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# Impact of climate change and sea level rise in coastal areas of India

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## Abstract:

India's coastal regions - such as Gujarat, Maharashtra, Goa, Tamil Nadu, Kerala, Odisha and West Bengal - with a coastline of about 7,500 km play an important role in the socio-economic development of the country. But in recent years, the effects of climate change and continued sea level rise have put these areas under serious threat. Problems such as rising sea levels, increased intensity of cyclones, salinity spreading inland, and land erosion are adversely affecting the ecology, population and livelihoods of these regions. The melting of ice sheets and glaciers due to climate change is causing sea levels to rise at a rate of about 3.3 mm per year, putting coastal populations at particular risk. The destruction of mangrove forests in the Sundarbans region of India, frequent cyclones in Odisha and Andhra Pradesh, and waterlogging and coastal flooding in metropolitan cities like Mumbai and Chennai underscore the seriousness of this threat. In addition, salinity impact of arable land and the impact on the fisheries industry is also of economic concern. Resolving these problems requires policy formulation based on coastal zone planning, robust disaster management systems, and community engagement. Protecting marine ecosystems, sustainable development strategies and developing climate resilient infrastructure are essential steps towards protecting India's coastal areas from the impacts of climate change. This paper explores in depth the current climate crisis in coastal India and offers practical solutions for long-term conservation.

**Keywords:** climate change, sea level rise, coastal zone, environmental impact, disaster management, India, ecological imbalance, migration, coastal ecology

## Introduction

In the geographical structure of India, the coastal areas are not only the centre of natural diversity but also play an extremely important role from the social, economic and cultural point of view. India's coastline is about 7,516 km long, passing through 13 states and union territories of the country. The region contributes to the development of the country in many aspects such as maritime trade, fisheries, tourism and biodiversity. But in the present global scenario, climate change and sea level rise have put the geographical, ecological and human structures of these coastal areas in serious jeopardy. In the present era, climate change has become a global challenge, the impact of which can be clearly seen at the regional level. Developing countries like India, with large populations living in coastal areas, are partic-

ularly vulnerable to this crisis. Temperature rise caused by climate change, erratic monsoons, more intense cyclones, and continued rise in sea levels have exposed India's coastal regions to multidimensional crises. According to UN reports and international climate bodies, many coastal cities in India could be partially or fully submerged by 2050 if sea levels continue to rise at the same pace. The main objective of this research is to analyse the geographical, environmental and social impacts of climate change and sea level rise in the coastal areas of India. Under this, it is necessary to understand how coastal ecology, human settlements, sources of livelihood, and coastal biodiversity are being affected by this change. The research will also analyse what conservation measures are being taken by the Government of India and various coastal States to deal with these impacts, and in what areas policy formulation is required.

A coastal zone is a geographical area where land and sea are in close contact with each other. It includes the coast, tidal areas, mangrove forests, deltas, estuaries and surrounding lands. Under the Coastal Regulation Zone (CRZ) notification, the coastal zone is defined as the area extending from the high tide line towards 500 metres of land and up to 100 metres in tidal affected rivers, lakes, creeks, etc. The coastal states of Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha and West Bengal in addition to the Union Territories of Puducherry, Andaman and Nicobar and Lakshadweep also have significant coastal areas. Major ports located in these coastal areas are Kolkata, Mumbai, Chennai, Kochi, Visakhapatnam, Kandla, Mangaluru, Paradip. The coastal areas are home to about 14% of India's total population, making them highly densely populated. Activities such as agriculture, fishing, water transport, industry and tourism are prominent in these coastal regions, making these regions economically important. But these activities are being adversely affected due to rise in sea level and impact of climate change.

