A Study on Climate Change and Increasing Natural Disaster in India

Tanmoy Mondal, Assistant Professor, Department of Geography, Arunachal University of Studies
Biplab Tripathy, Associate Professor, Department of Geography, Arunachal University of Studies
Subhechya Raha, Research Scholar, Department of Geography, Arunachal University of Studies

Abstract
Climate change is one of the major environmental challenges facing the world today. It has a significant impact on tropical and subtropical countries, especially in coastal regions. It is also a global threat to water and food security, agricultural supply chains, and many coastal cities worldwide. According to the 2021 IPCC report, flash floods, high temperatures, droughts, cyclones, and rising sea levels will continue to devastate regions in South Asia, including India. This paper examines the relationship between climate change and disasters in the context of India, along with the country's disaster profile and the increasing trend of such events. The Indian subcontinent is one of the world's most disaster-prone areas, with approximately 85% of India's territory vulnerable to one or multiple hazards. Erratic weather patterns, rising sea levels, glacier melt, and other factors have heightened the risks in the Indian subcontinent. Tackling the challenge of climate change and the increasing disaster risks holds particular significance for India. This paper aims to identify the causes of climate change and its impact on disasters in India. The study is based on secondary data, including satellite images and photography, as well as primary sources. Additionally, the study area map has been prepared using QGIS.
Keywords: Climate change, IPCC, Erratic weather, Sea level rise, Disaster

Introduction

The footprint of climate change is already visible in every country around the world, making it one of the most significant challenges for humanity in the 21st century. Climate change has become a significant contributing factor to numerous environmental disasters, referring to alterations in the Earth's temperature and weather patterns. These changes can occur naturally or be the result of human activities, but since the 1800s, human actions have been the primary driver of climate change. This is mainly due to the burning of fossil fuels, deforestation, and other factors like plastic pollution and urbanization. The burning of fossil fuels generates greenhouse gases that envelop the Earth like a blanket, trapping the sun's heat and leading to an increase in surface temperatures. Climate disasters, in turn, refer to events either caused or exacerbated by the effects of climate change, including rising temperatures, changing rainfall patterns, sea level rise, and increasingly violent weather. These events impact human societies and ecosystems in numerous ways, including loss of life, displacement, economic losses, and food scarcity.

According to the World Meteorological Organization, the last decade (2011-2020) was the warmest on record, with changes in the Earth's climate driven by increased heat-trapping greenhouse gases having widespread effects on the environment. The main greenhouse gases responsible for climate change include carbon dioxide and methane, originating from various human activities. Deforestation and land clearance can also release carbon dioxide, while landfills for garbage represent a major source of methane emissions. The main sectors contributing to greenhouse gas emissions are energy, industry, transportation, buildings, agriculture, and land use.

According to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment report in 2021, human emissions of greenhouse gases have already raised global temperatures by nearly 1.1 degrees Celsius since the pre-Industrial era (starting in 1750). It is expected that the global average temperature will increase by nearly 1.5 degrees Celsius within the next few decades, affecting all regions of the Earth. India, the seventh-largest country in the world, is situated in South Asia between 20.59°N and 78.96°E. Its total geographical area, bordered by the Indian Ocean, Bay of Bengal, Arabian Sea, and the Himalayan Mountain ranges, greatly influences its climate. India experiences tropical weather with scorching

summers, short and dry winters, and four distinct seasons - winter, summer, pre-monsoon, and post-monsoon. The climate of India is notably complex and has undergone significant changes in recent times. Due to climate change, India is now considered one of the most disaster-prone countries in the world, facing various disasters each year.

India is exceptionally vulnerable to climate change, with a high risk of disasters such as floods, droughts, landslides, and cyclones. Changes in temperature, precipitation patterns, sea level rise, and an increase in weather-related disasters pose substantial risks to agriculture, food security, and other services in India. Current weather events, such as cyclones, floods, droughts, and other climatic hazards, are becoming more frequent and intense due to climate change. Coastal states are particularly vulnerable in India, facing multiple hazards like floods, cyclones, and sea-level rise. Sea-level rise is one of the primary contributors to climate change, and the coastal states of India have seen an increase of 15-38 centimeters, affecting cities and major economic hubs.

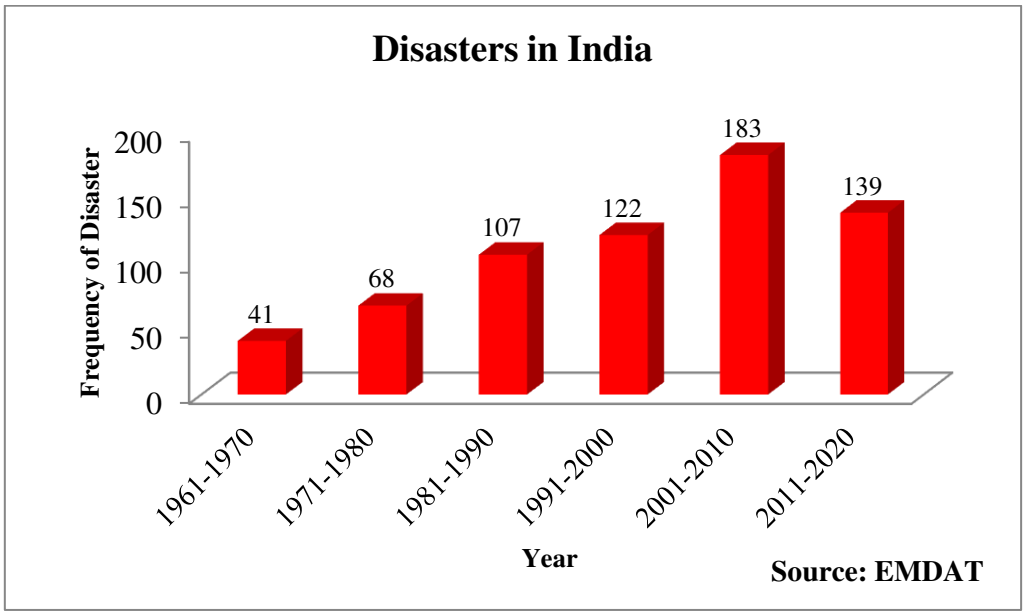

Figure No 1: Disaster in India during 1961 – 2020

In Figure No. 1, the total number of disasters in 1961-1970 was 41, and there has been a significant increase in the number of disasters in 2011-2020. Hydro-meteorological and climatological disasters accounted for 35 (as shown in Figure No. 2) during 1961-1970. However, due to the impact of climate change, the occurrence of disasters has steadily risen over the course of 2011-2020, resulting in a total of 139 disasters, with 131 of them being hydro-meteorological and climatological in nature.In the current decade (2021-2023), there have been 35 recorded disasters, with 34 of them being climate-related. This trend underscores the fact that climate change is contributing to a year-by-year increase in the occurrence of disasters.

