Chapter–2

Climate Change over Indian Coastal Belts: Special Emphasis on Orissa Coast

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2.1 Introduction

Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time (i.e., decades to millions of years). Climate change may refer to a change in average weather conditions, or in the time variation of weather around longer-term average conditions (i.e., more or fewer extreme weather events). Climate change is caused by factors such as biotic processes, variations in solar radiation received by Earth, movement of tectonic plates and volcanic eruptions. Certain human activities have also been identified as significant causes of recent climate change, often referred to as "global warming". Global warming is a burning issue which impacts all sections of the society. It refers to describe the current increase the Earth’s average temperature because of greenhouse gas build up to the atmosphere. On the other hands, climate change is a broader term that refers not only to global changes (increases or decreases) in temperature but also to changes in wind,

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precipitation, the length of seasons as well as the strength and frequency of extreme weather events like droughts and floods. It is to be mentioned that due to increase of earth surface averaged temperature, which is termed as "Global Worming'', the climate pattern as mentioned is changing rapidly and drastically. Therefore, global warming is one of the major causes of the climate change and climate change is manifested as its effect. Human greenhouse gas emissions are causing global warming, which in turn is causing climate change. However, because the terms are casually related, they are often used level, and a wide range of impacts on plants, wildlife, and humans. When scientists talk about the issue of climate change, their concern is about global warming caused by human activities. It is estimated by the increase of averaged earth surface temperatures particularly in lowest layer of the atmosphere. Increases in temperatures in our Earth's atmosphere can contribute to changes in global climate patterns. Global warming can be considered part of climate change along with changes in precipitation, sea level, etc. Among different parts of the world, the most vulnerable areas are the coastlines, which are normally less developed for most of the tropical developing countries like India, Bangladesh and Sri Lanka. The majority of the river system or deltas are passing through the costal belt which are already facing the brunt of climate change and projected to be affected adversely in the end of 21st century. Climate change could affect coastal areas in a variety of ways. Coasts are sensitive to sea level rise, changes in the frequency and intensity of storms, increases in precipitation, and warmer ocean temperatures as well as soil salinity, which directly impacts whole farming community. In addition, rising atmospheric concentrations of carbon dioxide (CO_2) are causing the oceans to absorb more of the gas and become more acidic. This rising acidity could have significant impacts on coastal and marine ecosystems. The following are the major issues to be remembered in the context of climate change and costal eco-systems:

- Coastal systems are particularly sensitive to three key drivers related to climate change: sea level rise, changes of ocean temperature and its level of acidity.
- Low-lying areas in the coastlines will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion due to relative sea level rise.
- Acidification and warming of coastal waters will continue with significant negative consequences for coastal ecosystems
- In addition to climate change induced risk, costal areas will also face social pressures due to population growth, economic development, and urbanization
- For the 21st century, the benefits of protecting against increased coastal flooding and land loss due to submergence and erosion at the global scale are larger than the social and economic costs of inaction

2.2 Background information of coastal zone:

The coast is a unique environment where land, sea and atmosphere interact and interplay continuously influencing a strip of spatial zone defined as coastal zone. In other words, coastal zones are the areas having the influence of both marine and terrestrial processes. Coastal zones are the most fertile and fragile piece of landmasses, which are quite often under

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pressure from both anthropogenic activities and natural processes. It supports a large amount of floral and faunal biodiversity. Coastal Zone is consisted with a wide range of biotic and abiotic processes habitats viz., coral reefs, mangroves, sea grasses, sand dunes, vegetated stungle, mudflats, salt marshes, estuaries and lagoons etc. Boundaries of the coastal zones are defined through a combination of distance to coast and elevation data. Different countries use different distance criteria for defining the coastal zone. In India, 500 m distance from the high tide line (landward) is taken for demarcating the coastal zone. Total coastline of the world is 35, 6000 km and the coastal area covers more than 10% of the earth surface. Because of the economic benefits that accrue from access to ocean navigation, coastal fisheries, tourism, recreation and industrialization, human settlements are often more concentrated in the coastal zone than elsewhere. About 40% of the world's population lives within 100 km of the coast. About 10% of the world's population resides in low elevation coastal zone (<10 m) making their lives highly vulnerable to coastal disasters.

2.3. Definition and scientific factors of coastal zone:

Coastal systems and low-lying areas include all areas near mean sea level. Generally, there is no single definition for the coast and the coastal zone/area where the latter emphasizes the area or extent of the coastal ecosystems. Coastal systems are consisted both of natural and human systems. The rocky coasts, beaches, barriers and sand dunes, estuaries and lagoons, deltas, river mouths, wetlands and coral reefs are the example of natural systems. These elements help define the seaward and landward boundaries of the coast. Coastal zone means the coastal waters and the adjacent shore lands. The coastal zone is the interface where the land meets the ocean, encompassing shoreline environments as well as adjacent coastal waters. “Coastal zone” means the geomorphologic area either side of the seashore in which the interaction between the marine and land parts occurs in the form of complex ecological and resource systems made up of biotic and abiotic components coexisting and interacting with human communities and relevant socio-economic activities. The zones are important areas because large numbers of world's population inhabit such zones. Coastal zones are continually changing because of the dynamic interaction between the oceans and the land. Waves and winds along the coast are both eroding rock and depositing sediment on a continuous basis, and rates of erosion and deposition vary considerably from day to day along such zones. The energy reaching the coast can become high during storms, and such high energies make coastal zones areas of high vulnerability to natural hazards. Thus, an understanding of the interactions of the oceans and the land is essential in understanding the hazards associated with coastal zones. Tides, currents, and waves bring energy to the coast, and thus we start with these three factors.

Tides: Tides are due to the gravitational attraction of Moon and to a lesser extent, the Sun on the Earth. Because the Moon is closer to the Earth than the Sun, it has a larger affect and causes the Earth to bulge toward the moon. At the same time, a bulge occurs on the opposite side of the Earth due to inertial forces. These bulges remain stationary while Earth rotates.