Climate change refers to changes in long-term global and regional climate patterns caused by human activities such as excessive use of fossil fuels, deforestation, and industrialisation. Among its most prominent manifestations are the increase in global temperature, the melting of icy regions, the rise of sea temperature and the constant rise in sea level. The rise in sea level is mainly due to two reasons: (i) increase in the amount of water in the sea due to melting of glaciers and polar ice, and (ii) expansion of ocean water, which increases the volume of water due to increase in temperature. In the context of India, studies by the Indian National Centre for Ocean Information Services (INCOIS) and the Indian Institute of Tropical Meteorology (IITM) have shown that sea level along the Indian coasts is rising at an average rate of 1.7 mm to 3.4 mm per year. This rate is higher than the global average, which is a serious warning for India. Particularly in the Sunderbans region, where the shoreline was kept stable by protecting mangrove forests, seawater intrusion and erosion have also increased rapidly. Severe cyclones that hit states like Odisha and Andhra Pradesh - such as 'Fani' (2019) and 'Yaas' (2021) - are evidence that climate change is increasing both the intensity and frequency of disaster in coastal areas. This situation is not only a crisis for the natural environment but also poses a challenge to human lives, livelihoods and coastal urbanisation.

## Major coastal areas of India

India's maritime boundary is an important component of the country's geographical structure, with a length of about 7,516.6 km, including 6,100 km of the mainland and 1,300 km of the insular coastline. This coastal area is ecologically sensitive and economically highly valued. The coastal regions of India can be classified into three parts: the west coast, the east coast and the peninsular region. These areas demand in-depth studies in the context of climate change impacts, sea level rise, and coastal ecological imbalances. India's western coast, also known as the 'Konkan' and 'Malabar' coasts, adjoins the Arabian Sea and its topography includes rocky shores, harbours, mangrove forests and backwaters. The Kutch and Saurashtra region of Gujarat has been a centre of coastal biodiversity as well as maritime trade. Areas like Bhuj and Dwarka are highly vulnerable to climate change as they open up to the sea. Due to the rise in the sea level, the problem of salinity is deepening in the salt producing areas of Kutch.

Areas like Mumbai, Raigad and Ratnagiri in the coastal parts of Maharashtra are located very close to the sea. Due to urbanisation and industrialisation, there is a huge pressure on the coastal land.



Goa, which is famous for its tourism and biodiversity, is facing coastal erosion from rising sea levels. Karwar, Mangaluru and Udupi regions of Karnataka are affected by the marine fishing industry. Recent cyclones here have damaged coastal settlements. The Malabar Coast of Kerala, which lies between the Western Ghats and the Arabian Sea, is being affected by extreme rainfall, landslides and incidents of sea incursion, especially in areas like Ernakulam, Kollam and Alipi.

The eastern coast is contiguous with the Bay of Bengal and the coastal stretch here is flat, sandy and with river deltas. The Coromandel Coast of Tamil Nadu is famous for the intensity of cyclones and the increasing problem of salinity. Areas like Chennai and Cuddalore are suffering from waterlogging, sea erosion and deposition of sediments. The delta of the Godavari and Krishna rivers in Andhra Pradesh is one of the most productive agricultural regions in the country, but rising salinity and rising coastal water levels are damaging arable land. Areas like Paradip, Ganjam and Bhadrak in Odisha are frequently affected by cyclonic storms. The super cyclones of 1999 and 2019 reflect the climatic sensitivity of the region. The Sunderbans region of West Bengal is the world's largest delta and mangrove forest area. This region is a direct example of climate change and sea level rise, where islands are disappearing and thousands of people are suffering environmental displacement. The ecosystem here is under threat in both Bangladesh and India.

