recognising this and have introduced significant changes in their approach towards disaster management. For instance, the Assam Government launched a new draft version of their State Disaster Management Plan (ASDMP) in August 2022, after consultation with as many as 26 of its departments (Sentinel, 2022). After mapping the Northeast's vulnerability to disasters, it seems apt to take inspiration from Japan- a country that faces frequent earthquakes, floods, landslides and volcanic eruptions due to its presence in the Pacific volcanic belt. With an average of 1500 landslides per year, the *Guide to Disaster Management* published by the Disaster Management Bureau of Japan outlines the country's strategy for managing disasters and increasing preparedness. As such, using a broad reference to the aforementioned guide as well as a comprehensive study of the state of Meghalaya so far (with respect to its SDMP, SAPCC and its disaster vulnerability profile), the author feels the implementation of the following policy recommendations in the state can be crucial towards addressing natural disasters (particularly floods & landslides) induced by climate change:

1. Establishment of a dedicated landslide monitoring, auditing and control cell: This cell should be manned by subject matter experts. It should be made autonomous with technical, administrative, financial and legal powers to function effectively on its own. This is in line with the recommendations of the Department of Science & Technology, Government of India from 2018 for Sikkim (and other states in the Northeast) (National Institute of Disaster Management-NIDM, 2018). This can be feasibly implemented for other disasters such as earthquakes and floods as well.

2. Installation of specialised Deterrence Piles & Restraining Walls: This practice is widely implemented in Japan (JBP, 2020). These structures can prevent landslides and soil erosion by holding together the soil particles and allowing the excessive surface/groundwater to flow down into the ground. Further, their construction/installation can be done rapidly without disturbing the daily lives or the surrounding environment.

3. Mapping landslide-prone areas at 1:50,000 scale using satellite systems: This is being extensively followed in the states of Himachal Pradesh and Uttarakhand, where Landslide Hazard Zonation (LHZ) maps are prepared, refined and highly magnified to identify vulnerable areas.

4. Formation of dedicated early-warning systems: This has been implemented in Sikkim since 2018, wherein more than 200 sensors have been installed in 12 locations (prone to floods and landslides) in/around the capital Gangtok. This indigenously-developed system can provide a warning up to 24 hours in advance, thereby providing time for evacuation and institutional responses.

5. Prevention of illegal construction: Construction in high-hazard zones should be made liable for independent geologist reviews without which No Objection Certificates (NOCs) can not be obtained by the builder/applicant. This can help prevent illegal/unplanned construction on slopes vulnerable to floods & landslides, and also encourage better land use and land planning by urban bodies.

6. Installation of Automatic-Rain Gauges (ARG)/Automatic Weather Stations (AWS) to help keep a check on excessive surface runoffs, which are among the leading triggering constituents for floods and landslides in the Northeast.

Conclusion

Climate change poses a huge risk to lives and livelihoods across the globe. Some climate events are slow in their onset- like sea level rise (SLR), rise in the temperature, and glacial retreat- and have an impact on the ecology and mankind over time; while some other climate events- flash floods, heavy landslides- happen suddenly and are known to have an immediate devastating impact. The frequency of such extreme climate events has only risen in India & across the world in recent decades. Between 1999 and 2018, there have been over 12,000 extreme climate events globally, resulting in 495,000 deaths and economic losses amounting to nearly USD 3.54 trillion (Mohanty, 2020). Developing countries like India are particularly prone to such events. Further, the Himalayan region in the north- along with the northeastern part- of the country is relatively more vulnerable to climate change & induced natural disasters due to its fragile geography, active tectonic movements, irregular trends in precipitation, and a sensitive ecosystem. From glacial retreats and unchecked rapid urbanisation to declining forest covers and age-old policies, the IHR is facing the brunt of some of the most devastating natural disasters the country has seen in recent years- Kedarnath, Chamoli, etc. Such events bring to light the urgent need to take climate action through relevant policies & techniques, as highlighted towards the end of this study. The review of the vast literature available on these areas of study, the identification of vulnerable locations & key disasters in those areas, the analysis of national & state-level climate policies, and the eventual section dealing with the actionable policy recommendations are designed to ensure that the reader shall be able to gauge how the Himalayan region of India can be better prepared for withstanding adverse climate events in the future.

