G20 CLIMATE RISK ATLAS

Impacts, policy, economics

cmcc

INDIA

With the scientific contribution of Enel Foundation

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

INDIA
CLIMATE

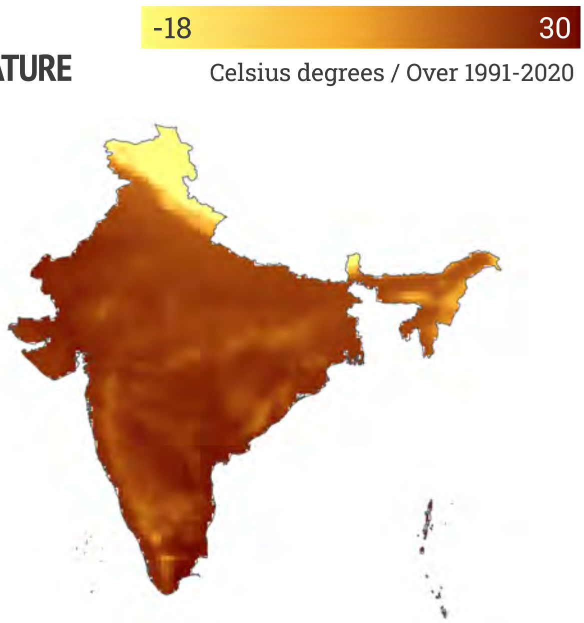
OVERVIEW

The climate in India is generally monsoonal whilst at the same time possessing a wide variety that ranges from tropical in the south to temperate and alpine in the Himalayan north. India's climate is strongly influenced by the Himalayas and the Thar Desert. The Himalayas act as a barrier to cold winds from central Asia, keeping most of the country warmer than other places found at similar latitudes around the world. The Thar Desert attracts the summer monsoon winds from the south-west regulating the rainy season.

TEMPERATURE

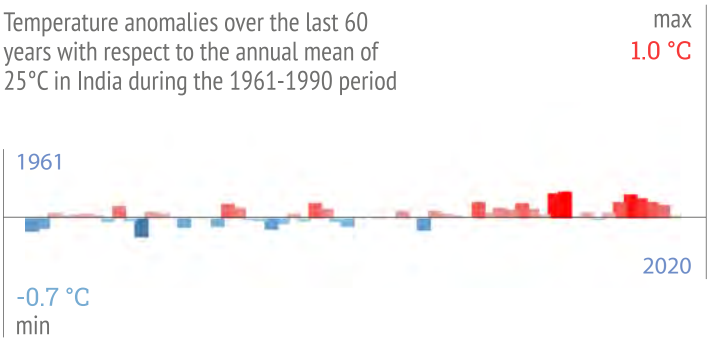
The temperature regime in India is controlled by the distance from water bodies, ocean currents and relief characteristics. In general, annual temperatures are fairly homogeneous and fall in the northern part of the country.

MEAN TEMPERATURE



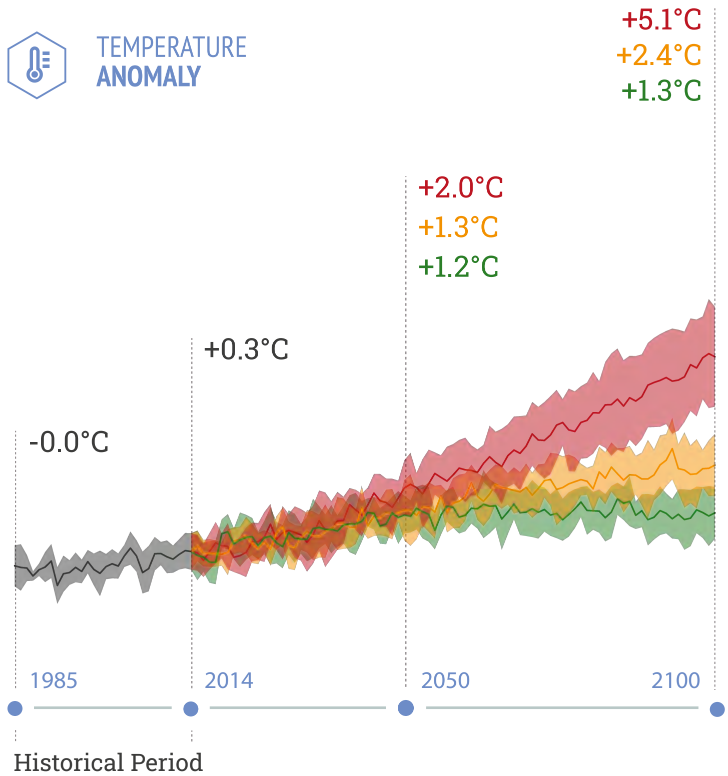
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 25°C in India during the 1961-1990 period



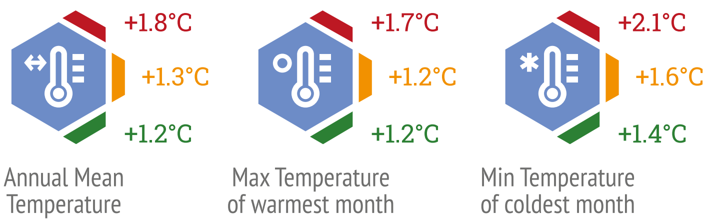
TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under +1.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.