India's insular coastal areas are divided into two main groups - the Andaman and Nicobar Islands (in the Bay of Bengal) and the Lakshadweep Islands (in the Arabian Sea). The Andaman and Nicobar Islands are a group of 572 islands, many of which are inhabited. The region is being affected by seismic activities, sea storms and sea level rise. The Tsunami of 2004 had severely affected both the geographical location and the social structure of the region. Due to climate change, the coral reefs here are depleting, which is posing a threat to biodiversity. Lakshadweep, which is a group of coral atolls, is most threatened by sea level rise. The average height here is only 1 to 2 meters above the sea level, so with just a little increase the whole island can come in the condition of being submerged. Environmentalists have warned that the survival of many islands in Lakshadweep will be in jeopardy if the emission of greenhouse gases is not stopped in the next few decades. The traditional livelihoods of these islands - such as fishing, coconut production and marine tourism - are being deeply impacted. Thus, India's coastal areas are not only symbols of the country's geographical diversity and cultural richness, but have also become indicators of global climate change. The sustainability and conservation of these areas is essential not only from an environmental point of view, but also from an economic and social point of view.

### **The main causes of climate change**

In the current global context, climate change is not just an environmental problem, but a social, economic and political crisis. Its impact is widely reflected on the surface temperature, rainfall trends, sea level, ecosystems and various systems of human life. Particularly in tropical countries like India, where coastal populations and ecological diversity are high, the problems caused by climate change become even more complex. Several factors are driving climate change, including global warming, rising greenhouse gas emissions, human activities, and rising sea surface temperatures. Global warming is a central element of climate change. It refers to the long-term increase in the average temperature of the earth, which has increased at a rapid pace, especially after the Industrial Revolution (1750 AD). The main reason for this warming is the increase in the concentration of greenhouse gases such as carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and water vapour, which trap solar energy in the Earth's atmosphere and do not allow heat to escape. This process is called the "greenhouse effect," which artificially raises the temperature of the Earth. Reports by the World Meteorological Organisation (WMO) and the Intergovernmental Panel on Climate Change (IPCC) make it clear that the average temperature of the Earth's surface has increased by about 1.1 °C since the second half of the 20th century (1). India has also witnessed a steady rise in temperature, which has not only increased the incidence of droughts, floods, and erratic monsoons, but has also accelerated the pace of sea level rise. The situation is particularly worrisome for the coastal areas like Western Ghats, Ganga Delta and Sunderbans.



Human activities are the main cause of climate change. The first of these is industrialisation, which involves the burning of huge amounts of fossil fuels such as coal, oil and natural gas. This not only leads to the emission of greenhouse gases but also adds elements like dust and sulphate aerosols to the atmosphere, disrupting the rainfall cycle and temperature balance. Changes in land use due to urbanisation, concretisation, increasing number of vehicles and excessive consumption of energy have led to the Urban Heat Island Effect in cities, which increases local temperatures and affects the weather system. For example, extreme rainfall events and unexpected rise in sea level in coastal metros like Mumbai and Chennai can be attributed to this effect. Deforestation or indiscriminate cutting of forests is another serious cause, which disturbs the climate balance. Forests are natural absorbers of carbon dioxide. When deforestation occurs, this natural barrier is eliminated and more CO<sub>2</sub> remains in the atmosphere. In India, large-scale illegal deforestation and industrial expansion in coastal areas such as the Western Ghats, Sunderbans, and Andaman and Nicobar are deepening the crisis.

Sea surface temperature (SST) is a key indicator of climate change. This temperature not only affects the marine ecology, but also contributes to the intensity of cyclones, the monsoon trend, and sea level rise. When the temperature of the sea increases, the volume of water increases which is called 'thermal expansion', and it increases the sea water level. According to data from India's National Institute of Oceanography (NIO) and INCOIS, the SST in both the Bay of Bengal and the Arabian Sea is increasing at an average rate of 0.16 °C per decade. This rate is higher than the global average, which is a matter of particularly serious concern for India. The increase in SST has a direct impact on coastal biodiversity such as coral reefs, fish species and mangrove forests. In addition, the intensification of SSTs is leading to more intense and frequent cyclones, which cause displacement of coastal populations, loss of livelihoods and habitat degradation.