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- The tidal bulges result in a rhythmic rise and fall of ocean surface, which is not noticeable to someone on a boat at sea, but is magnified along the coasts. Usually there are two high tides and two low tides each day, and thus a variation in sea level as the tidal bulge passes through each point on the Earth's surface.
- Along most coasts the range is about 2 m, but in narrow inlets tidal currents can be strong and fast and cause variations in sea level up to 16 m.
- The highest high tides occur because the Sun also exerts a gravitational attraction on the Earth, there are also monthly tidal cycles that are controlled by the relative position of the Sun and Moon. When the Sun and the Moon are on the same side of the Earth (new Moon) or on opposite sides of the Earth (full Moon). The lowest high tides occur when the Sun and the Moon are not opposed relative to the Earth (quarter Moons).
- These highest high tides become important to coastal areas during hurricane season and you always hear dire predications of what might happen if the storm surge created by the tropical cyclone arrives at the same time as the highest high tides.

Fluctuations in Water Level: Long-term changes in sea level occur because of daily fluctuation of sea level due to tides. Such sea level changes can be the result of local effects such as uplift or subsidence along a coast line. But, global changes in sea level can also occur. Such global sea level changes are called ***eustatic*** changes, which basically oppose the local changes. ***Eustatic*** sea level changes are the result of either changing the

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volume of water in the oceans or changing the shape of the oceans. For example, during glacial periods much of the water evaporated from the oceans is stored on the continents as glacial ice. This causes sea level to become lower. As the ice melts at the end of a glacial period, the water flows back into the oceans and sea level rises. Thus, the volume of ice on the continents is a major factor in controlling ***eustatic*** sea level. Global warming, for example could reduce the amount of ice stored on the continents, thus cause sea level to rise. Since water also expands (increases its volume) when it is heated, global warming could also cause thermal expansion of sea water resulting in a rise in eustatic sea level. Changing the shape of the oceans occurs if volcanic output on the sea floor or at oceanic ridges increases substantially, thus raising the floor of the oceans.

Oceanic Currents: Most visible part of 3-dimension ocean currents is the surface ocean currents that are mainly driven by the wind. Upwelling drives vertical currents whereas the deep ocean currents are driven by down welling. The density, temperature and salinity between the surface waters and the deep ocean waters are not identical. The surface of the oceans moves in response to winds blowing over the surface. The winds, in effect, drag the surface of oceans creating a current of water that is usually no more than about 50 meters deep. Thus, surface ocean currents tend to flow in patterns similar to the winds and are reinforced by the *Coriolis Effect*. The surface currents have the following properties: a) Circulation is clockwise in the northern hemisphere and counter clockwise in the southern hemisphere due to *Coriolis effect*. b) Cooler waters from higher latitudes circulate toward the equator. This cool water become warm at the equator

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and circulates back toward the poles. c) If surface waters move away from the coast, water from below rises to replace the water removed, resulting in upwelling. d) Ocean currents run generally eastward in the middle latitudes. It blows in the clockwise direction in the northern hemisphere and counter clockwise in the southern hemisphere. e) Seawater also circulates vertically as a result of changes in density controlled by changing salinity and temperature. Because it controlled by both temperature and salinity differences, is called thermohaline circulation.

2.4. Coastal Erosion and Sediment Transport: Coastlines are zones along which water is continually making hedges. Waves can both erode rock and deposit sediment. Because of the continuous nature of ocean currents and waves, energy is constantly being expended along coastlines and they are thus dynamically changing systems, even over short time scales.

Erosion by Waves: The motion of waves is only felt to a depth of 1/2 times the wavelength. When a coastline is shallower than 1/2 times the wavelength, then waves can be only eroded. Vigorous erosion is possible due to the sudden release of energy as the wave flings itself onto the shore. Rigorous erosion of sea floor takes place between shoreline and breakers. Between 1 and 1.5 times wave height, waves break at depths. Thus for 6 m tall waves, rigorous erosion of sea floor can take place in up to 9 m of water. In the breaker zone rock particles carried in suspension by the waves are hurled at other rock particles. As these particles collide, they are abraded and reduced in size. Smaller particles are carried more easily by the waves,

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and thus the depth to the bottom is increased as these smaller particles are carried away by the retreating surf.

2.5. Coastal Hazards

Polar Melting: Sea level is rising gradually due to rapid melting of snow and ice. Ice sheets in Greenland and Antarctica are shrinking three times faster than they were in the 1990s, and their contribution to global sea level rise is growing. Detrimental effects include loss of polar bear habitat and increased mobile ice hazards to shipping. The loss of ice albedo may cause the ocean to absorb more heat, which is termed as a positive feedback. The increase of ocean surface temperature may accelerate the rate of melting both in the glacier and in the Greenland ice cap. Melting of the Antarctic ice will projected to be increased further to sea level.

Ocean Acidification: Ocean acidification is the ongoing decrease in the pH of the Earth's oceans, caused by the uptake of carbon dioxide (CO_2) from the atmosphere. An estimated 30–40% of the carbon dioxide released by humans into the atmosphere dissolves into oceans, rivers and lakes. A cause for considerable concern, there appears to be no benefits to the change in pH of the oceans. This process is caused by additional CO_2 being absorbed in the water, and may have severe destabilising effects on the entire oceanic food chain.

Melting Glaciers: Glaciers are large sheets of snow and ice that are found on land for long period of time. They are found in the high altitude mountains region of America, Europe and Asia and many parts of the world. Warmer temperatures cause glaciers to melt faster than they can accumulate new snow. Melting glaciers have several different effects. For

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example, the melting of glaciers in the Himalayas will affect the drinking supplies of the millions of people residing in the Indo-Gangetic plain. This will have a major impact on the hundreds of millions of people living on low-lying land in Bangladesh, India and Nepal. The glacier from the Asia will be impacted more compared to the glaciers in Africa, the Arctic and the Amazon because of its high population size. In India, the *Gangotri* glacier, which supports one of India's largest river basins, is receding at an average rate of 23 meters per year. As results, it is projected that the river Ganges eventually will become a seasonal river, which is largely dependent on monsoon rains.