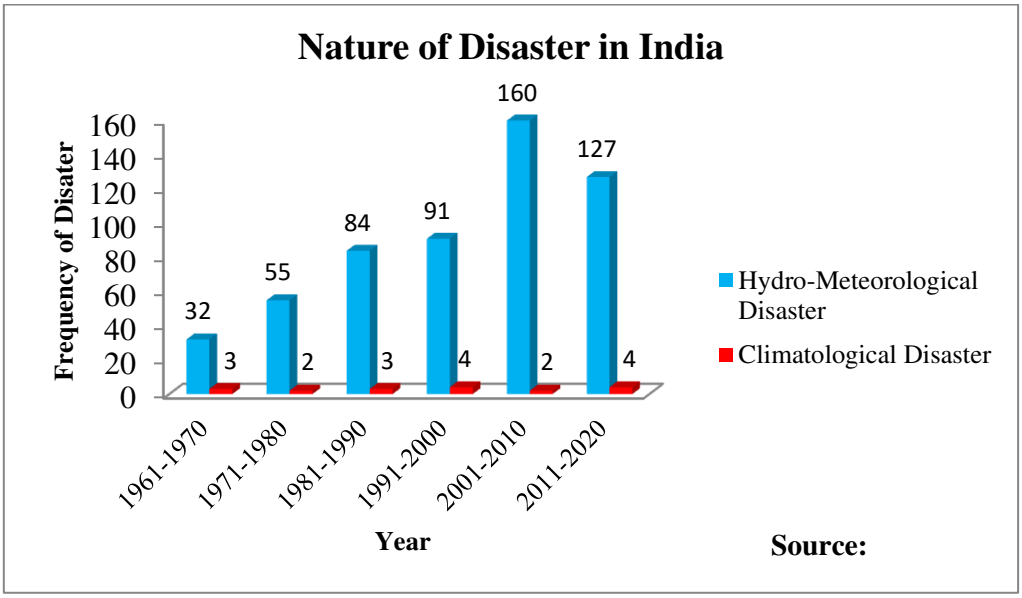

Figure No 2. Nature of Disaster in India

The effects of disasters are far-reaching, with their severity leaving people, places, and ecosystems exposed and vulnerable. Every year, millions of people are affected by these disasters. In India, from 1961 to 2023, disasters have affected a total of 247,98,25,592 people in various ways, with 245,01,24,207 people impacted by climate-related disasters.

Objective

1. To identify the effects of Climate change in India
2. To identify the risks related to climate change in India
3. Area of effects in India.

Methods & Materials

To identify changes in climate, climatic data have been utilized, collected from various sources including EMDAT, National Weather Services, IMD, Ministry of Earth Science, Cyclone eAtlas, IMD, and NASA Earth Observatory. This data will be instrumental in discussing trends in temperature and the number of cyclones in selected areas for identifying changes in climate and associated risks.

Analysis

1. **Effect of climate change in India**
    a. **Increase the Temperature and heat waves**

Global climate change has multifaceted effects on our planet. One of the most significant symptoms is the rising temperature, which impacts not only the climate but also biodiversity, crops, human health, and more. India is no exception to this critical issue, experiencing a noticeable trend of increasing temperatures along the west coast, central India, the interior peninsula, and the North-Eastern region. This rise in temperature can result in more frequent and intense heatwaves. Over the years, the average temperature in India has increased by approximately 0.76°C from 1901 to 2021.