### Effects of sea level rise

Continuous rise in sea level is one of the most serious environmental problems of the present time, which is creating a massive geo-economic and social crisis, especially for coastal countries like India. This increase is not the result of oceanic expansion alone, but has multifaceted impacts on groundwater, agriculture, residential structures, and entire ecosystems. This rise in sea level is mainly due to melting of glaciers and warming of ocean waters. Three aspects in particular need to be understood in this sub-theme - coastal erosion and land degradation, intensification of floods and cyclones, and saline water percolation into groundwater and its impact on agriculture. Coastal erosion is the process by which the waves, currents and tides of the sea gradually cut through the land and drain it into the sea. Sea level rise makes this process more rapid. In coastal areas of India, this problem is particularly seen in the Sunderbans of West Bengal, Puri of Odisha and the Krishna delta region of Andhra Pradesh. According to studies published by the Indian National Centre for Ocean Information Services (INCOIS) and the Geological Survey of India, about 33 per cent of India's total coastline is under the influence of coastal erosion. This is not only causing land loss, but the existence of many coastal villages has also come under threat. Several islands in the Sunderbans region such as Goremari and Lohachara have been submerged in the sea, leading to environmental displacement of thousands of people.

Another serious effect of sea level rise is an increase in the intensity of coastal flooding and tropical cyclones. When the sea level rises, more seawater enters the land during storms and tides, increasing both the intensity and area of flooding. It proves to be more devastating especially in areas where the population density is high, such as Mumbai, Chennai and Kolkata. According to the India Meteorological Department (IMD), the frequency of cyclones forming in the Bay of Bengal has increased in the last few decades, and they are becoming more intense category. For example, the 'Fani' cyclone of 2019 and 'Yaas' cyclone of 2021 caused widespread destruction in the coastal areas of Odisha and West Bengal. Due to the rise in sea level, the coastal line is retreating and flood events are spreading inland to a greater depth than before. This not only leads to loss of human lives but also causes heavy damage to infrastructure such as roads, railways, bridges and power systems.

Sea level rise is also causing the problem of saltwater intrusion into the hinterland, known as



salt water intrusion'. When the seabed rises, it enters freshwater reservoirs and groundwater sources, increasing their salinity. This situation is particularly disastrous for the coastal farming system as saline water destroys soil fertility and reduces crop production. In coastal districts of Tamil Nadu such as Nagapattinam and Ramanathapuram, cultivation of paddy and vegetables has been severely affected due to saline water. A similar situation has been observed in Kottayam and Alappuzha districts of Kerala, where contamination of seawater in lakes and ponds has affected fisheries and drinking water quality. Also, in Ganjam and Paradip regions of Odisha, the organic productivity of coconut, betel nut and other trees has declined due to excess of saline water. The ingress of saline water into groundwater not only renders agricultural land barren, but also renders potable water sources unsuitable, leading to health problems and a double whammy for the rural population - economic as well as social.

### **Social and economic impact**

India's coastal areas are extremely sensitive not only in terms of geography but also in terms of social and economic structure. Climate change and sea level rise are having a profound impact on the social status, population structure, economic base and infrastructure of these regions. In India's western and eastern coastal states - Odisha, West Bengal, Kerala, Tamil Nadu, Andhra Pradesh and Maharashtra - a large number of people depend on coastal agriculture, fisheries and tourism. When climate disasters repeatedly affect these regions, the social structure there becomes unstable, and the indicators of economic development begin to move in a negative direction. The population of coastal areas is facing displacement due to rise in sea level and increase in frequency of natural calamities like cyclones, floods. There are two types of displacement - one, temporary displacement when people flee to safer places in times of disaster; and the other, permanent displacement when they are forced to leave their villages, homes and livelihoods permanently.