Sea Level Rise: Sea level is presently rising and the rate of sea level rise may increase due to melting of continental ice sheets mainly from the Greenland and Antarctica. People in the low-lying coastal regional will be more vulnerable due to sea level rise, storms and tsunami. Many parts of the world are low-lying and will be severely affected by modest sea rises. Agriculture in the costal are impacted because of soil becoming saline. Seawater is contaminating rivers as it mixes with fresh water further upstream, and aquifers are becoming polluted. Given that the IPCC did not include melt-water from the Greenland and Antarctic ice-caps due to uncertainties at that time, estimates of sea-level rise are feared to considerably underestimate the scale of the problem. There are no proposed benefits to sea-level rise. In Bangladesh alone, sea level is predicted to rise 45 cm by 2050, affecting 10%–15% of the land area and an estimated 35 million people. Most of the Megacities namely Kochi, Kolkata, and Mumbai which are considered as economic hubs of India is projected to be affected adversely due to sea level rise by around 15–38 cm by 2050. A high proportion of Sri Lankan coastal land is less than 1 meter above sea level, and could be submerged with the rising tides. [Source: Climate Change in South Asia by Asian Development Bank, 2010]

Storms - great storms such as hurricanes or other winter storms can cause erosion of the coastline at much higher rate than normal. Storm can damage the costal land and erosion is more due its high intensity and energy. Note that the El Niño driven storms on the west coast caused extensive coastal erosion in 1998. High winds blowing over the surface of the water during storms bring more energy to the coastline and can cause more rapid rates of erosion. Erosion rates are higher because:

- During storms wave velocities are higher and thus larger particles can be carried in suspension. This causes sand on beaches to be picked up and moved offshore, leaving behind coarser grained particles like pebbles and cobbles, and reducing the width of the beach.
- During storms waves reach higher levels onto the shoreline and can thus remove structures and sediment from areas not normally reached by the incoming waves.
- Because wave heights increase during a storm, waves crash higher onto cliff faces and rocky coasts. Larger particles are flung against the rock causing rapid rates of erosion.
- As the waves crash into rocks, air occupying fractures in the rock becomes compressed and thus the air pressure in the fractures is increased. Such pressure increases can cause further fracture of the rock.

Tsunami: Tsunamis are giant ocean waves caused by earthquakes or volcanic eruptions under the sea. Out in the depths of the ocean, tsunami waves do not dramatically increase in height. But as the waves travel inland, they build up to higher and higher heights as the depth of the ocean decreases. The speed of tsunami waves depends on ocean depth rather than the distance from the source of the wave. Tsunami waves may travel as fast as jet planes over deep waters, only slowing down when reaching shallow waters. While tsunamis are often referred to as tidal waves, this name is discouraged by oceanographers because tides have little to do with these giant waves. Some times sea waves can have wave heights up to 30 m, and have great potential to wipe out coastal cities.

Extreme Heat: Temperatures that continue 10^0C or more beyond the mean high temperature for the region and last for several weeks are defined as extreme heat. Humid or muggy conditions, which add to the discomfort of high temperatures, occur when a "dome" of high atmospheric pressure traps hazy, damp air near the ground. Excessively dry and hot conditions can stimulate dust storms and decreased visibility. The situation became more dangerous when a heat wave combined with a drought.

Changing Rain and Snow Patterns: As temperature rise causes air to warmer and lighter, more moisture evaporates from land and water into the atmosphere. More moisture in the air generally means we can expect more precipitation but, this extra precipitation is not distributed evenly around the globe, and some places might actually get less precipitation than they used to get which is termed as arid or drought condition.

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Drought: It is a natural hazard and its impact varies from region to region. Drought can therefore be difficult for people to understand. Drought can define differently for different purpose like agricultural drought and hydrological drought, which are not the same. It is equally difficult to define, because what may be considered a drought in, say, Bali (six days without rain) would certainly not be considered a drought in Libya (annual rainfall less than 180 mm). Generally drought originates from a deficiency of precipitation over an extended period of time usually a season or more resulting in a scarcity of water for some activity, group, or environmental sector. Its impacts result from the interaction between the natural event (less precipitation than expected) and anthropogenic activity.

Ground water level: The most highlighted impacts of climate change could be variations in quality and level of surface water as well as ground water. Potential decrease and quality of groundwater supplies is the prime concern of the regional water managers as well as government because most of the household water consumption and drinking water supply and irrigation facilities are meet from the pumping of ground water. As groundwater aquifers are fed mainly by precipitation or through interplay of surface water bodies, the direct influence of climate change on precipitation and surface water ultimately affects groundwater systems. It is well known that groundwater is an integral part of landscape and regional hydrological cycle. To understanding the likely consequences of future climate change on groundwater systems, it is essential to know the details of regional hydrological cycle and its two major components namely recharge and runoff. The groundwater systems will be affected by changes in recharge which will encompasses due to changes in precipitation and evapotranspiration.

(a) Soil Moisture

The amount of water stored in the soil is fundamentally important to agriculture and has an influence on the rate of actual evaporation, groundwater recharge, and generation of runoff. Soil moisture contents are directly simulated by global climate models, albeit over a very coarse spatial resolution, and outputs from these models give an indication of possible directions of change. The local effects of climate change on soil moisture, however, will vary not only with the degree of climate change but also with soil characteristics. The water holding capacity of soil will affect possible changes in soil moisture deficits; the lower the capacity, the greater the sensitivity to climate changes. Climate change also may affect soil characteristics, perhaps through changes in waterlogging or cracking, which in turn may affect soil moisture storage properties. Infiltration capacity and water-holding capacity of many soils are influenced by the frequency and intensity of freezing.