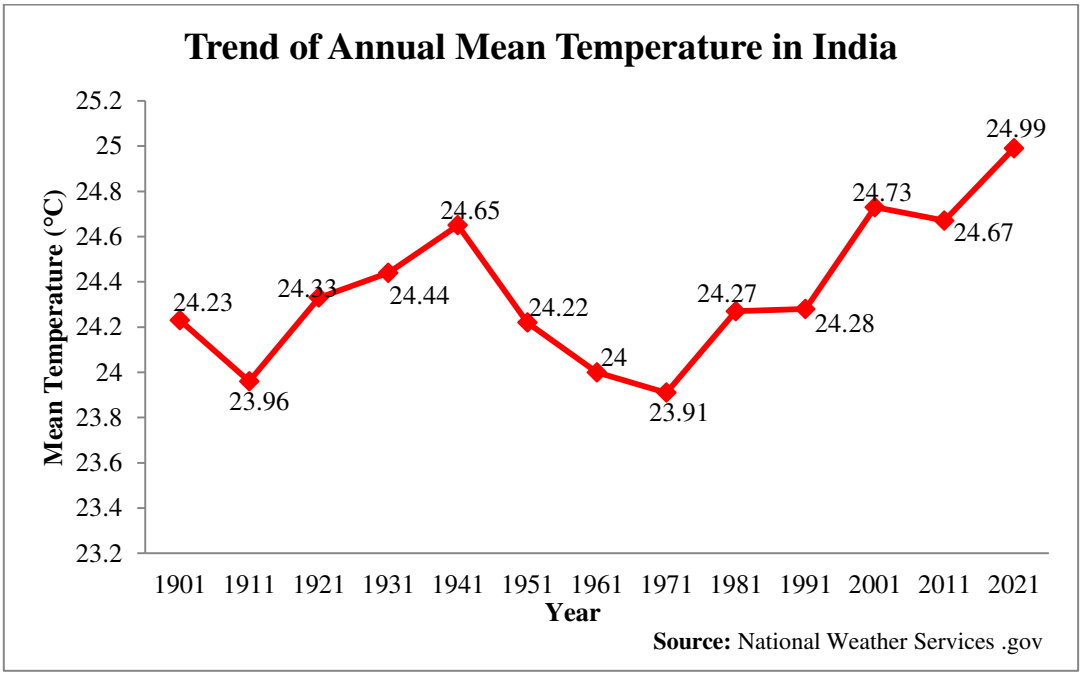

Figure No 3: Trend of Annual Temperature in India

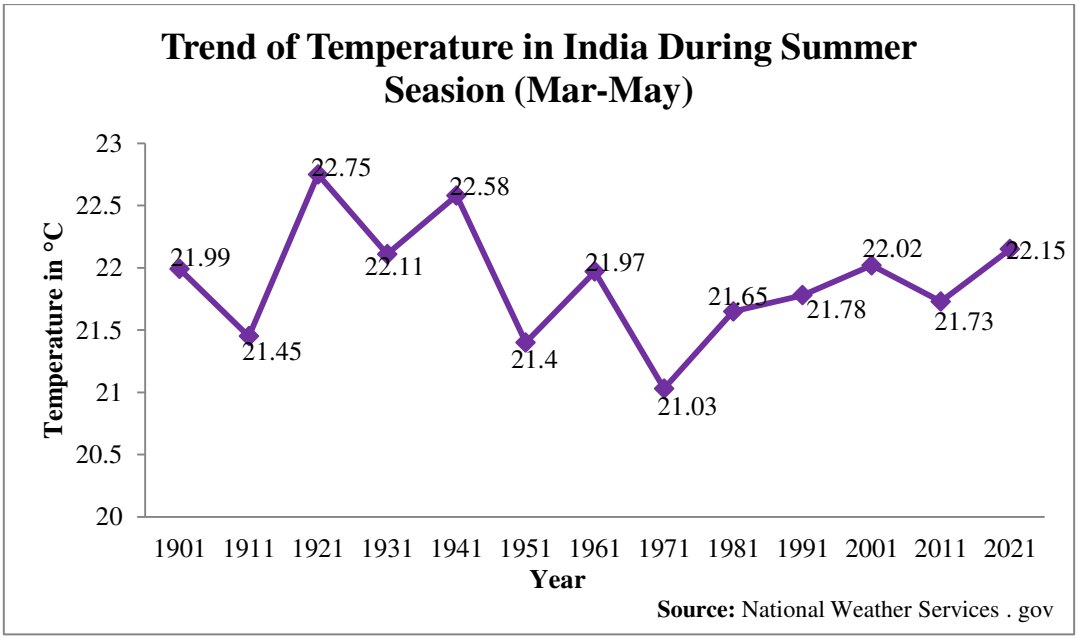

Figure No 4. Summer Time Temperature in India

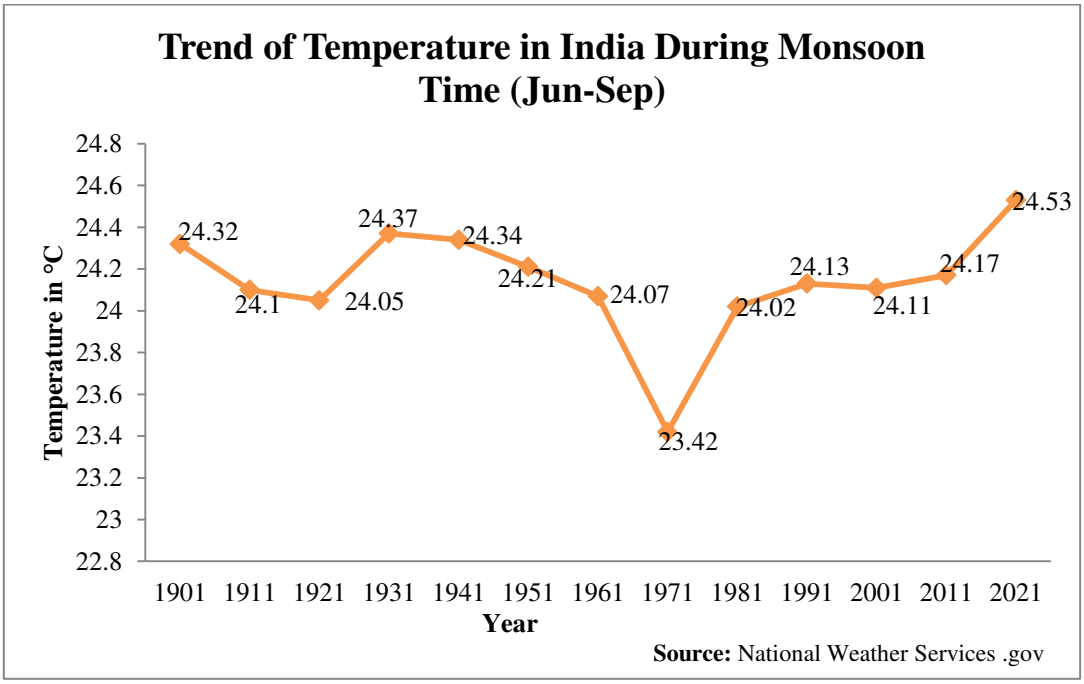

Figure No 5: Monsoon Time Temperature in India

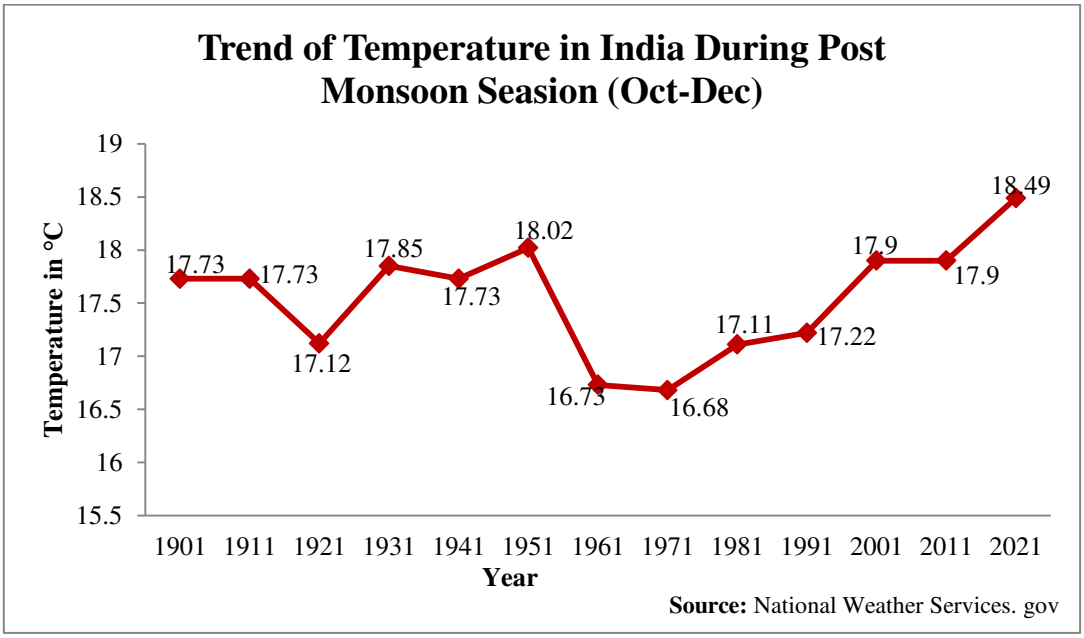

Figure No 6: Post Monsoon Temperature in India

The average temperature in India has been steadily rising due to global warming. During the monsoon season, temperatures increased by 0.21°C from 1901 to 2021. Post-monsoon (3C) and summer (3B) periods have also witnessed rising temperatures due to the effects of climate change, exacerbating the issue of drought in India.

b. Erratic Monsoons

India's rainfall patterns are primarily governed by the monsoon, but climate change has disrupted the monsoon, causing irregular and erratic weather with inadequate rainfall and high temperatures. The number of rainy days is decreasing, while the intensity of rainfall on each day is increasing. According to the Indian Meteorological Department (IMD), climate change has resulted in some alarming statistics. In

2018, monsoon rainfall was the sixth-lowest since 1901, and in 2019, the monsoons progressed at their slowest rate in at least 12 years. Over the span of 66 years (1950 to 2015), extreme rain events over central India have seen an increase. Another study highlights that extreme rainfall has also increased in Southern and Central India due to climate change.

Figure No. 4 illustrates the irregular rainfall in India. In 1951, the total rainfall was 1060.4, while in 1961, it increased to 1399.3. However, from 1991 to 2011, rainfall decreased due to climate change. Interestingly, in 2021, rainfall increased again. This erratic trend in rainfall has resulted in India facing both floods and droughts simultaneously, disrupting the agricultural system due to the unpredictability of heavy or insufficient rainfall.