PRECIPITATION

The precipitation regime in India is very complex and is mainly governed by monsoon winds from the southwest. The rainy season is between June and September, during which almost 75% of annual precipitation occurs.

Average precipitation in India is around 1,250 millimetres per year, although a huge spatial variation can be detected. The west coast and north-east India receive more than 4,000 millimetres of precipitation per year. On the other hand, areas such as western Rajasthan and adjacent parts of Gujarat, Haryana, and Punjab see less than 600 millimetres per year. The rest of the country receives moderate precipitation. Due to the nature of monsoons annual precipitation is highly variable.

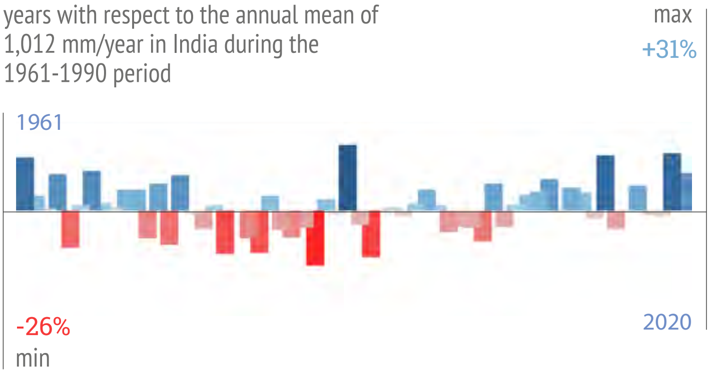
MEAN PRECIPITATION

156 — 7,773

mm/year / Over 1991-2020

PRECIPITATION TREND

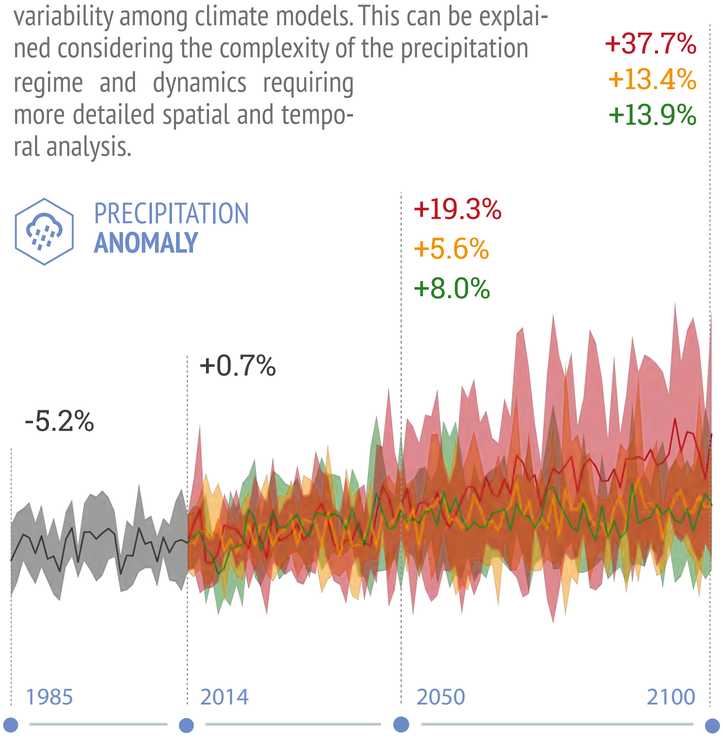
Precipiation anomalies over the last 60 years with respect to the annual mean of 1,012 mm/year in India during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a very complex signal, under all emissions scenarios, with a very large variability among climate models. This can be explained considering the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.