(b) Groundwater Recharge and Resources

Groundwater is the major source of water across much of the world, particularly in rural areas in arid and semi-arid regions, but there has been very little research on the potential effects of climate change. Aquifers generally are replenished by effective rainfall, rivers, and lakes. This water may reach the aquifer rapidly, through macro-pores or fissures, or more slowly by infiltrating through soils and permeable rocks overlying the aquifer. A change in the amount of effective rainfall will alter recharge, but

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so will a change in the duration of the recharge season. Increased winter rainfall, as projected under most scenarios for mid-latitudes, generally is likely to result in increased groundwater recharge. However, higher evaporation may mean that soil deficits persist for longer and commence earlier, offsetting an increase in total effective rainfall. Various types of aquifer will be recharged differently. The main types are unconfined and confined aquifers. An unconfined aquifer is recharged directly by local rainfall, rivers, and lakes, and the rate of recharge will be influenced by the permeability of overlying rocks and soils. Macro-pore and fissure recharge is most common in porous and aggregated forest soils and less common in poorly structured soils. It also occurs where the underlying geology is highly fractured or is characterized by numerous sinkholes. Such recharge can be very important in some semi-arid areas. In principle, “rapid” recharge can occur whenever it rains, so where recharge is dominated by this process it will be affected more by changes in rainfall amount than by the seasonal cycle of soil moisture variability.

Shallow unconfined aquifers along floodplains, which are most common in semi-arid and arid environments, are recharged by seasonal streamflows and can be depleted directly by evaporation. Changes in recharge therefore will be determined by changes in the duration of flow of these streams, which may locally increase or decrease, and the permeability of the overlying beds, but increased evaporative demands would tend to lead to lower groundwater storage. The thick layer of sands substantially reduces the impact of evaporation. It will be noted from the foregoing that unconfined aquifers are sensitive to local climate change, abstraction, and seawater intrusion. However, quantification of recharge is complicated by the characteristics of the aquifers themselves as well as overlying rocks and soils. A confined aquifer, on the other hand, is characterized by an overlying bed that is impermeable, and local rainfall does not influence the aquifer. It is normally recharged from lakes, rivers, and rainfall that may occur at distances ranging from a few kilometres to thousands of kilometres. Aside from the influence of climate, recharge to aquifers is very much dependent on the characteristics of the aquifer media and the properties of the overlying soils. Several approaches can be used to estimate recharge based on surface water, unsaturated zone and groundwater data. Among these approaches, numerical modelling is the only tool that can predict recharge. Modelling is also extremely useful for identifying the relative importance of different controls on recharge, provided that the model realistically accounts for all the processes involved. However, the accuracy of recharge estimates depends largely on the availability of high quality hydrogeologic and climatic data. Determining the potential impact of climate change on groundwater resources, in particular, is difficult due to the complexity of the recharge process, and the variation of recharge within and between different climatic zones. Attempts have been made to calculate the rate of recharge by using carbon-14 isotopes and other modelling techniques. This has been possible for aquifers that are recharged from short distances and after short durations. However, recharge that takes place from long distances and after decades or centuries has been problematic to calculate with accuracy, making estimation of the impacts of climate change difficult. The medium through which recharge takes place often is poorly known and very heterogeneous, again challenging recharges modelling. In general, there is a need to intensify research on modelling techniques, aquifer characteristics, recharge rates, and seawater intrusion, as well as monitoring of groundwater abstractions. This research will provide a sound basis for assessment of the impacts of climate change and sea-level rise on recharge and groundwater resources.

(c) Coastal Aquifers:

When considering water resources in coastal zones, coastal aquifers are important sources of freshwater. However, salinity intrusion can be a major problem in these zones. Salinity intrusion refers to replacement of freshwater in coastal aquifers by saltwater. It leads to a reduction of available fresh groundwater resources. Changes in climatic variables can significantly alter groundwater recharge rates for major aquifer systems and thus affect the availability of fresh groundwater. Salinization of coastal aquifers is a function of the reduction of groundwater recharge and results in a reduction of fresh groundwater resources. Sea-level rise will cause saline intrusion into coastal aquifers, with the amount of intrusion depending on local groundwater gradients. Shallow coastal aquifers are at greatest risk. Groundwater in low-lying islands therefore is very sensitive to change. A reduction in precipitation coupled with sea-level rise would not only cause a diminution of the harvestable volume of water; it also would reduce the size of the narrow freshwater lenses. For many small island states, such as some Caribbean islands, seawater intrusion into freshwater aquifers has been observed as a result of over pumping of aquifers. Any sea-level rise would worsen the situation. A link between rising sea level and changes in the water balance is suggested by a general description of the hydraulics of groundwater discharge at the coast. Fresh groundwater rides up over denser, salt water in the aquifer on its way to the sea, and groundwater discharge is focused into a narrow zone that overlaps with the intertidal zone. The width of the zone of groundwater discharge measured perpendicular to the coast, is directly proportional to the discharge rate. The shape of the water table and the depth to the freshwater/saline interface are controlled by the difference in density between freshwater and salt water, the rate of freshwater discharge and the hydraulic properties of the aquifer. The elevation of the water table is controlled by mean sea level through hydrostatic equilibrium at the shore.

2.6. Agriculture and food security: Climate change is a contributory factor to the food price crisis. It impacts is more serious on agriculture and food security in developing countries. Climate change is already affecting food security and it is expected to have even greater impacts in coming years. Higher temperatures lead to heat stress for plants, increasing sterility and lowering overall productivity. Higher temperatures also increase evaporation from plants and soils, increasing water requirements while lowering water availability. In many places, growing seasons are changing, ecological niches are shifting, and rainfall is becoming more unpredictable and unreliable both in its timing and its volume. This is leading to greater uncertainty and heightened risks for farmers, and potentially eroding the value of traditional agricultural knowledge such as when to plant particular crops. Rising seas contaminate coastal freshwater aquifers with salt water. Several small island states are already having serious problems with water

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quality, which is affecting agricultural productivity. Higher seas also make communities more vulnerable to storm surges, which can be 5-6 metres high. The storm surge from cyclone Nargis travelled 35 kilometres inland, killing 140,000 people and flooding around 14,400 km, an area one-third the size of Switzerland. The interactions between climate change, water scarcity and declines in agricultural productivity could lead to regional tensions and even open conflict between states already struggling with inadequate water supplies due to rising populations and over-pumping of groundwater.

2.7. Cyclones and other extreme weather events: Global warming will cause an increase in the sea surface temperatures and this in turn will have impact on the frequency, intensity or tracks of cyclones hitting coastal zones. Studies suggest that with a rise in sea temperature by 2-4 °C, intensity of cyclones hitting the coastal areas can go up by 10-20%.