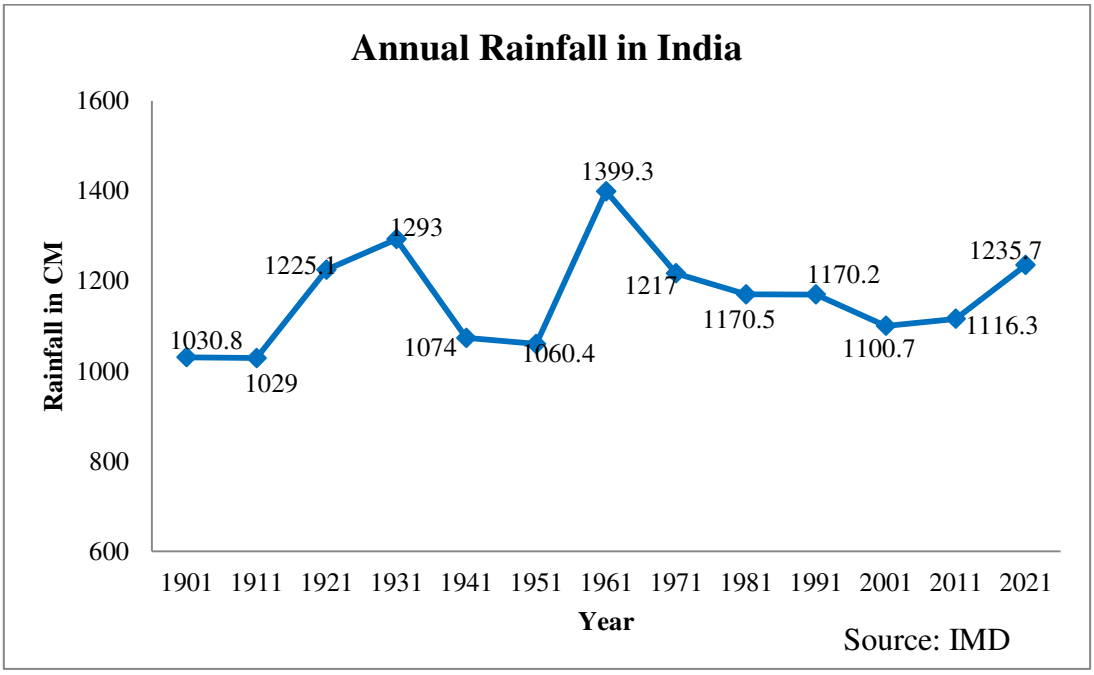

Figure No 7: Annual rainfall in India

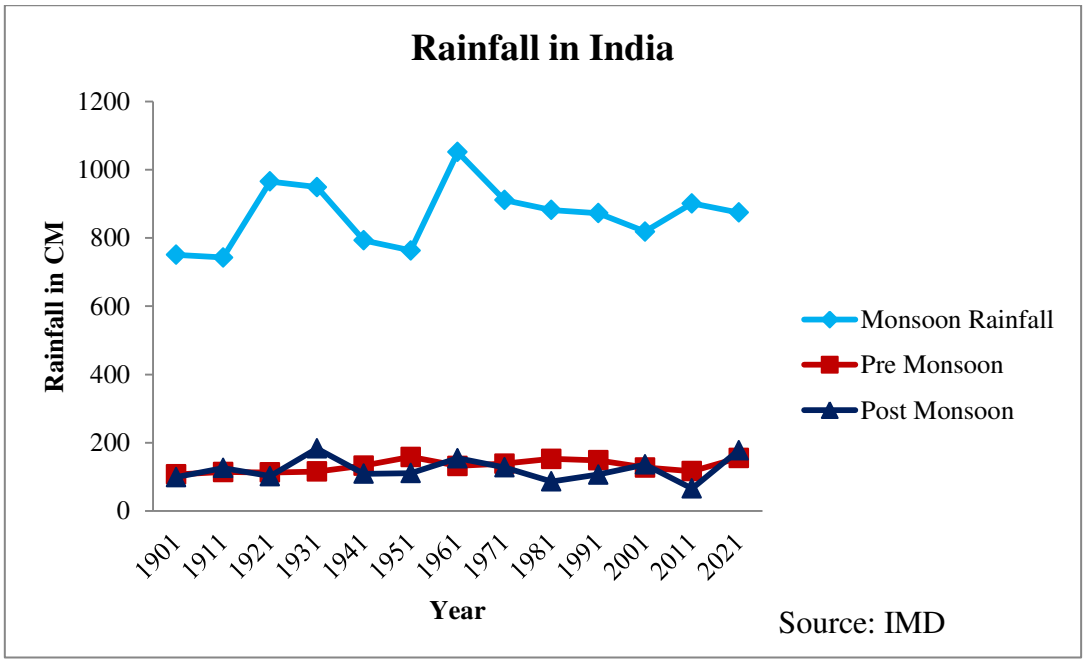

Figure No 8: Seasonal rainfall in India

In Figure 4(B), the monsoon rainfall has decreased and become irregular, with pre-monsoon rainfall being less than post-monsoon rainfall, which has also become erratic.

c. Floods

Floods have been recurrent natural disasters in India, and the impacts of climate change are exacerbating their frequency and intensity. Erratic monsoon patterns, intense rainfall, and changing river flows have increased the frequency and severity of floods in India. Factors such as deforestation, improper river management, and unplanned urbanization have compounded these impacts. In India, 40 million hectares are prone to floods, with 8 million hectares affected each year, and this is increasing annually due to climate change. The Gangetic and Brahmaputra regions in the North and North-East are the most flood-prone areas, and other flood-prone regions include the Narmada and Tapti basins in the North-West and the Mahanadi, Krishna, and Cauvery River basins in Central India. Climate change influences stream flow patterns through changes in precipitation and snowmelt from Himalayan glaciers, which poses risks to the Himalayan region of India. Climate change has played a role by altering weather patterns and contributing to heavy rainfall, leading to floods. Higher temperatures have caused glacier melting, resulting in glacial lake outbursts and increased river water flow, causing devastating floods in India. Western India may experience very high river discharges more frequently due to intense rainfall. Apart from changes in snowmelt and precipitation in the Himalayas, changes in the pattern, intensity, and frequency of rainfall will significantly impact floods. Climatic changes are the result of more frequent high-intensity rainfall events in India. Flood disasters are the leading cause of economic damage and loss of human life in India. Uttarakhand experienced devastating flash floods in June 2013, resulting in the loss of thousands of lives and extensive infrastructure damage. In December 2015, Chennai, the capital of Tamil Nadu, witnessed unprecedented flooding, resulting in nearly 100 casualties and extensive property loss. Kerala experienced one of its worst flood events in August 2018, resulting in over 400 deaths and massive destruction. Climate change contributed to these disasters by increasing rainfall intensity during the monsoon season. The state of Assam faces annual floods affecting millions of people. In 2023, several districts in Assam, including Jorhat, Barpeta, Kamrup, Goalpara, have been severely affected. Nearly 28,000 people in Barpeta and 9,000 in Lakhimpur have been severely impacted, with 253 villages and 1,526,08 hectares of crop areas damaged. Bihar is one of the most flood-prone states in India, with nearly 100 villages affected and over 50,000 people displaced due to flooding. The districts of Araia, Purnea, Madhepura, Saharsa, Jamui, Katihar, and Banka are among the most affected. Due to heavy rainfall, which is the result of climate change, Himachal Pradesh faced flood events in 2023. Around 170 houses have collapsed, more than 100 people have been affected, and nearly 88 have lost their lives due to the swirling floodwaters. The residential areas along the Jamuna River have been closed, roads submerged, and thousands of people severely affected. After 45 years, the floodwaters came close to the Taj Mahal, and after 40 years, the Jamuna River flowed at a record high through the capital. These events are indicative of the extreme climate changes occurring in India. Climate change has intensified these floods by altering rainfall patterns and increasing the frequency of extreme weather events. The Brahmaputra River, which flows through Assam, is particularly susceptible to flooding due to heavy rainfall and glacial melt from the Himalayas.

d. **Drought**

Climate change can contribute to prolonged and more severe droughts. Droughts can cause water scarcity, impacting agriculture, livestock, and overall water availability for communities. In India, the area prone to drought has increased by 57% since 1997 due to climate change. Seventy-four districts and 13 states in India are drought-affected areas. From 2020 to 2022, drought has impacted nearly two-thirds of the country. India has experienced 41 droughts from 1801 to 2003, including 22 major droughts. In 2002, India experienced a severe drought, affecting nearly 56% of the geographical area. Rajasthan is one of the most drought-prone areas in India, with many farmers struggling due to drought. The most drought-affected areas are West Bengal, Bihar, Uttar Pradesh, Jharkhand, and other states.

Table No 1: Details of Drought from 1951 to 2002

S. N.	Year	Percentage of affected area in India	Category
1	1951	33.2	Moderate
2	1952	25.8	Slight
3	1965	42.9	Moderate
4	1966	32.3	Moderate
5	1968	20.6	Slight
6	1969	19.9	Slight
7	1971	13.3	Slight
8	1972	44.4	Severe
9	1974	29.3	Moderate
10	1979	39.4	Moderate
11	1982	33.1	Moderate
12	1985	30.1	Moderate
13	1986	19.0	Slight
14	1987	49.2	Severe
15	2002	Areas in 14 States	Severe

Source: Draught Affected States

Table No 2: Probability of occurrence of drought in different meteorological sub division of India

Meteorological sub division	Frequency of deficient rainfall (75% of normal or less)
Assam	Very rare, once in 15 years
West Bengal, Madhya Pradesh, Konkan, Bihar and Orissa	Once in 5 years
South Interior Karnataka, Eastern Uttar Pradesh and Vidarbha	Once in 4 years
East Rajasthan, Gujarat and Western Uttar Pradesh	Once in 3 years
West Rajasthan, Tamil Nadu, Jammu &Kashmir and Telangana	Once in 2.5 years

Source: Draught Affected States

e. Rise in sea levels

The rise in sea levels is one of the significant consequences of climate change, impacting the coastal regions of India. This phenomenon exacerbates the frequency and severity of disasters, posing numerous challenges for the country. According to reports from the Ministry of Earth Science, the average rate of sea level rise along the Indian coast was approximately 1.7 mm/year from 1900 to 2000. This has put cities like Chennai and Kolkata at risk. The Sunderbans in West Bengal, a UNESCO World Heritage site, faces severe threats due to rising sea levels. Increased inundation and erosion have resulted in land loss, impacting agriculture, livelihoods, and biodiversity. Over the last two decades, sea levels have risen by 30 mm/year in the Sunderbans delta, leading to a 12 percent loss of the shoreline. Ghoramara Island in the Sunderbans has experienced extensive erosion and land loss due to sea level rise. Over recent decades, several villages on the island have been submerged, forcing the local population to be displaced. Major coastal cities like Chennai and Mumbai in India have already witnessed the consequences of rising sea levels.