References

1. Aggarwal, M. (2018, December 21). *Assam most vulnerable to climate change in Indian Himalayan region: Study*. Mongabay. Retrieved November 1, 2022, from https://india.mongabay.com/2018/12/assam-most-vulnerable-to-climate-change-in-indian-himalayan-region-study/

2. Aggarwal, M., & Ghosh, S. (2022, June 22). *IPCC climate change report: What does it mean for India?: IDR.* India Development Review. Retrieved September 20, 2022, from https://idronline.org/article/environment/ipcc-climate-change-report-what-does-it-mean-for-india/?gclid=Cj0KCQiAhf2MBhDNARIsAKXU5GSL5WP4yrErmyH1zmEZw1VMRGOaVfT3pHKffTwJ6Dcu7BcohMsvDEkaAq-JEALw_wcB

3. Amateur Seismic Centre (ASC), Pune. (2022, January). *ASC- Seismicity of Meghalaya, India.* Amateur Seismic Centre, Pune. Retrieved September 22, 2022, from http://www.asc-india.org/seismi/seis-meghalaya.htm

4. Bhardwaj, A. (2013). *Directory of water resources in Himachal Pradesh*. http://www.hpccc.gov.in/. Retrieved September 22, 2022, from http://www.hpccc.gov.in/documents/Water%20Sources%20in%20Himachal%20Pradesh.pdf

5. CEEW. (2020, December 10). *75% districts and half of India's population vulnerable to extreme climate events: CEEW study.* Council on Energy, Environment and Water (CEEW). Retrieved September 20, 2022, from https://www.ceew.in/press-releases/75-districts-and-half-india%E2%80%99s-population-vulnerable-extreme-climate-events-ceew-study.

6. Chavez, N., & Pokharel, S. (2018, August 18). *Rain receding in Kerala after the worst floods in nearly a century.* CNN. Retrieved September 22, 2022, from https://edition.cnn.com/2018/08/18/asia/kerala-floods/index.html

7. Collective, H. (2016, November). *Dried & state of the rivers - Himachal Pradesh dusted - Himdhara.* http://www.himdhara.org/. Retrieved September 22, 2022, from http://www.himdhara.org/wp-content/uploads/2017/10/State-of-the-Rivers-Report-final-2017-Himachal-Pradesh.pdf

8. Disaster Management Cell, Himachal Pradesh. (2015, March). *Preparation of Hazard, Vulnerability & Risk Analysis atlas and report for the state of Himachal Pradesh.* Shimla; Disaster Management Cell, Department of Revenue, Government of Himachal Pradesh.

9. Dogra, B. (2022, September 19). *Not just climate change, mismanaged rivers, towns also led to deluge in South Asia.* Counterview Open Forum. Retrieved November 1, 2022, from https://www.counterview.in/2022/09/not-just-climate-change-mismanaged.html

10. Dubash, N. K., & Jogesh, A. (2014, February 16). *An analysis of the Odisha Climate Change Action Plan.* CPR. Retrieved November 1, 2022, from https://cprindia.org/briefsreports/an-analysis-of-the-odisha-climate-change-action-plan/

11. Eckstein, D., Künzel, V., & Schäfer, L. (2021, January). *Global Climate Risk Index 2021*. Bonn, Germany; Germanwatch.

12. Eriksson, M., Jianchu, X., Shrestha, A. B., Vaidya, R. A., Nepal, S., & Sandström, K. (2009). *The changing himalayas - preventionweb*. ICIMOD. Retrieved September 22, 2022, from https://www.preventionweb.net/files/11621_icimodthechanginghimalayas1.pdf

13. Forest Survey of India. (2019). *India State of Forest Report 2019- Himachal Pradesh*. fsi.nic.in. Retrieved September 22, 2022, from https://www.fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-himachal-pradesh.pdf

14. Froude, M. J., & Petley, D. n. (2018, August). *Global Fatal Landslide Database.* Department of Geography, University of Sheffield, UK.

15. Geological Survey of India (GSI). (2020, August). *Landslide Hazard in India.* Retrieved September 22, 2022, from https://www.gsi.gov.in/webcenter/portal/OCBIS/pageGeoInfo/pageLANDSLIDEHAZRD/pageLandslideHazardHome?_adf.ctrl-state=124xff3stl_220.