PRECIPITATION ANOMALY



Historical Period

EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual total precipitation	+11.4%	+7.5%	+9.4%
Precipitation of wettest month	+10.7%	+7.1%	+9.3%
Precipitation of warmest quarter	+6.6%	+5.8%	+3.2%

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

Agricultural drought proportion of time	% of time	+21%	+13%	+11%
Hydrological drought proportion of time	% of time	+12%	+8%	+7%
Heatwave duration	% of time	+2,515%	+525%	+160%
Runoff increase	% of area	+17%	+6%	+3%
Agricultural drought frequency	% of change	+48%	+20%	+13%
Hydrological drought frequency	% of change	+7%	+6%	+11%
Heatwave frequency	% of change	+97%	+55%	+32%
Runoff decrease	% of area	+43%	+33%	+17%

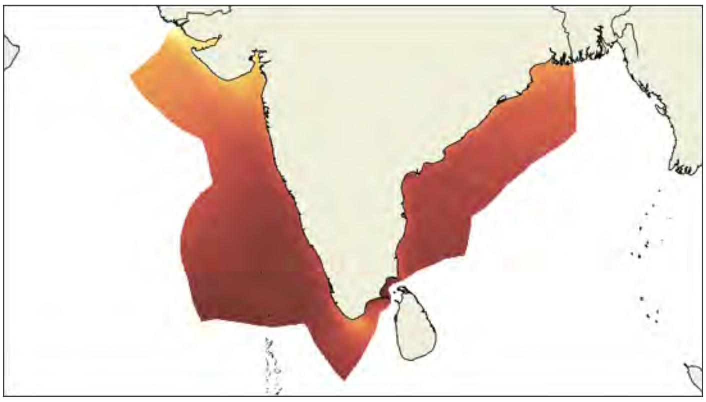
INDIA
OCEAN

OCEAN IN INDIA

India's marine exclusive economic zone (EEZ) has mostly warm coastal waters, which are characterized by a mosaic of ecosystems such as coral reefs, backwaters, mangroves, and seagrasses meadows. Indian coastal systems can be divided in two main areas: the Bay of Bengal and the Laccadives region on the western side.

CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the rather homogeneous climate of the region, with sligthly colder waters in the northern areas.

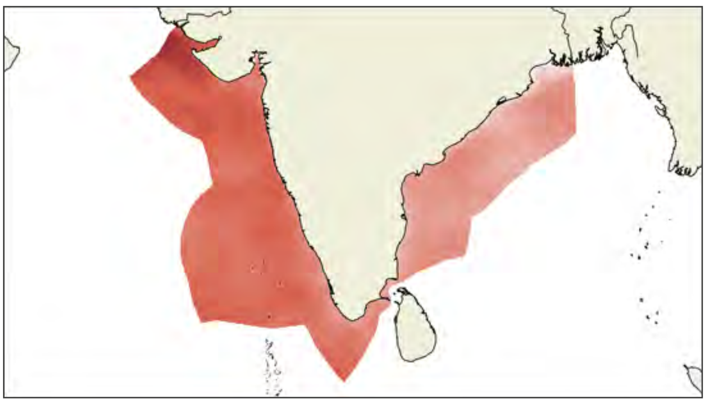


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND



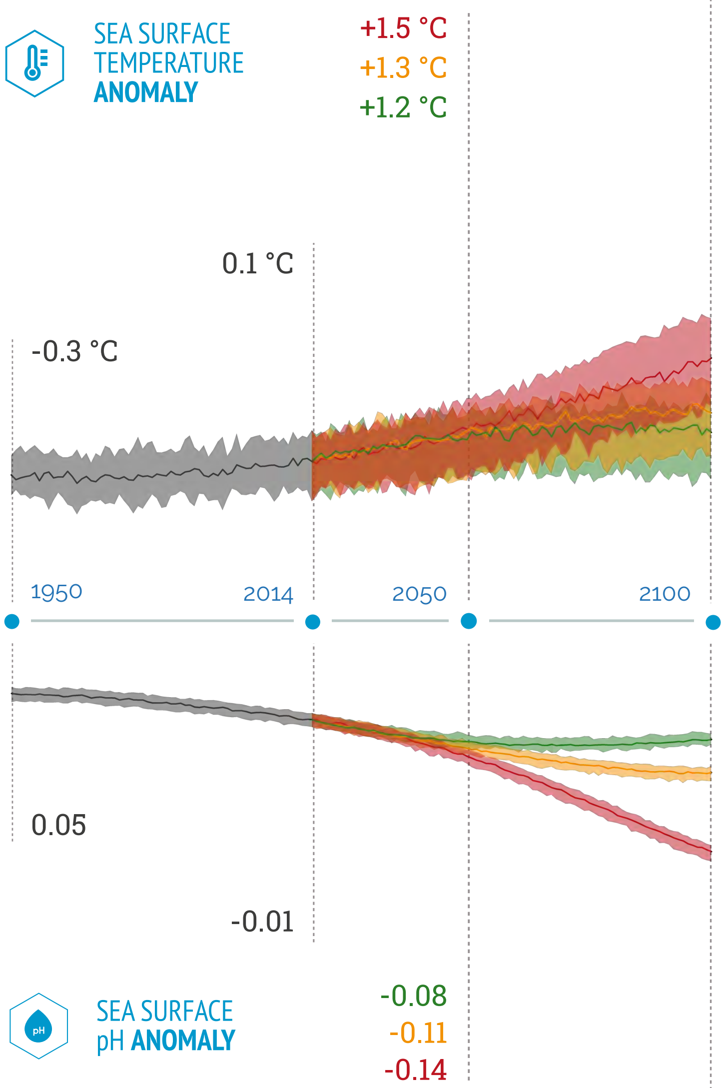
Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values in 2100 close to +4°C under a high emissions scenario.