The Table shows that the Indian ports which are situated at the coastal area are in very high risk due to sea level rise.

Table No 3: Sea level rise in India in various Ports

Indian Ports	Sea level rise mm/year
Kandla	3.18
Okha	1.5
Mumbai	0.74
Kochi	1.3
Chennai	0.3
Visakhapatnam	0.9
Port Blair	2.2
Paradip	1.03
Haldia	2.89
Diamond Harbour	5.16

Source: Ministry of Earth Science

f. Devastating tropical cyclones and storm surges

Tropical cyclones and storm surges are natural weather phenomena that originate in low-pressure systems forming over warm ocean waters. These systems bring with them strong winds, heavy rainfall, and storm surges, primarily affecting coastal areas. They typically form in regions such as the Bay of Bengal, the Indian Ocean, and the Arabian Sea. However, the impact of climate change on these events has raised concerns about increasing disaster risks, especially in countries like India India, with its extensive coastline, is highly vulnerable to cyclones and storm surges. The Bay of Bengal, in particular, is prone to cyclone activity. States situated along the eastern and southern sides of the Bay of Bengal, including Odisha, West Bengal, Andhra Pradesh, and Tamil Nadu, are frequently affected by cyclones.

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Table No 4: List of the Major Cyclonic Strom which hits of the India from 2009-2023

Sl. No.	Year	Name of Cyclone	Region	Effected Area
1	2009	Cyclone Phyan	Arabian Sea	Tamil Nadu, Goa, Maharashtra, Gujarat and Karnataka
2	2012	Cyclone Nilam	Bay of Bengal	Mahabalipuram
3	2013	Cyclone Phailin	Bay of Bengal	Devastating impact in Odisha and Andhra Pradesh
4	2014	Cyclone Hudhud	Bay of Bengal	Severe damage to Visakhapatnam and Odisha
5	2016	Cyclone Vardah	Bay of Bengal	Andaman and Nicobar islands, Chennai, Kancheepuram and Visakhapatnam
6	2018	Cyclone Ockhi	Arabian Sea	Kerala, Tamil Nadu and Gujarat
7	2019	Cyclone Fani	Bay of Bengal	Odisha
8	2019	Cyclone Bulbul	Bay of Bengal	Odisha, West Bengal and Bangladesh
9	2020	Cyclone Amphan	Bay of Bengal	West Bengal and Bangladesh
10	2021	Cyclone Tauktae	Arabian Sea	Gujarat
11	2021	Cyclone Yaas	Bay of Bengal	Odisha and West Bengal

12	2021	Cyclone Tauktae	Arabian Sea	Gujarat, Maharashtra and Karnataka
13	2021	Cyclone Gulaab	Bay of Bengal	Andhra Pradesh and Odisha
14	2022	Cyclone Jawad	Bay of Bengal	Odisha and Andhra Pradesh
15	2022	Cyclone Asani	Bay of Bengal	Andhra Pradesh and Tamil Nadu
16	2022	Cyclone Sitrang	Bay of Bengal	Assam, Odisha West Bengal and Andaman and Nicobar Islands
17	2022	Cyclone Mandous	Bay of Bengal	Chennai
18	2023	Cyclone Biparjoy	Arabian Sea	Gujarat

Source: EMDAT

Cyclones and storm surges pose a significant threat to coastal regions and contribute to sea-level rise along the Indian coastline. Climate change has increased the risk of storm surges and cyclones in India. The impacts of cyclones and storm surges exacerbated by climate change are numerous and severe. They include a significant risk to human life, potential loss of lives during the cyclone itself, as well as from subsequent flooding and disease outbreaks in the aftermath. Infrastructure damage is another consequence, including the destruction of homes, roads, bridges, and other essential facilities. The economic costs are substantial, as affected regions often suffer from disruptions to agriculture, fisheries, and other industries, leading to long-term socio-economic consequences.

g. Urban heat island

Urban heat islands (UHIs) occur when cities experience higher temperatures than the surrounding rural areas. Several parts of India have been experiencing severe heatwaves due to climate change, which causes the temperatures in urban areas to be higher than normal. In recent years, the urban heat island effect in India has accelerated in megacities and towns. Due to UHIs, cities are becoming hotter day by day, with UHI intensities increasing by up to 8-10°C in urban areas. The UHI effect has been observed to impact spatiotemporal rainfall patterns, temperature, and heat-related morbidity and mortality in Indian cities. The rise in temperature is primarily caused by the prevalence of buildings, houses, and roads in cities made of concrete, which traps heat. During the summer season, UHIs in Indian cities are observed to be in the range of 10.5 – 14°C. Delhi exhibits the highest UHI intensity in the range of 13.4 – 14.0°C, while Kolkata has the lowest UHI intensity in the range of 10.5 – 11.7°C.

2. Risks related to climate change in India

a. Sea level Rise

Sea level rise is one of the major risks of climate change and poses a significant threat to Indian coastal cities. Even small changes in sea level can have a significant impact on the coastline. According to a report from the World Meteorological Organization, cities like Mumbai, Chennai, Kolkata, and other coastal cities in India are at risk due to sea level rise. The Ministry of Earth Sciences reported in 2021 that sea levels along the Indian coast had risen by approximately 1.7 mm/year from 1900 to 2000. In the Sunderbans delta, sea levels have risen by 30 mm/year in the last two decades, leading to a 12 percent loss of the shoreline. In 1994, measurements showed that sea levels were rising at a rate of about 0.78 mm/year in Mumbai, 1.14 mm/year in Kochi, and 0.75 mm/year in Visakhapatnam. However, Chennai experienced a decrease of about 0.65 mm/year. Analyzing tide gauge data revealed that the net mean sea level at Diamond Harbour rose by 5 mm/year between 1948 and 2010. Reports suggest that Mumbai, Kochi, Mangalore, Chennai, Kolkata, Visakhapatnam, and Thiruvananthapuram are at risk of being submerged by 2050 due to sea level rise. Therefore, gradual sea level rise, resulting from climate change, poses a significant risk to coastal states and major cities in India.

b. Frequent cyclonic problem

Climate change has led to higher sea surface temperatures, which, in turn, have increased the occurrence of devastating storms in the ocean. The Indian Ocean region is one of the most cyclone-prone areas globally, with an average of 5 to 6 cyclones each year. Seven percent of global cyclones originate in the Arabian Sea and the Bay of Bengal, with most occurring in the Bay of Bengal (4:1) in the Indian region. From 2006 to 2020, 61 cyclones hit the coastal states of India, with the highest numbers recorded in Odisha (20), West Bengal (14), and Andhra Pradesh (11). Climate change has played a significant role, with rising sea surface temperatures resulting in an increased number of cyclones each year in the Indian Ocean and Bay of Bengal. According to the National Disaster Management Authority (NDMA) in 2022, 75% of the Indian coastline is affected by cyclones and related hazards.