16. Guhathakurta, P., Narkhede, N., Menon, P., Prasad, A. K., & Sangwan, N. (2020, January). *Observed Rainfall Variability and Changes over Himachal Pradesh State.* PUNE; INDIA METEOROLOGICAL DEPARTMENT MINISTRY OF EARTH SCIENCES.

17. Guhathakurta, P., Sreejith, O. P., & Menon, P. A. (2011). *Impact of climate change on extreme rainfall events and flood risk in India.* Journal of Earth System Science, 120(3), 359–373. https://doi.org/10.1007/s12040-011-0082-5

18. Gupta, A., & Kulkarni, H. (2018, August). *Inventory and Revival of Springs in the Himalayas for Water Security.* New Delhi; NITI Aayog.

19. Himachal Pradesh State Disaster Management Authority (HP SDMA). (2017). *Himachal Pradesh State Disaster Management Plan 2017*. Shimla; Himachal Pradesh State Disaster Management Authority.

20. Himalayan Landslide Society (HILS). (2021, November). *Himalayan landslide society - Background - HILS.* http://hils.org.np/. Retrieved September 22, 2022, from http://www.hils.org.np/hils/index.php/organization/background

21. IANS. (2022, September 18). *Assam govt concerned as 15 districts most vulnerable to climate change*. Business Standard News. Retrieved September 22, 2022, from https://www.business-standard.com/article/current-affairs/assam-govt-concerned-as-15-districts-most-vulnerable-to-climate-change-122091701069_1.html

22. IMD (2013) *State Level Climate Change trends in India. Meteorological Monograph No. ESSO/IMD/ EMRC/02/2013*. India Meteorological Department (IMD), Ministry of Earth Sciences, Government of India. Available at http://environicsindia.in/wp-content/uploads/2018/09/StateLevelClimateChangeMonoFinal.pdf

23. Indian Institute of Technology (IIT) Mandi. (2019, March). *The Story of Climate Change in Himachal Pradesh*. Mandi; Indian Institute of Technology (IIT) Mandi. https://www.iitmandi.ac.in/ISTP/projects/2019/reports/Group%2002.pdf

24. Indian Institute of Technology Mandi, Indian Institute of Technology Guwahati, & Indian Institute of Science Bengaluru. (2019). *Climate Vulnerability Assessment for Adaptation Planning in India Using a Common Framework*. New Delhi; Department of Science & Technology, Government of India. Available at https://dst.gov.in/sites/default/files/Full%20Report%20%281%29.pdf

25. Karmakar, R. (2020, August 2). *In Assam, a trail of broken barriers*. The Hindu. Retrieved September 22, 2022, from https://www.thehindu.com/news/national/other-states/in-assam-a-trail-of-broken-barriers/article32244695.ece

26. Krishnan, R., Shrestha, A. B., Ren, G., Rajbhandari, R., Saeed, S., Sanjay, J., Syed, M. A., Vellore, R., Xu, Y., You, Q., & Ren, Y. (2019). *Unravelling climate change in the Hindu kush himalaya: Rapid warming in the mountains and increasing extremes*. The Hindu Kush Himalaya Assessment, 57–97. https://doi.org/10.1007/978-3-319-92288-1_3

27. Kulkarni, A., Patwardhan, S., Kumar, K. K., Ashok, K., & Krishnan, R. (2013, May 1). *Projected climate change in the Hindu kush–Himalayan region by using the high-resolution regional climate model PRECIS*. BioOne Complete. Retrieved September 20, 2022, from https://bioone.org/journals/mountain-research-and-development/volume-33/issue-2/MRD-JOURNAL-D-11-00131.1/Projected-Climate-Change-in-the-Hindu-KushHimalayan-Region-By-Using/10.1659/MRD-JOURNAL-D-11-00131.1.full

28. Kulkarni, A. V., & Karyakarte, Y. (2014, January 25). *Special section: Science of the Himalaya observed ... - Current Science.* Current Science. Retrieved September 20, 2022, from https://currentscience.ac.in/Volumes/106/02/0237.pdf