2.8. Energy Security: Changes in temperature, precipitation, sea level, and the frequency and severity of extreme events will likely affect how much energy is produced, delivered, and consumed in the United States. Warmer temperatures may result in higher energy bills for air conditioning in summer, and lower bills for heating in winter. Energy usage is also connected to water needs. Energy is needed for irrigation, which will most likely increase due to climate change. Also, energy is generated by hydropower in some regions, which will also be impacted by changing precipitation patterns.

2.9. Water Security: Fresh water is crucial to human society not just for drinking, but also for farming, washing and many other activities. It is

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expected to become increasingly scarce in the future, and this is partly due to climate change. Understanding the problem of fresh water scarcity begins by considering the distribution of water on the planet. Approximately 98% of our water is salty and only 2% is fresh. Of that 2%, almost 70% is snow and ice, 30% is groundwater, less than 0.5% is surface water (lakes, rivers, etc) and less than 0.05% is in the atmosphere. Climate change has several effects on these proportions on a global scale. The main one is that warming causes polar ice to melt into the sea, which turns fresh water into seawater, although this has little direct effect on water supply.

Another effect of warming is to increase the amount of water that the atmosphere can hold, which in turn can lead to more and heavier rainfall when the air cools. Although more rainfall can add to fresh water resources, heavier rainfall leads to more rapid movement of water from the atmosphere back to the oceans, reducing our ability to store and use it. Warmer air also means that snowfall is replaced by rainfall and evaporation rates tend to increase. Yet another impact of higher temperatures is the melting of inland glaciers. This will increase water supply to rivers and lakes in the short to medium term, but this will cease once these glaciers have melted. In the sub-tropics, climate change is likely to lead to reduced rainfall in what are already dry regions. The overall effect is an intensification of the water cycle that causes more extreme floods and droughts globally.

When planning future water supplies, however, the global picture is less important than the effect of warming on fresh water availability in individual regions and in individual seasons. This is a much more complicated thing to predict than global trends. The IPCC technical report on climate change and water concludes that, despite global increases in rainfall, many dry regions including the Mediterranean and southern Africa will suffer badly from reduced rainfall and increased evaporation. As a result, the IPCC special report on climate change adaptation estimates that around one billion people in dry regions may face increasing water scarcity.

However, the degree to which this will happen cannot be predicted with confidence by current models. In many regions different models cannot even agree on whether the climate will become wetter or drier. For example, a recent study of future flows in the River Thames at Kingston shows a possible 11% increase over the next 80 years relative to the last 60 years. However, under an identical emissions scenario, the same report shows an alternative projection of a 7% decrease in flows.

Especially little is known about future declines in regional groundwater resources because of lack of research on this topic, even though around 50% of global domestic water supply comes from groundwater. Although scientists are making progress in reducing uncertainty about fresh water scarcity, these kinds of unknowns mean that water supply strategies must be adaptable so that they can be effective under different scenarios.

The direct impact of climate change is not the only reason to be concerned about future fresh water scarcity a fact highlighted by a recent United Nations Environment Programme report. The increasing global population means more demand for agriculture, greater use of water for irrigation and more water pollution. In parallel, rising affluence in some countries means a larger number of people living water-intensive lifestyles, including watering of gardens, cleaning cars and using washing machines and dishwashers.

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Rapidly developing economies also result in more industry and in many cases this comes without modern technology for water saving and pollution control. Therefore concerns about climate change must be viewed alongside management of pollution and demand for water.

2.10 Human Health: Weather and climate play a significant role in people's health. Changes in climate affect the average weather conditions that we are influencing weather patterns, which is manifested by extreme weather. Warmer average temperatures will likely lead to hotter days and more frequent and longer heat waves**.** This could increase the number of heat-related illnesses and deaths. Increases in the frequency or severity of extreme weather events such as storms could increase the risk of dangerous flooding, high winds, and other direct threats to people and property. Warmer temperatures could increase the concentrations of unhealthy air and water pollutants. Changes in temperature, precipitation patterns, and extreme events could enhance the spread of some diseases. The impacts of climate change on health will depend on many factors. These factors include the effectiveness of a community's public health and safety systems to address or prepare for the risk and the behaviour, age, gender, and economic status of individuals affected. Impacts will likely vary by region, the sensitivity of populations, the extent and length of exposure to climate change impacts, and society's ability to adapt to change. Warmer winters would mean fewer deaths, particularly among vulnerable groups like the aged. However, the same groups are also vulnerable to additional heat, and deaths attributable to heatwaves are expected to be approximately five times as great as winter deaths prevented. It is widely believed that warmer climes will encourage migration of disease-bearing insects like mosquitoes and malaria is already appearing in places it hasn't been seen before.

2.11. Migration: Migration adds another layer of complexity to the scenario. In the 21st century the world could see substantial numbers of climate migrants people displaced by either the slow or sudden onset of the effects of climate change. The United Nations' recent Human Development Report stated that, worldwide, there are already an estimated 700 million internal migrants those leaving their homes within their own countries. Overall migration across national borders is already at approximately 214 million people worldwide, with estimates of up to 20 million displaced in 2008 alone because of a rising sea level, desertification, and flooding. Oli Brown, a scientist from the International Institute for sustainable development, predicts a tenfold increase in the current number of internally displaced persons and international refugees by 2050. It is important to acknowledge that there is no consensus on this estimate. In fact there is major disagreement among experts about how to identify climate as a causal factor in internal and international migration. But even though the root causes of human mobility are not always easy to decipher, the policy challenges posed by that movement are real. A 2009 report by the International Organization for Migration produced in cooperation with the United Nations University and the Climate Change, Environment and Migration Alliance cites numbers that range from "200 million to 1 billion migrants from climate change alone, by 2050," arguing that "environmental drivers of migration are often coupled with economic, social and developmental factors that can accelerate and to a certain extent mask the impact of climate change. The report also notes that “migration can result from different environmental factors, among them gradual environmental degradation including desertification, soil and coastal erosion and natural disasters such as earthquakes, floods or tropical storms. Clearly, then, climate change is expected to aggravate many existing migratory pressures around the world. Indeed associated extreme weather events resulting in drought, floods, and disease are projected to increase the number of sudden humanitarian crises and disasters in areas least able to cope, such as those already mired in poverty or prone to conflict.