+3.6 °C
+2.1 °C
+1.4 °C



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

-0.08
-0.17
-0.36

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Arabian Sea

Bay of Bengal

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	Arabian Sea				Bay of Bengal			
Temperature	28.01°C	+1.6 °C	+1.36 °C	+1.34 °C	28.23°C	+1.34 °C	+1.2 °C	+1.12 °C
pH	8.07	-0.14	-0.11	-0.08	8.07	-0.14	-0.1	-0.08
Oxygen	200.96 mmol/m³	-2.44 %	-2.35 %	-1.52 %	204.91 mmol/m³	-2.08 %	-1.45 %	-1.51 %
Chlorophyll	0.23 mg/m³	-13.6 %	-19.3 %	-14.47 %	0.46 mg/m³	-5.66 %	-14.81 %	-7.84 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-17.1%

-8.8%

ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

INDIA COASTS

OVERVIEW

India's 17,000 kilometres of shoreline and coastal zones is densely populated with approximately 14% of the population concentrated in coastal districts, amounting to approximately 200 million people. India's coastal areas are very diverse, with a wide range of geomorphology types and ecosystems, including rocky coasts, sandy beaches, mangroves, tidal flats, estuaries and coastal lagoons. The main coastal cities are Mumbai, on the west coast, Chennai, on the east coast, and Kolkata, on the Ganges Delta.

Shoreline Length — 17,181 km

Sandy Coast Retreat at 2050 — -116.3 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change may exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on the coastal zone of India are mainly driven by rising sea levels and possible changes in storm intensity and direction, which can exacerbate erosion issues and drive flooding of low lying coastal areas. In addition, changes in rainfall patterns may also exacerbate flooding risk for low lying coastal areas. These impacts are of particular concern in areas where people's livelihoods are based on coastal resources and tourism and in India's coastal mega-cities.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of India, with a yearly average increase of approximately 1.56 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050 — 1.56 mm/year — 0.23 m — 0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 2.05 metres at present day to 2.23 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050 — 2.05 m — 2.31 m — 2.23 m

OBSERVED STORMS

The wave climate influencing the Indian coast is very dynamic and driven by seasonally reversing monsoon winds. Annual average significant wave height ranges from 1.5 to 2.5 metres, with the highest waves reaching more than 3 metres. The wave climate is also influenced by the annual and inter-annual variability in monsoon wind and rainfall. In the Indian Ocean north of the equator tropical cyclones can form throughout the year on either side of India.

FUTURE STORMS

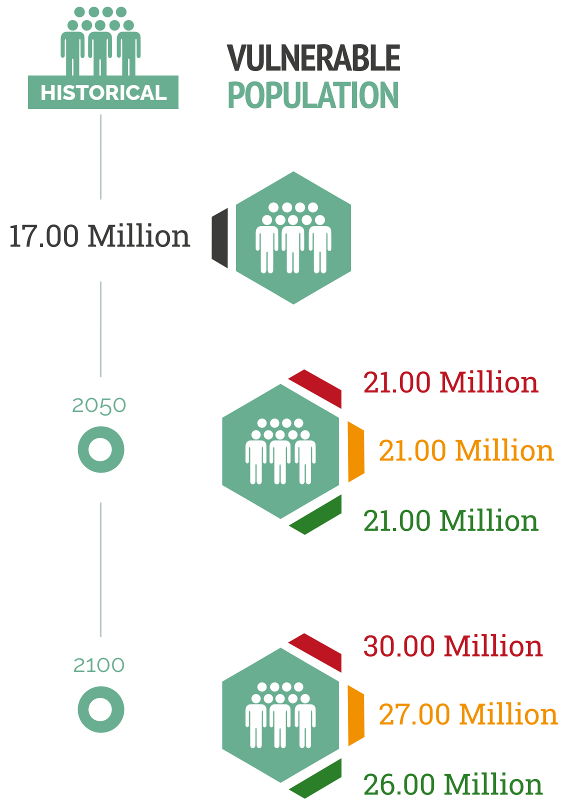
Waves and storms around the Indian coast are expected to change in the future. Recent projections show an increase in wave heights and periods along much of the Indian coast, with maximum wave heights increasing by more than 30% in some locations. At most locations along the east coast, wave periods are expected to increase by almost 20%, whereas along the west coast an increase of around 10% is expected. Similarly, water elevation due to cyclone activity is expected to increase.