29. Lahiri, I. (2021, August 11). *IPCC climate change report: What should be India's immediate plan of action?* TheQuint. Retrieved September 20, 2022, from https://www.thequint.com/climate-change/ipcc-climate-change-report-2021-what-should-be-india-immediate-plan-of-action#read-more

30. Manzar, O. (2013, July 1). *Uttarakhand crisis underlines Community Radio's importance.* mint. Retrieved September 22, 2022, from https://www.livemint.com/Opinion/DaNUP0lpIPqbXmlmhawaJI/Uttarakhand-crisis-underlines-community-radios-importance.html

31. Meghalaya Climate Change Centre (MCCC). (2019, May 1). *NAPCC &* Meghalaya SAPCC. MCCC. Retrieved November 1, 2022, from https://meghalayaccc.org/napcc-meghalaya-sapcc/

32. Ministry of Home Affairs (MHA). (2011). *Disaster Management of India Manual 2011*. New Delhi; Ministry of Home Affairs, Govt of India.

33. Mohanty, A. (2020, December 10). *Preparing India for Extreme Climate Events*. Council on Energy, Environment and Water (CEEW).

34. Nath, V. (2021). *Analysis of the snow cover area of the Gangotri and surrounding glaciers using remote sensing and GIS*. International Journal for Research in Applied Science and Engineering Technology, 9(8), 2761–2776. https://doi.org/10.22214/ijraset.2021.37865

35. National Institute of Disaster Management (NIDM). (2018, September). *Landslides Hazard Zonation Map of India.* Available at https://cdn.s3waas.gov.in/s399bcfcd754a98ce89cb86f73acc04645/uploads/2018/09/2018090689.pdf

36. National Institute of Disaster Management (NIDM). (2019, September). *National Landslide Risk Management Strategy*. National Institute of Disaster Management. Retrieved September 30, 2022, from https://www.nidm.gov.in/PDF/pubs/NDMA/26.pdf

37. Official, W. W. F. (n.d.). Himalayas. *WWF*. Retrieved September 20, 2022, from https://www.worldwildlife.org/places/eastern-himalayas

38. PBS, F. (2014, October 21). *The Himalayas ~ tectonic motion: Making the Himalayas.* PBS - NATURE. Retrieved September 22, 2022, from https://www.pbs.org/wnet/nature/the-himalayas-tectonic-motion-making-the-himalayas/6342/

39. Patwardhan, A. (2011, March). *Report of the Study Group on Himalayan glaciers.* ResearchGate. Retrieved September 20, 2022, from https://www.researchgate.net/publication/316858999_Report_of_the_Study_Group_on_Himalayan_Glaciers_Submitted_to_the_Principal_Scientific_Adviser_Government_of_India

40. Platform, J. B. (2020). *Bosai Solution Database: Japan Bosai Platform*. Bosai Solution Database | Japan Bosai Platform. Retrieved September 22, 2022, from https://www.bosai-jp.org/en/solution/category

41. Prakash, S. (2011, December). *Historical records of socio-economically significant landslides in India.* ResearchGate. Retrieved September 22, 2022, from https://www.researchgate.net/publication/272905239_Historical_Records_of_Socio-economically_Significant_Landslides_in_India

42. Press Information Bureau (PIB). (2022, August 3). *Cabinet approves India's Updated Nationally Determined Contribution to be communicated to the United Nations Framework Convention on Climate Change.* Https://Www.pib.gov.in/. Retrieved September 22, 2022, from https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1847812.

43. Rajasekar, U., & Dashora, L. (2017, July). *REVIEW OF EARLY WARNING SYSTEM SHILLONG CITY*. Shillong; USAID-GoI-UNDP.

44. Randhawa, S. S., & Gautam, N. (2021, July 20). *Assessment of Spatial Distribution of Seasonal Snow Cover during the Year 2020-21 in Himachal Pradesh Using AWIFS Satellite Data.* State Centre on Climate Change, Himachal Pradesh. Retrieved September 20, 2022, from https://drive.google.com/file/d/1qxetS4CtssrlepwKF631_9EdZzZPfedc/view

45. Rao, V. B., Franchito, S. H., Gerólamo, R. O., Giarolla, E., Ramakrishna, S. S., Rao, B. R., & Naidu, C. V. (2016). *Himalayan warming and climate change in India*. American Journal of Climate Change, 05(04), 558–574. https://doi.org/10.4236/ajcc.2016.54038