2.12. Marine Fisheries and Coastal Communities: There are 2100 marine fishes villages along the Indian coast. Report from the Central Marine Fisheries Research Institute indicated that 450 villages out of 2100 are vulnerable to the sea level rise. The population of these fishing villages is also high, 500,000 inhabitants in Kerala, and 200,000 in Tamil Nadu, which indicates the extent of threat to traditional livelihoods.

Scientist said that due to warming, the water line for 28 degrees has been moving northwards, as a result two varieties used by the lower middle classes the oil sardine (locally known as tarli) and Mackerel is now available along Indian coasts.

The more knowledgeable fishermen were able to relate to the fact that the cause of global warming, the increasing energy requirement and therefore the increasing take over of off-shore fishing grounds, is directly affecting their access to livelihood related sites much like the plight of the Tribals in distant Orissa, whose forests have been sacrificed for mining of bauxite.

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American fisheries catch or harvest five million metric tons of fish and shellfish each year. These fisheries contribute more than $1.4 billion to the economy annually. Many fisheries already face multiple stresses, including overfishing and water pollution. Climate change may worsen these stresses. In particular, temperature changes could lead to significant impacts. The ranges of marine species have shifted northward as waters have warmed. The ranges of many fish and shellfish species may change. Many marine species have certain temperature ranges at which they can survive. For example, cod in the North Atlantic require water temperatures below 54°F. Even sea-bottom temperatures above 47°F can reduce their ability to reproduce and for young cod to survive. In this century, temperatures in the region will likely exceed both thresholds. Many aquatic species can find colder areas of streams and lakes or move northward along the coast or in the ocean. Some diseases that affect aquatic life may become more prevalent in warm water. For example, in southern New England, lobster catches have declined dramatically. A temperature-sensitive bacterial shell disease likely caused the large die-off events that led to the decline. Changes in temperature and seasons could affect the timing of reproduction and migration. Many steps within an aquatic animal's lifecycle are controlled by temperature and the changing of the seasons. For example, in the Northwest warmer water temperatures may affect the lifecycle of salmon and increase the likelihood of disease. Combined with other climate impacts, these effects are projected to lead to large declines in salmon populations.

2.13. Tourism Sector: Coastal tourism is the largest component of the global tourism industry. Over 60% of Europeans opt for beach holidays and beach tourism provides more than 80% of U.S. tourism receipts. More than 100 countries benefit from the recreational value provided by their coral reefs, which contributed US$11.5 billion to global tourism

Observed impacts: Observed significant impacts on coastal tourism have occurred from direct impacts of extreme events on tourist infrastructure, indirect impacts of extreme events namely coastal erosion, coral bleaching, and short-term adverse tourist perception after the occurrence of extreme events including flooding, tropical storms and storm surges. Recent observed climate change impacts on the Great Barrier Reef include coral bleaching in the summers of 1997–1998, 2001–2002, and 2005–2006 and extreme events including floods and cyclones. The stakeholders show a high level of concern for climate change, and various resilience initiatives have been proposed and developed by the Great Barrier Reef Marine Park Authority. Global warming has an effect on tourism and the economies of many nation example, in Europe, in the Baltic region in the Mediterranean and in 51 countries worldwide. The studies provide varying details, although it is difficult to draw overarching conclusions on tourism demand for coastal destinations. With increased temperature in mid-latitude countries and coupled with increased storms in tropical areas, tourist flows could decrease from mid-latitude countries to tropical coastal regions with large developing countries and small island nations most affected. The Mediterranean would likewise be affected in summer. The relationship between the impacts of climate change and specific tourist behaviour is not

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well established. Usually tourists do not consider climate variability or climate change in their holidays although there are a few studies that show the contrary. As for future impacts on coastal tourism, there is high confidence in the impacts of extreme events and sea level rise aggravating coastal erosion. A scenario of 1-m sea level rise by 2100 would be a potential risk to Caribbean tourism. The presence of coastal tourism infrastructure will continue to exacerbate beach reduction and coastal ecosystems squeeze under rising sea levels, as exemplified in Martinique Carbonate reef structures would degrade under a scenario of at least 2°C by 2050–2100 with serious consequences for tourism destinations in Australia, the Caribbean, and other small islands. The costs of future climate change impacts on coastal tourism are enormous. For example, in the Caribbean community countries, rebuilding costs of tourist resorts are estimated US$10 to 23.3 billion in 2050. A hypothetical 1-m sea level rise would result in the loss or damage of 21 airports, inundation of land surrounding 35 ports, and at least 149 multi-million dollar tourism resorts damaged or lost from erosion to the coastal beach areas. In summary, while coastal tourism can be related to climate change impacts, it is more difficult to relate tourism demand directly to climate. Coastal tourism continues to be highly vulnerable to weathers**.** Scientists are forecasting that the Caribbean and its surrounding areas will register a constant increase in temperature. The same can be said about the Mediterranean basin. Global warming has interesting effects on the tourism industry.

2.14. Wildlife: Warmer temperatures and precipitation changes will likely affect the habitats and migratory patterns of many types of wildlife. The range and distribution of many species will change, and some species that cannot move or adapt may face extinction.

2.15. Recreational opportunities: Many outdoor activities may benefit from longer periods of warm weather. However, some other outdoor activities could be compromised by increased beach erosion, increased heat waves, decreased snowfall, retreating glaciers, reduced biodiversity and changing wildlife habitats.

2.16. Health of costal people: The relationship between health of coastal populations and climate change include direct linkages (e.g., floods, droughts, storm surges, and extreme temperatures) and indirect linkages (e.g., changes in the transmission of vector-, food-, and water-borne infectious diseases and increased salinization of coastal land that affects food production and freshwater supply and ecosystem health). Coastal and particularly informal settlements concentrate injury risk and death from storm surges and rainfall flooding. This section deals with human health in the context of the coastal zone. Understanding the relationship between climate and health is often confounded by socioeconomic factors that influence coastal settlement patterns and the capacity of authorities to respond to health-related issues.