Many islands, especially in the Sunderbans, such as Goremari and Sutela, are submerged in the sea. Thousands of families have been forced to migrate from West Bengal's South 24 Parganas and North 24 Parganas districts. Similarly, coastal towns like Paradip and Gopalpur in Odisha have also witnessed gradual migration of population. These migrants are called 'environmental migrants' who migrate from one place due to climatic or environmental crises. This migration creates many social crises, such as the growth of urban slums, unemployment, lack of education and health facilities, and social conflict. The economy of the coastal areas of India is mainly based on three sectors - fisheries, agriculture and tourism. But climate change is taking a heavy toll on these three regions. Rising sea temperatures and changes in acidity are affecting the natural habitats of fish. This is leading to a decline in fish productivity, species diversity and fertility. Fishing operations in states like Kerala, Andhra Pradesh and Goa have been adversely affected, leading to loss of income for thousands of fishermen families.

The situation in the agricultural sector is even worse. Due to the rise in sea level, saline water enters the inland groundwater, which reduces soil fertility. Paddy and coconut cultivation have been affected in the coastal districts of Tamil Nadu and Odisha. At the same time, due to climate instability, the productivity of crops is decreasing due to lack of timely rainfall or excessive rainfall. Tourism, which is a major income source of India's coastal areas, is in crisis due to coastal erosion, storms and haphazard coastal development. The shrinking of beaches and destruction of infrastructure at tourist destinations like Goa, Puri, Kovalam, Mahabalipuram have led to a decline in tourist arrivals, directly impacting the livelihood of the locals.

Many of India's largest cities - such as Mumbai, Chennai, Kolkata, Visakhapatnam - are located close to the sea and are experiencing frequent floods, waterlogging, and storms due to climate change. The infrastructure of these cities - such as roads, bridges, railway lines, water supply systems, sewerage networks, and power distribution systems - is under severe threat. Train services are disrupted during monsoon floods in Mumbai and hospitals and schools have to be closed due to waterlogging in Chennai. In many areas, seawater seeps into the ground water and damages the foundations of buildings. Additionally, overheating and the heat island effect are causing an increase in electricity consumption, leading to an energy crisis. All this together challenges the planning and sustainable development

strategies of coastal urbanisation.

## Conclusion

The impact of climate change and sea level rise today is not just an environmental concern, but a broader crisis affecting social and economic stability. Especially in a country like India, where coastal areas have a high population density, rich biodiversity and many sources of livelihood are directly linked to the marine and coastal ecology, this crisis is deepening. Signs of climate change have been clearly visible in India's coastal regions during the last two decades - an average sea level rise of 3.2 mm per year, sustained rise in sea surface temperatures, and intensification of extreme cyclones. These changes have resulted in serious crises such as coastal erosion, land degradation, saltwater intrusion, degradation of agricultural land, depletion of fishery resources, and displacement of coastal communities. Natural defensive systems such as coral reefs and mangrove forests are weakening. At the same time, the impact of these changes in the ecosystem is not only natural but also social. Coastal cities like Kolkata, Chennai, Mumbai, Puri, Visakhapatnam have witnessed a steady increase in extreme rainfall and waterlogging events, leading to crumbling infrastructure. It makes clear that climate change is a holistic crisis, whose challenges are multifaceted and deeply intertwined at the ecological, economic and social levels.

For a developing country like India, the challenge of development is equally important along with the climate crisis. Therefore, there is a need for a strategy that prioritises climate adaptation while continuing development. Sustainable development is based on this idea. It brings together economic growth, social justice and environmental protection. 'Nature-based solutions' should be adopted for sustainable development in coastal areas, such as mangrove restoration, marine biodiversity conservation, and promotion of organic farming. Along with this, the government will have to strengthen adaptation strategies such as 'Climate Resilient Infrastructure', rethinking of coastal land use, and the role of local administration. Adequate use of global resources such as climate finance and technical cooperation is also essential for India. This will require effective participation in international fora, exchange of technological innovations, and promotion of the concept of climate justice. The climate crisis can be brought under control not only through policy formulation but also through robust implementation on the ground and active participation of local communities. This holistic assessment and suggestions conclude that a multi-pronged, participatory and science-based policy approach is needed to keep India's coastal areas safe from climate change. The bigger the crisis, the more coordinated, people-centric and long-term the solution must be.

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