VULNERABILITY AND RISK

Approximately 64 million people live in low elevated coastal areas that are less than 10 metres above sea level. These areas are exposed to both coastal erosion and storm surges, with the highest exposure found on the east coast of India. Most of the people in low lying coastal areas are concentrated in the Ganges Delta, one third of which is within the Indian territory, including the city of Kolkata which is home to 4.5 million people.

With a growing coastal economy and an increasing population in coastal areas, India has been managing recent coastal risks with large scale investments aimed at protecting infrastructure, with numerous programs dealing with coastal risk management.

Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 17 million to 21 million by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

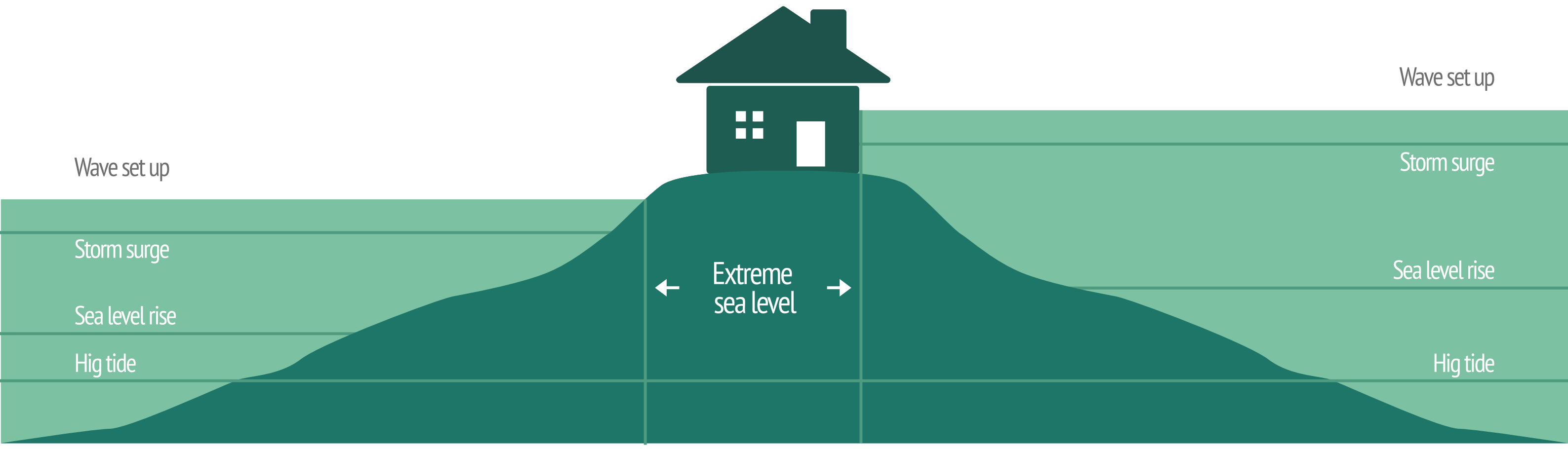
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmo-spheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

INDIA WATER

OVERVIEW

In India, demand for water resources has been escalating due to a fast growing population over the past century. Total population has already surpassed 1.3 billion and is expected to stabilize only by the year 2050.

Increasing domestic, agricultural, and industrial water requirements are serious challenges for India. Monsoons, the most important source of water for the country, undergo large inter-annual variations associated with global anomalies.

Hence, large disparity in rainfall are reflected in water resources. As a result, vast areas of interior India are arid and semi-arid, with consequent water availability issues.

Renewable internal freshwater resources
1,446 billion m^3

Renewable internal freshwater resources per capita
1,080 m^3

The Ganges-Brahmaputra-Meghna system is the major contributor to the total water resources potential of the country. Its share amounts to about 60% of total water resource potential of all rivers. About 40% of utilisable surface water resources are presently found in this large system. In the majority of river basins, present utilisation is high and in the range of 50-95% of utilisable surface resources. In rivers such as the Narmada and Mahanadi, however, utilisation percentage is quite low. The corresponding values for these basins are 23% and 34%, respectively.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Per capita availability of freshwater in all major river basins is decreasing rapidly as a result of changes in climate and a growing population. Available resources, in addition, are being depleted and degraded at a fast pace and a large part of river basins will face water scarcity by the year 2050. Even without taking into account the possible impacts of climate change, eight river basins will be critically water scarce by 2050.

KEY POINT RUNOFF

Major and medium river basins contribute over 90% of the total runoff in the country. Locally, surface runoff is expected to decrease drastically in arid and semi-arid India in the future.