46. Romshoo, S. A., Fayaz, M., Meraj, G., & Bahuguna, I. M. (2020). *Satellite-observed glacier recession in the Kashmir Himalaya, India, from 1980 to 2018*. Environmental Monitoring and Assessment, 192(9), 1–17. https://doi.org/10.1007/s10661-020-08554-1

47. Sabin, T. P., Krishnan, R., Vellore, R., Priya, P., Borgaonkar, H. P., Singh, B. B., & Sagar, A. (2020). *Climate change over the Himalayas.* Assessment of Climate Change over the Indian Region, 207–222. https://doi.org/10.1007/978-981-15-4327-2_11

48. Santoshi, N. (2022, September 22). *Gangotri Glacier retreated by 1,700m since '35: Study*. Hindustan Times. Retrieved September 22, 2022, from https://www.hindustantimes.com/india-news/gangotri-glacier-retreated-by-1-700m-since-35-study-101663783000831.html

49. Scott, C. A., Zhang, F., Mukherji, A., Immerzeel, W., Mustafa, D., & Bharati, L. (2019). *Water in the Hindu Kush Himalaya.* The Hindu Kush Himalaya Assessment, 257–299. https://doi.org/10.1007/978-3-319-92288-1_8

50. Meghalaya State Disaster Management Authority (SDMA). (2021, November). *A Note on Disaster Management: Specific Emphasis on Women.* SDMA: Meghalaya State Disaster Management Authority. Retrieved September 22, 2022, from https://megrevenuedm.gov.in/msdma/msdma_sdma.html

51. Sentinel, The. (2022, August 5). *Assam government launched draft of new disaster management plan.* Sentinel Assam News. Retrieved September 22, 2022, from https://www.sentinelassam.com/north-east-india-news/assam-news/assam-government-launched-draft-of-new-disaster-management-plan-606000

52. Sharma, A. (2020, August 29). *Monsoon death reaches 161 as torrential rains and landslides paralyse Himachal.* https://www.outlookindia.com/. Retrieved September 22, 2022, from https://www.outlookindia.com/website/story/india-news-monsoon-death-reaches-161-as-torrential-rains-and-landslides-paralyse-himachal/359503

53. Singh, S. S., & Barik, S. (2021, May 27). *Cyclone Yaas makes landfall in Balasore, triggers heavy damage.* The Hindu. Retrieved September 22, 2022, from https://www.thehindu.com/news/national/cyclone-yaas-makes-landfall-in-balasore-triggers-heavy-damage/article34652295.ece

54. Sorkhabi, R. (2009, December). *Geologic formation of the Himalayas.* The Himalayan Club. Retrieved September 22, 2022, from https://www.himalayanclub.org/hj/66/9/geologic-formation-of-the-himalaya/

55. Sujatha, E. R., & Sridhar, V. (2021). *Landslide susceptibility analysis: A logistic regression model case study in Coonoor, India.* Hydrology, 8(1), 41. https://doi.org/10.3390/hydrology8010041

56. Sumeda. (2022, June 25). *Explained: Assam's annual tryst with devastating floods.* The Hindu. Retrieved September 22, 2022, from https://www.thehindu.com/news/national/other-states/assam-flood-devastation-monsoon-brahmaputra-reason-cause/article65549836.ece

57. Tayal, S. (2019, November). *Climate change impacts on Himalayan glaciers and implications on energy: TERI.* TERI: The Energy And Resources Institute. Retrieved September 20, 2022, from https://www.teriin.org/sites/default/files/2019-11/cc-impact-himalayan-glacier.pdf

58. V, Shaharban. (2018). *Climate change and disaster management in India.* SSRN Electronic Journal, 262–272. https://doi.org/10.2139/ssrn.3153859

59. Vasudeva, V. (2022, August 20). *Himachal Pradesh prone to natural disasters, says study.* The Hindu. Retrieved September 22, 2022, from https://www.thehindu.com/sci-tech/energy-and-environment/annual-trysts-with-natures-fury-reveal-himachal-pradeshs-reckoning-with-fragile-ecology/article65790936.ece