Observed impacts: Mortality risk in coastal areas is related to exposure and vulnerability of coastal populations to climate hazards (e.g., A regional analysis of changes in exposure, vulnerability, and risk indicates that although exposure to flood and cyclone hazards has increased since 1980, the risk of mortality has generally fallen. The reductions reflect a strengthening of the countries' capacity to respond to disasters. However,

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mortality is still rising in the countries with the weakest risk governance capacities. Coastal regions face a range of climate-sensitive diseases. Increased saline intrusion is linked to increased hypertension disease with greater occurrence in pregnant women living in coastal regions compared to further inland. Increasing temperature, humidity, and rainfall can increase vector-borne diseases such as malaria, dengue, leishmaniasis, and chikungunya and diarrhea, infectious gastrointestinal disease, rotovirus, and salmonella. The parasitic disease schistosomiasis, endemic in many tropical and small island coastal regions is also sensitive to temperature increase.

2.17. Mitigating Against Coastal Hazards: Shoreline protection can be divided into two categories: hard stabilization in which structures are built to reduce the action of the waves and soft stabilization which mainly refers to adding sediment back to a beach as it erodes away.

Hard Stabilization: Seacliff's, since they are susceptible to landslides due to undercutting, and barrier islands and beaches, since they are made of unconsolidated sand and gravel, are difficult to protect from the action of the waves. Human construction can attempt to prevent erosion, but cannot always protect against abnormal conditions.

Two types of hard stabilization are often used. One type interrupts the force of the waves. Seawalls are built parallel to the coastline to protect structures on the beach. A seawall is usually built of concrete or piles of large rocks. Waves crash against the seawall and are prevented from running up the beach. Breakwaters serve a similar purpose, but are built slightly offshore, again preventing the force of the waves from reaching the beach and any structures built on the beach.

The other type interrupts the flow of sediment along the beach. These structures include groins and jetties, built at right angles to the beach to trap sand and widen the beach.

2.18. Orissa coast

The coastal Orissa is mainly depositional in nature which is formed by the deltas of six major rivers namely the Subarnarekha, the Budhabalanga, the Baitarani, the Brahmani, the Mahanadi, and the Rushikulya. Orissa coast has some of the excellent mangroves. Presence of Chilka Lake (Largest brackish water lake in Asia) in the coastal Orissa makes the region rich in biodiversity and hot spot of tourism. Mudflats are wide expanse of fine grained soft clay and silt which are observed on the Balasore coast, near Devi estuary and also near Chilka lagoon. Vast starch of subtidal mudflats is observed from Dhamra river to Chandipur. Sandy beaches are well marked along the coastline from the Bahuda estuary near Andhra Pradesh border to the Devi mouth and mouth of Mahanadi to Dhamra river. Rare minerals like monazite, ilmenite, zircon, rutile, sillimanite etc are found in the sandy beach of the southern coast of Orissa. The sandy beach of Puri in the footsteps of Bay of Bengal is a tourist attraction from all over the world. Muddy coast of Orissa consists of more sand particles which is non-sticky in nature. Spits are well developed along the coastline near major estuaries. The is a network of creeks namely the Luna, Jambu, Kharnasi, Khola and Batighar jora creek are found in mangroves occurring near the mouth of the Mahanadi river. These creeks are almost parallel to the coast. The mangrove vegetation includes tree, scrub and palm species. Important species in this locality includes *Avicennia spp. Acrosticum spp.* and *Phoenix spp.*

Distribution and creeks of the Brahmani and the Baitarani river provides a suitable ecological niche for the growth of mangrove vegetation. The second largest mangal formation in India is found in the mangroves of Bhitarkanika. Important mangrove species in the Bhitarkanika includes *Avicennia Alba, A. officinalis, Excoecaria agallocha, Heritiera minor, Sonneratia apetala, Rizophora mucronata, R. candlena* etc. The mangroves of Balasore Coast are quite different from other deltaic area due to absence of fresh water inflow except in the Dhamra river mouth. The level of salinity remains very high except during monsoon season. The species are mainly *Avicennia Alba*. The Chilka Lake on the Orissa coast is connected to the Bay of Bengal by a long and narrow channel. Figure 1 shows Coastal landuse distribution in Orissa. Mudflat occupies 229.26 sq km, Lagoon occupies 733.30 sq km, Forest occupies 569.10 sq km and Habitation with vegetation occupies 1133.56 sq km (Table 1).

2.19. How does climate change affect coastal marine ecosystems?

The major factors which influence the climate in a marine coastal ecosystems are sea level rise, warming of ocean, and ocean acidification. Rising sea level impacts marine ecosystems by drowning some plants and animals as well as by inducing changes in some parameters such as light, salinity, and temperature. The impact of sea level is related mostly to the tendency of animals (e.g., corals) and plants (e.g., mangroves) to keep up with the vertical rise of the sea. Mangroves and coastal wetlands can be sensitive to these shifts and could discharge some of their stored compounds, adding to the atmospheric supply of greenhouse gases. They raise the metabolism of species exposed to the higher temperatures and can

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be fatal to those already living at the upper end of their temperature range.