At a country scale, an average change in surface runoff by approximately -9% and +2% is expected respectively under low and medium emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 17%, 33.4% or 43% of the country will likely experience an increase in runoff, while 3%, 6.4% or 17% of the surface of the country will likely experience a decrease in runoff, respectively.

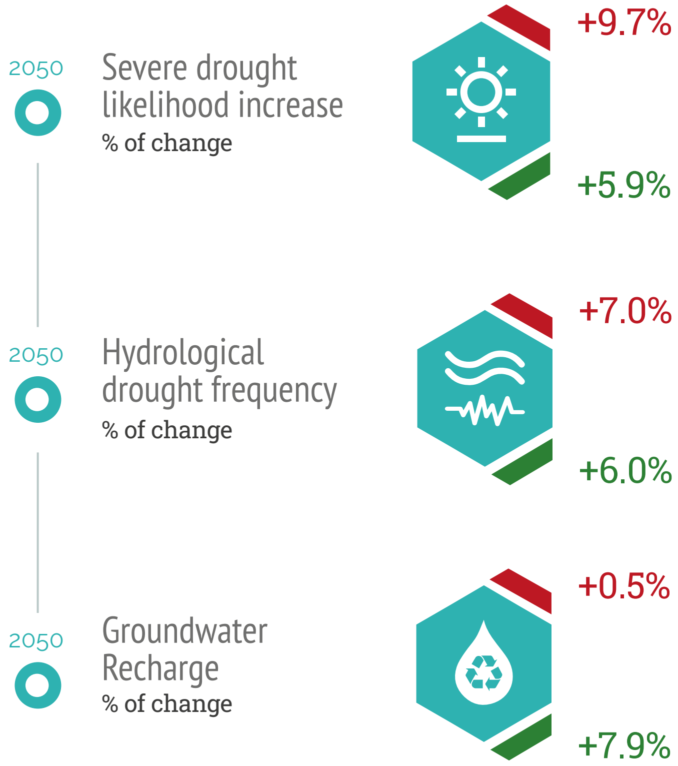
2050
Changes in annual runoff
% of change
+2.3%
-8.5%

2050
Runoff increase
% of area
+43.0%
+17.0%

KEY POINT DROUGHTS

Drought causes significant water and food insecurity, leading to economic losses and financial risks in developing countries like India. Droughts pose enormous challenges for drinking and irrigation water supply and also affect the economy of India, where more than 68% of people are dependent upon agriculture. Moreover, about 18% of India's total area is drought-prone, and about 50 million people are annually affected by drought. India faces droughts due to poor summer monsoons caused by natural climate variability or climate change.

In the Deccan Plateau region of India significant drought conditions occur once in 3 years. The Deccan region sees the highest frequency of severe droughts in all of India.



KEY POINT GROUNDWATER

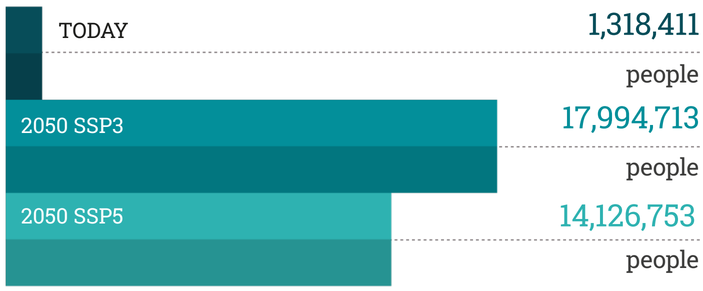
A large part of India is under intensive agriculture and mostly irrigated with this resource. Rapid groundwater depletion remains one of India's most profound sustainability challenges. Extraction of non-renewable groundwater for irrigation in India was used on about 68 cubic kilometres of land per year for the year 2000, which is the highest in the world.

Sustaining groundwater is essential for meeting the needs of food and water in the current and projected future climate, and these necessities appear even more urgent in the northwest regions such as Punjab. There are uncertainties associated with groundwater recharge under climate change, which are linked to precipitation projections under the future climate. Groundwater storage is projected to increase in some Indian areas under the future climate in the absence of groundwater extraction for irrigation primarily due to projected increase in precipitation. Nevertheless, longer droughts and projected increase in irrigation water demands can pose further challenges to already depleted groundwater resources in India.

KEY POINT FLOODS

The increased risk of flash floods as a result of changing rainfall patterns over India has been reported in several recent studies. Extreme precipitation events in India in the past caused flooding, affected the economy, and resulted in the loss of lives. For instance, an extreme precipitation (940 millimetres in 18 hours) event in Mumbai (July 2005) was a disaster that led to flooding that affected 20 million people and caused around 1,200 deaths. Similarly, Mumbai experienced flooding in September 2017 due to extreme precipitation (330 millimetres in 24 hours), which largely affected road transportation. Furthermore, Chennai received 483 millimetres of precipitation in 48 hours in November 2015, which had a devastating impact causing widespread damage. By 2050 slight changes in the number of days with intense precipitation (more than 50 millimetres of rain) is expected, with a small increase of 0.20 days under a low emissions scenario and 0.32 days under a medium emissions scenario.