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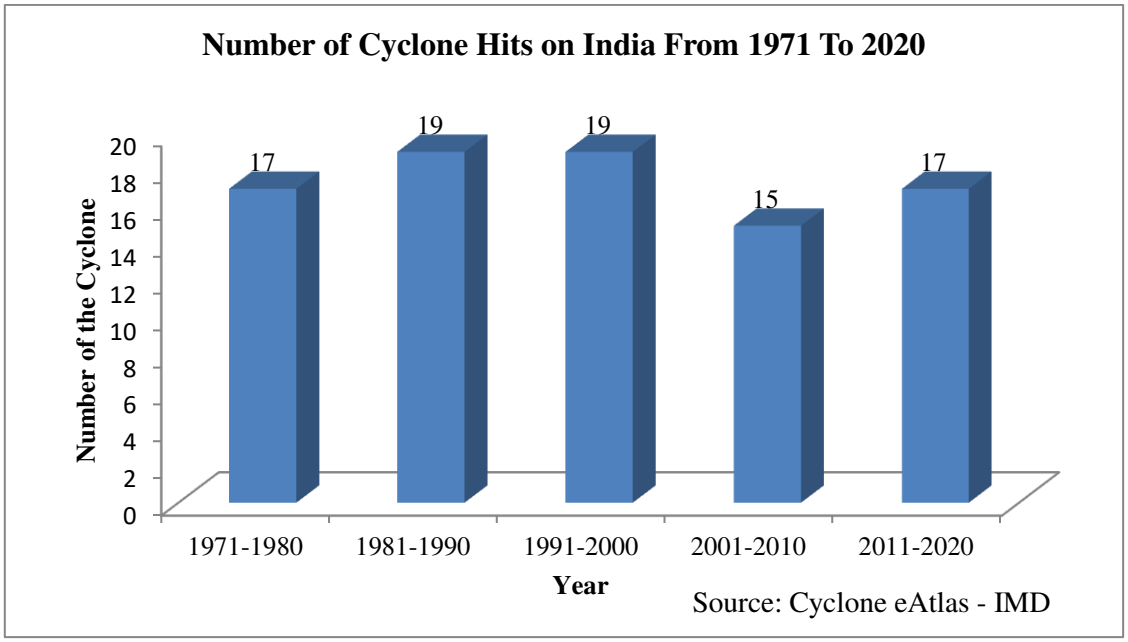

Figure No 9: Cyclones hits in India from 1971 to 2020

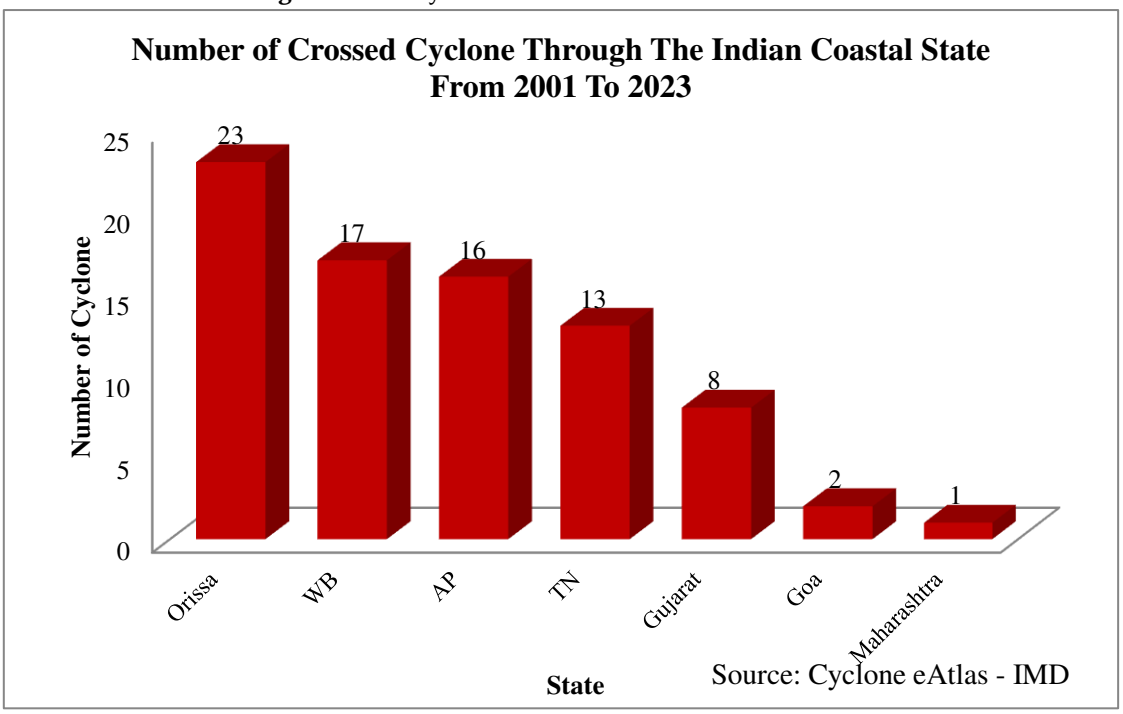

Figure No 10: Cyclone crossed over the Indian costal state

c. Himalayan disturbance

The Himalayas host the largest area of glacial ice outside the Polar Regions. Climate change exerts a strong influence on precipitation patterns over the Himalayas and has led to the melting of glaciers. The Himalayan region has experienced a maximum warming of 2.5°C from 1950 to 1999, with projections indicating it could reach as high as 9°C by 2100. The western Himalayas, in particular, saw a temperature increase of 2.7°C between 1979 and 2007. In the Hindu Kush Himalayan region, temperatures are 0.3 degrees higher than the normal range. The rising temperatures in the Himalayan regions have led to the formation of numerous glacial lakes and the melting of glaciers, resulting in an increased risk of flooding. The loss of glaciers has significant implications for water availability, particularly during the summer season. The rivers of northern India, such as the Indus, Ganges, Brahmaputra, and Kosi River, are primarily snow-fed, making them susceptible to high flood risks during the rainy season. In 2008, the states of Bihar and Assam in India were severely affected by floods, primarily caused by the Kosi and Brahmaputra Rivers. Increased temperatures and drought in the Himalayan region have further exacerbated glacier melt, contributing to the risk of rising sea levels. The Gangotri Glacier, one of the largest in the Himalayas, has been receding since 1780, with a more rapid retreat observed after 1971 due to climate change. Over the last 25 years, the Gangotri glacier has retreated by more than 850 meters. Additionally, the Siachen and Pindari Glaciers have retreated at rates of 31.5 meters and 23.5 meters per year, respectively. In other studies, the Milam Glacier in the Kumaon Himalaya retreated by 9.1 meters per year from 1901 to 1997. The DokrianiBamak Glacier in Garhwal Himalaya retreated by 586 meters during the period from 1962 to 1997. The Kangto and Gorichen Glaciers of the Himalayas are also retreating due to rising temperatures.

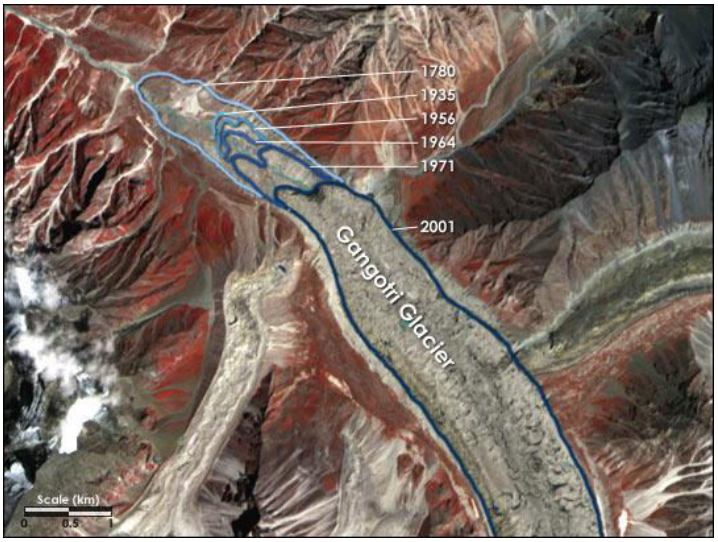

Figure No 11: Melted of Gangotri Glacier**. Source:** NASA Earth Observatory,**(https://earthobservatory.nasa.gov/)**

According to the Geological Survey of India, the glaciers in the Satluj River Basin, including Gara, GorGarang, ShauneGarang, and NagpoTokpo Glaciers, have been retreating at rates of 4.22 to 6.8 meters per year. In the Chenab River Basin, glaciers such as Bara Shigri, ChhotaShigri, Miyar, Hamtah, NagpoTokpo, Triloknath, and Sonapani Glaciers have experienced even more significant retreat, with rates ranging from 6.81 to 29.78 meters per year. These rates of retreat are indicative of the substantial impact of climate change on glacier melt in these regions.