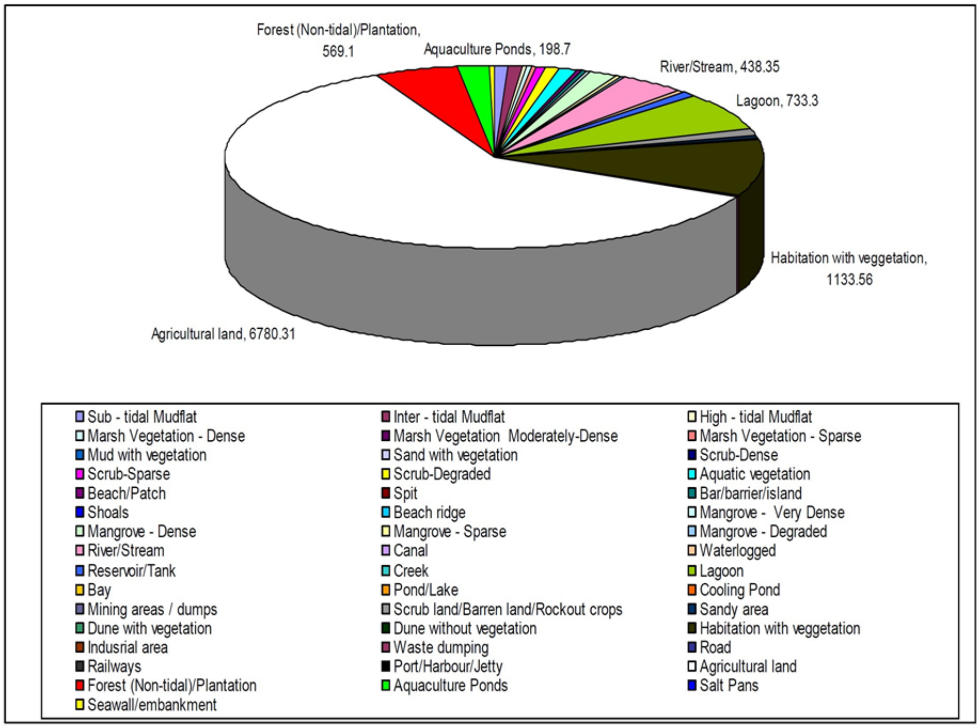

Figure 1: Coastal Land use distribution of Orissa

(Source ISRO, Ahmedabad)

Warmer ocean leads to coral bleaching, which weakens those animals and makes them vulnerable to mortality. Warmer temperature makes the migration of the many species of the marine plants and animals towards the poles. When atmospheric CO_2 is absorbed into the ocean, it reacts to produce carbonic acid (H_2CO_3), which increases the acidity of seawater and diminishes the amount of a key building block (carbonate) used by marine ‘calcifiers’ such as shellfish and corals to make their shells and skeletons and may ultimately weaken or dissolve them.

Table 1: Coastal Landuse area of Orissa (Source ISRO, Ahmedabad)

S. No.	Landuse class	Area in sq km
1	Sub - tidal Mudflat	85.27
2	Inter - tidal Mudflat	95.56
3	High - tidal Mudflat	48.43
4	Marsh Vegetation - Dense	4.09
5	Marsh Vegetation Moderately-Dense	27.67
6	Marsh Vegetation - Sparse	19.11
7	Mud with vegetation	0.99
8	Sand with vegetation	4.52
9	Scrub-Dense	2.26
10	Scrub-Sparse	62.75
11	Scrub-Degraded	91.63
12	Aquatic vegetation	113.55
13	Beach/Patch	43.77
14	Spit	5.3
15	Bar/barrier/island	18.64
16	Shoals	0.86
17	Beach ridge	1.22
18	Mangrove - Very Dense	37.68
19	Mangrove – Dense	167.53
20	Mangrove – Sparse	36.98
21	Mangrove - Degraded	30.35
22	River/Stream	438.35
23	Canal	8.2
24	Waterlogged	66.71
25	Reservoir/Tank	79.02
26	Creek	15.36
27	Lagoon	733.3
28	Bay	10.95
29	Pond/Lake	2.24
30	Cooling Pond	1.41
31	Mining areas / dumps	1.48
32	Scrub land/Barren/land/Rockout crops	105.03
33	Sandy area	53.16
34	Dune with vegetation	13.61
35	Dune without vegetation	16.89
36	Habitation with vegetation	1133.56
37	Industrial area	14.97
38	Waste dumping	2.39
39	Road	10.7
40	Railways	3.63
41	Port/Harbour/Jetty	4.71
42	Agricultural land	6780.31
43	Forest (Non-tidal)/Plantation	569.1
44	Aquaculture Ponds	198.7
45	Salt Pans	19.11
46	Seawall/embankment	19.31
	Total Area	**11200.36**

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2.20. How is climate change influencing coastal erosion?

Coastal erosion is influenced by many factors such as Sea level, currents, winds, and waves. Coastal erosion is much sever during the storms as the storms add energy to these effects. Erosion of river deltas is also influenced by precipitation patterns inland which change patterns of freshwater input, runoff, and sediment delivery from upstream. All of these components of coastal erosion are impacted by climate change.

Based on the simplest model, a rise in mean sea level usually causes the shoreline to recede inland due to coastal erosion. Increasing wave heights can cause coastal sand bars to move away from the shore and out to sea. High storm surges also tend to move coastal sand to offshore. Higher waves and surges increase the probability that coastal sand barriers and dunes will be over-washed or breached. More energetic and/or frequent storms exacerbate all these effects. Changes in wave direction caused by shifting climate may produce movement of sand and sediment to different places on the shore, changing subsequent patterns of erosion.

2.21. How can coastal communities plan for and adapt to the impacts of climate change, in particular sea level rise?

An increasing focus of coastal use planning is on precautionary measures, that is, measures taken even if the cause and effect of climate change is not established scientifically. These measures can include things like enhancing coastal vegetation and protecting coral reefs. For many regions, an important focus of coastal use planning is to use the coast as a natural system to buffer coastal communities from inundation, working with nature rather than against it, as in the Netherlands. While the details and

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implementation of such planning take place at local and regional levels, coastal land management is normally supported by legislation at the national level. The approaches available to help coastal communities adapt to the impacts of climate change fall into three general categories:

1) Protection of people, property, and infrastructure is a typical first response. This includes “hard” measures such as building seawalls and other barriers, along with various measures to protect critical infrastructure. “Soft” protection measures are increasingly favored. These include enhancing coastal vegetation and other coastal management programs to reduce erosion and enhance the coast as a barrier to storm surges.
2) Accommodation is a more adaptive approach involving changes to human activities and infrastructure. These include retrofitting buildings to make them more resistant to the consequences of sea level rise, raising low-lying bridges, or increasing physical shelter capacity to handle needs caused by severe weather. Soft accommodation measures include adjustments to land use planning and insurance programs.
3) Managed retreat involves moving away from the coast and may be the only viable option when nothing else is possible. Some combination of these three approaches may be appropriate, depending on the physical realities and societal values of a particular coastal community. The choices need to be reviewed and adjusted as circumstances change over time.

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