POPULATION AFFECTED BY RIVER FLOODS

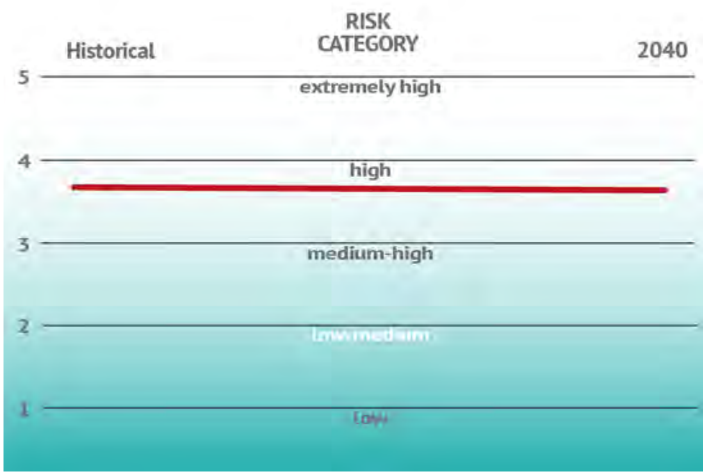


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

India's water stress level is considered high for the recent past (1960-2014 average), and it is expected to remain that way in the near future (2030-2050) based on climate change projections.



INDIA AGRICULTURE

OVERVIEW

With a population of 1.37 billion people, India is one of the most populous countries in the world. Given its large spatial distribution and agro-ecosystem diversity, several farming systems exist with a significant cultivation of rice, wheat, sugarcane, vegetables and fruit trees.

Whereas agricultural contribution to national GDP has declined over the last decades, a large share of the population still depends on agriculture for its subsistence. Irrigation schemes are still expanding to enhance food security. In fact, over 14% of India's population is thought to be undernourished. Agriculture adsorbs over 90% of total water withdrawal in a country with high stress on water resources, raising severe sustainability issues if it is to sustain further irrigation development and cope with climate risks.

379.9 Mt Sugarcane

174.7 Rice

99.9 Mt Wheat

51.3 Mt Potato

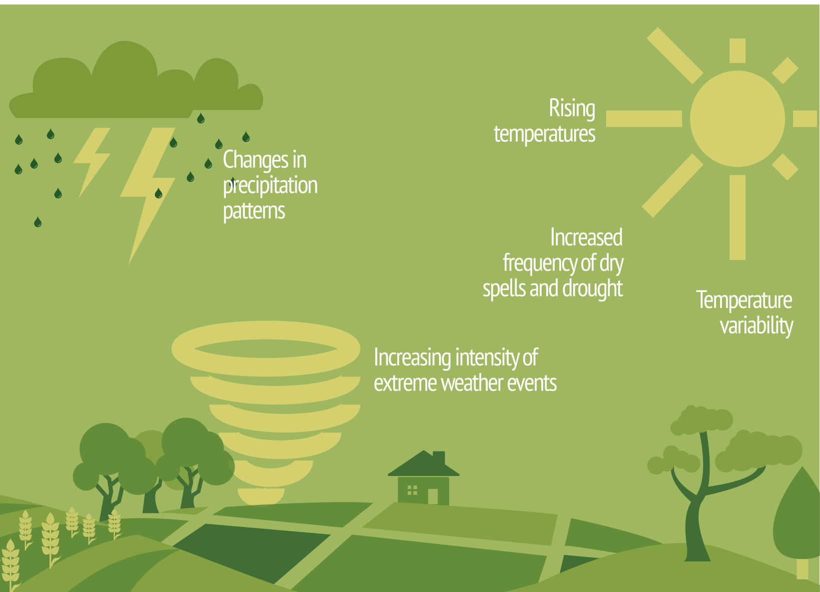
28.7 Mt Maize

24.9 Mt Mango

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	228,143 USD Million	27.9 %	170,130 Thousand HA	60,432 Thousand HA
2018	398,681 USD Million	15 %	169,416 Thousand HA	70,400 Thousand HA

EXPECTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.