Table No 5: Record of retreating of some glaciers in the Himalaya

Glacier Name	Period	Time	Retreat of snout (meter)	Average retreat of Glacier (meter/year)
Triloknath	1969-1995	27	400	14.81
Bara Shigri	1906-2000	94	3600	38.29
Chhota Shigri	1988-2000	130	1100	84.62
Pindari	1845-1966	122	2840	23.28
Milam	1849-1997	149	2472	16.59
Gangotri	1849-2002	148	3588	24.24
Siachen	1962-2001	39	936	24
South Terong	1962-2001	39	3970	101.79
Zemu	1977-1884	8	194	24.25

Source: Statistics Related to Climate Change-India 2015, mospi.gov.in/sites/default/files/publication_reports/climateChangeStat2015.pdf

d. Landslide due to ice level change

Landslides occur when rock, debris, or earth moves down a slope under the influence of gravity. Current changes in the Earth's climate may be contributing to an increased landslide hazard in glacier regions. Due to climate change, catastrophic slope failures are occurring in mountain glaciers, especially in the cryosphere, when they lose their equilibrium. Increasing temperatures, changes in precipitation patterns, and decreased glacier ice are resulting in an elevated hazard. Climate change is expected to increase the frequency and intensity of landslides in the Himalaya Region of India. The impact of landslides on climate change and the subsequent increase in disasters in India is a complex issue influenced by various factors. Landslides are geological phenomena caused by a combination of natural and human-induced factors, and their occurrence and severity can be exacerbated by climate change. Rising temperatures, glacier ice melt, and increased rainfall are contributing to more frequent and severe landslides in India.

Table No 6: History of Avalanche in India

Year	Disaster type	Location
1986	Avalanche	Jammu and Kashmir State
1988	Avalanche	Jammu and Kashmir, Ladakh
1995	Avalanche	Kashmir province
1998	Avalanche	Sikkim
2003	Avalanche	Administrative unit not available district (Jammu and Kashmir province)
2005	Avalanche	Administrative unit not available districts (Jammu and Kashmir province)
2010	Avalanche	Administrative unit not available district (Jammu and Kashmir province)
2016	Avalanche	Jammu and Kashmir (Administrative unit not available) (Siachen glacier)
2017	Avalanche	Sonamanrg (Ganderbal district), Gurez Valleys (Jammu and Kashmir state)

Source: EMDA

e. Heavy rainfall and flash flood

Climate change is intensifying the monsoon, making it stronger and more erratic, which is increasing the frequency and ferocity of floods in India. Rising global temperatures have led to a concerning trend of prolonged periods without rain, followed by sudden bouts of excessive rainfall. The entire North-Indian region is witnessing floods and flash floods as a consequence of climate change. Climate change is amplifying hydrological extremes in India, significantly increasing the frequency of heavy rainfall events, leading to more intense flash floods in hilly regions. Cloudbursts are common in the hilly regions of India and are a result of climate change, triggering flash floods. According to the IPCC, India has seen a 40 percent increase in flash floods over the past three years. In 2020, India experienced 132 flash flood events, which rose to 145 in 2021, and in 2022, India witnessed 184 flash floods due to heavy rainfall. The Ministry of India has noted, "There has been a significant increase in extreme weather events, including intense rainfall activity, due to global warming. The frequency of localized heavy rainfall activity has also increased significantly, leading to a higher occurrence of landslides and flash floods."

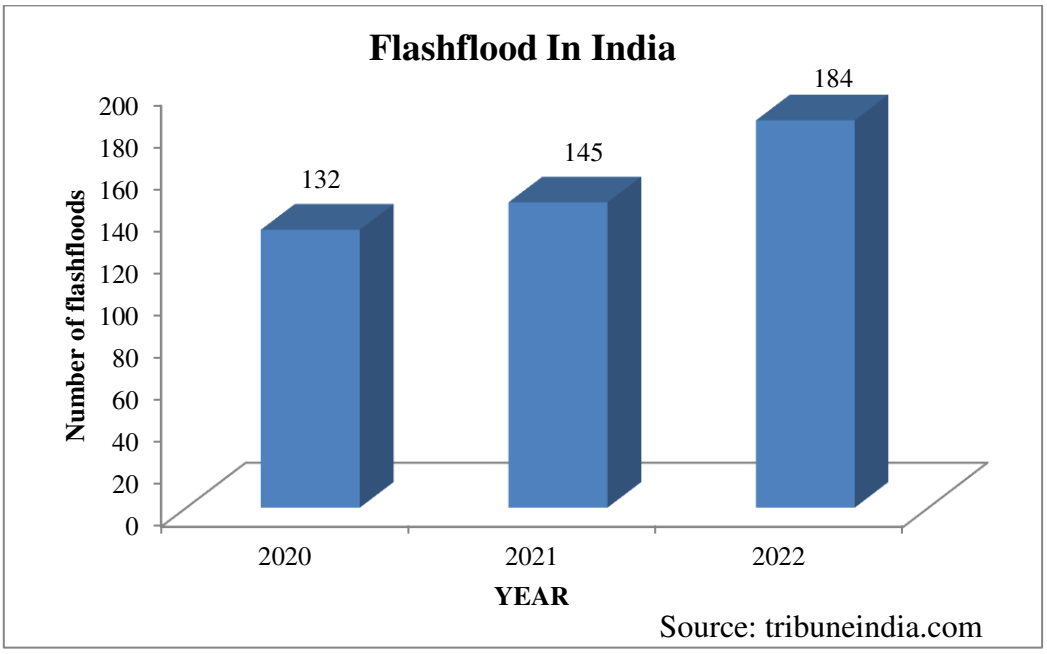

Figure No 12: Flashflood in India from 2020 to 2022

3. Effected area in India

The Indian subcontinent, with its unique geophysical setting and socio-economic conditions, is highly vulnerable to various natural disasters. The country faces the risk of disasters due to numerous factors, both natural and human-induced. Approximately 57% of the Indian landmass is susceptible to earthquakes, 28% to drought, 12% to floods, 8% to cyclones, and recently, rising sea levels have emerged as a drastic disaster event for India. The assessment of disaster vulnerability in India is based on various composite indicators. India's geographic conditions have given rise to five distinctive regions: the Himalayan region, the plain region, the hilly parts of the peninsula region, and the coastal zone, each with its own specific and multi-layered vulnerabilities. Currently, the country is witnessing an increase in the frequency and intensity of disasters, resulting in widespread devastation. India is vulnerable to various disasters, including cyclones, heavy rains, floods, landslides, droughts, and more. States such as Assam, Bihar, Gujarat, Himachal Pradesh, Kerala, West Bengal, Odisha, Uttarakhand, Tamil Nadu, Andhra Pradesh, among others, are particularly vulnerable to these disasters. More than 80% of the population in India resides in areas prone to extreme hydro-meteorological disasters. The southern, northern, northeastern, western, and central parts of India are highly susceptible to such extreme disasters. The northeastern states are prone to floods, while the

southern and central regions of India face the risk of droughts. The accompanying map illustrates the major disaster-prone regions in India associated with climate change-related disasters.

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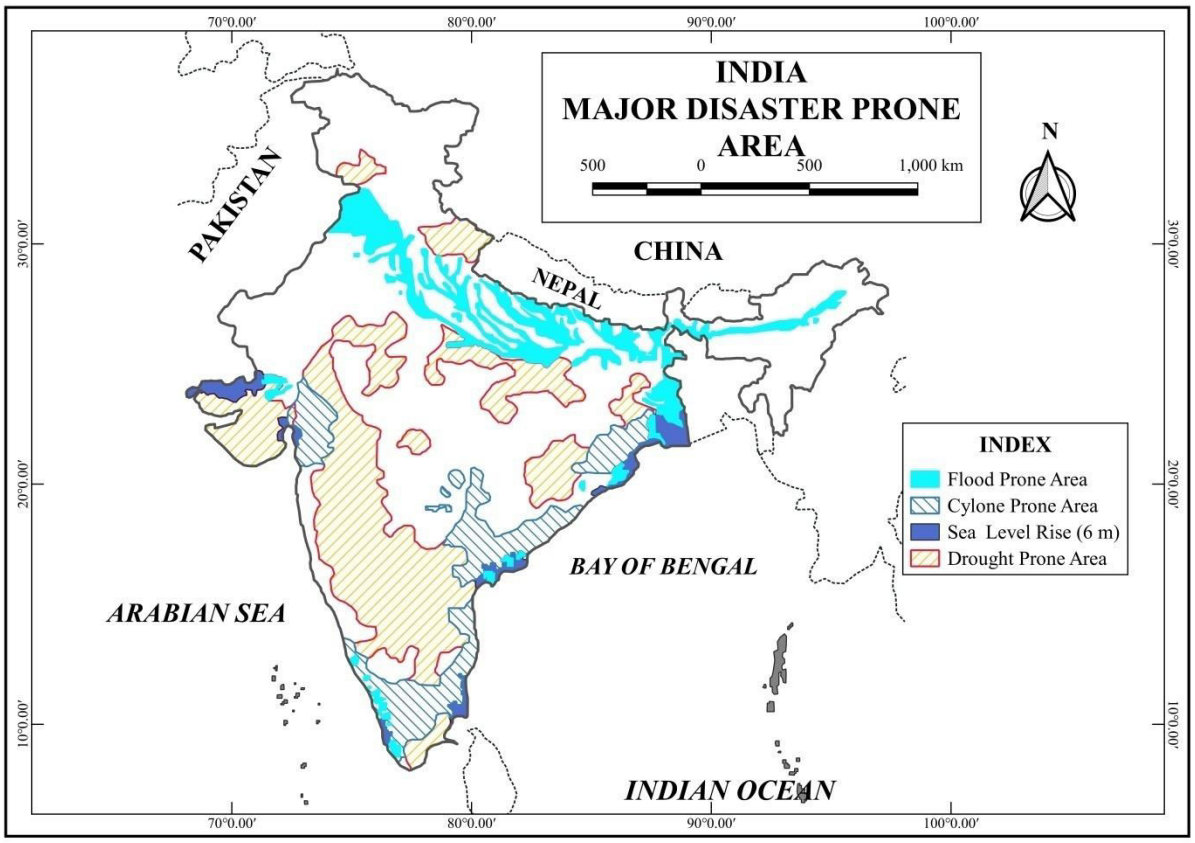

Figure No 13: Major disaster prone area in India

According to the National Climate Vulnerability Assessment Report (2021), certain states and districts in India are highly vulnerable to current climate risks and key drivers of vulnerability.

Highly Vulnerable States: The report identifies Jharkhand, Mizoram, Odisha, Chhattisgarh, Assam, Bihar, Arunachal Pradesh, and West Bengal as states highly vulnerable to climate change.

Lower-middle Vulnerable States: Himachal Pradesh, Telangana, Sikkim, and Punjab fall into the category of lower-middle vulnerable states.

Low Vulnerable States: Uttarakhand, Haryana, Tamil Nadu, Kerala, Nagaland, Goa, and Maharashtra are considered low vulnerable states.

Highly Vulnerable Districts: When looking at individual districts, Assam, Bihar, and Jharkhand have over 60% of their districts categorized as highly vulnerable.
Extreme climatic events can have a profound impact on the environment and society, including the loss of life, property, and livelihoods. In recent years, the occurrence of extreme climate events and the associated losses have become highly visible in India.

Table No 7: Lost by the natural disaster

Year	Live Lost Human (in No)	Cattle Lost (in No)	Houses Damaged (in No)	Cropped Areas Affected (in Lakh hecters)
2001-02	834	21269	346878	18.72
2002-03	898	3729	462700	21.00
2003-04	1992	25393	682209	31.98
2004-05	1995	12389	1603300	32.53
2005-06	2698	110997	2120012	35.52
2006-07	2402	455619	1934680	70.87
2007-08	3764	119218	3527041	85.13
2008-09	3405	53833	1646905	35.56
2009-10	1677	128452	1359726	47.13
2010-11	2310	48778	1338619	46.25
2011-12	1600	9126	876168	18.87
2012-13	948	24360	671761	15.34
2013-14	5845	102998	1210227	63.746
2014-15	1696	92180	725390	26.855
2015-16	1543	64230	1654817	33.57
2016-17	1550	23544	549422	28.27
2017-18	2494	49168	1193462	38.52
2018-19	2025	122967	1556571	17.09
2019-20	2422	71755	744589	114.29
2021-22	2002	53228	780053	50.40

Source: Annual Report , Ministry of Home Affairs (MHA)

Findings &Conclusion

Climate change has emerged as a significant and alarming factor that exacerbates the potential for natural disasters in India, particularly those associated with cyclones and storm surges. This phenomenon is a result of multiple interconnected elements, such as rising sea levels, warming oceans, and the intensification of cyclones, which collectively contribute to more severe impacts on the nation. The consequences are far-reaching, encompassing the loss of human lives, substantial damage to critical infrastructure, and extensive economic losses. These implications are not isolated; they are intertwined with the broader context of climate change and its resultant environmental degradation, including global temperature increases, glacial melt down, and sea level rise.

One of the most conspicuous effects of climate change is the rise in global temperatures. As greenhouse gases continue to accumulate in the Earth's atmosphere, the planet's average temperature steadily increases. This temperature surge has a profound impact on oceanic conditions, providing the energy necessary for cyclones to intensify. Warmer oceans serve as breeding grounds for more potent storms, which, in turn, increases the disaster potential associated with cyclones and storm surges. India, with its extensive coastline, is particularly susceptible to these escalating threats.

Another consequence of climate change is the melting of glaciers, both at a regional and global scale. The Himalayan glaciers, for instance, are receding at an alarming rate, contributing to the rise in sea levels. As glaciers lose mass, more water flows into the oceans, leading to a continuous increase in sea levels. The coastal regions of India, already vulnerable to cyclones and storm surges, face the double whammy of rising sea levels and more intense cyclonic activity.

Furthermore, the nexus between climate change and environmental degradation is undeniable. As the climate continues to evolve, ecosystems are disrupted, habitats are lost, and biodiversity is threatened. Coastal areas in India are experiencing rapid development, spurred by industrialization and urbanization,

but this progress comes at a significant cost. The relentless expansion of urban centers and industries in these regions often leads to deforestation, habitat destruction, and pollution, further aggravating the vulnerability of the local population to climate-associated calamities.

In light of these pressing challenges, it is imperative for India to adopt a holistic and multifaceted approach to address the growing risk associated with cyclones and storm surges intensified by climate change. Mitigation efforts, which aim to reduce greenhouse gas emissions and slow down the process of climate change, are of paramount importance. India can contribute significantly by promoting clean energy technologies, reducing its carbon footprint, and participating in international climate agreements. Improving early warning systems is another critical aspect of disaster risk reduction. Timely and accurate information can save lives by enabling people to evacuate and prepare for incoming cyclones. Cutting-edge technology, such as satellite-based monitoring and early warning systems, can provide vital information, giving vulnerable communities the time they need to take preventive measures.

Additionally, investing in infrastructure resilience is vital. This involves designing and constructing buildings, roads, and utilities that can withstand the destructive forces of cyclones and storm surges. Adequate coastal protection measures, including seawalls and mangrove conservation, can further mitigate the impacts of these natural disasters. By adopting proactive measures, India can better adapt to the changing climate and minimize the impact of future cyclones and storm surges. The lessons learned from past disasters should inform policy decisions and strategies for the future. Collaboration at the national and international levels is indispensable, as climate change is a global challenge that requires a concerted effort to mitigate its effects. In doing so, India can protect its communities and safeguard its future against the increasingly dire consequences of climate-induced cyclones and storm surges. It is not only a matter of safeguarding infrastructure and economies but also, and most importantly, the lives and well-being of its citizens.

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