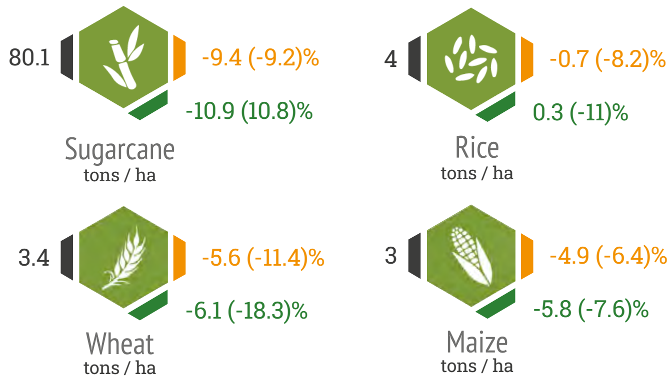


CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

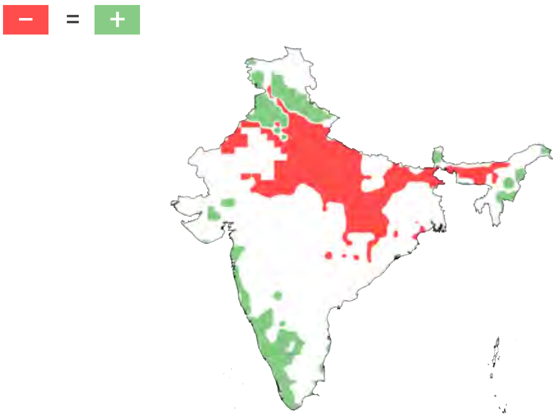
Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.



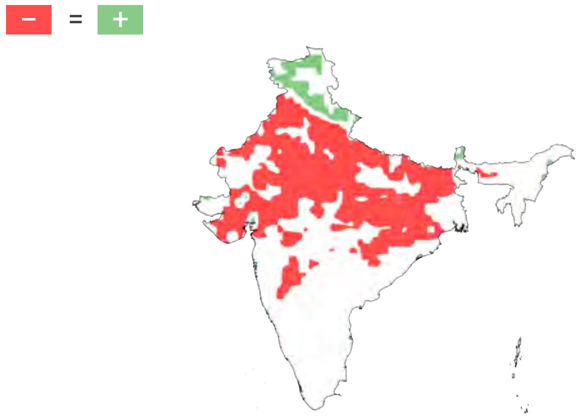
2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, diseases, or extreme events.

CHANGE IN RICE



CHANGE IN WHEAT

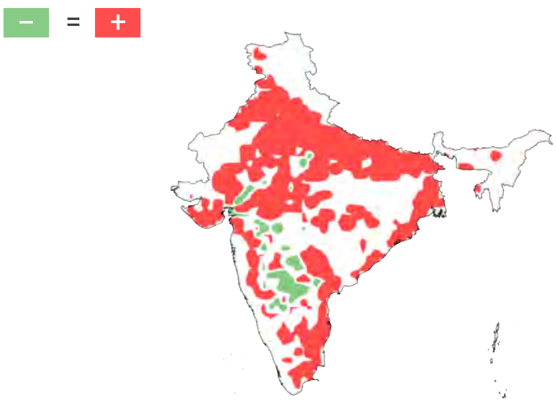


Increasing temperatures will have a strong negative effect on rice yield, especially in the northern and central areas where 15% to 40% of current rainfed rice locations may be at risk. Positive effects on rice yield can be expected in the southern, and to a certain extent eastern, regions. Productivity of wheat is projected to decrease up to 20% in some areas. The strongest decline is expected over central and south-central areas, whereas an increase is foreseen for cooler environments. Sugarcane is a climate sensitive crop and will show a marked decline in crop yields due to higher temperatures overcoming optimum level for photosynthesis. Mango production may be harmed in tropical regions with already prevailing high temperatures. On the other hand, rising minimum temperatures are extending farming into new areas which were previously too cold for mango production.

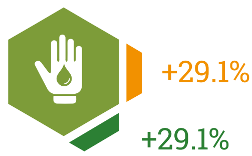
ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have some positive effects on some of the most widely used crops. However, higher temperatures will generally require an increase in irrigation demand due to higher plant evapotranspiration. Utilization of freshwater resources is already significantly high in agriculture, and projected to increase in the future. Climate change will reduce water resources and enhance streamflow seasonal variability. Large parts of India have been dependent on groundwater resources for intensive cereal production. Groundwater may be further depleted and unable to act as a resilient resource under future and more extreme droughts.

CHANGE IN WATER DEMAND



Agriculture
Water Demand
% of change



2050

To meet agricultural demand for a growing population and cope with climate risks, it will be essential to further promote usage of wastewater and sustainable agriculture through water-efficient adaptation practices.

INDIA FORESTS

FORESTS IN INDIA

India's vast and varied topography hosts a diverse range of forests: from moist and dry tropical forests to temperate and subtropical montane ones, as well as Himalayan and scrub forests.

Over 20% of India's forests are primary, making them some of the richest in terms of biodiversity. Indian forests provide water, health, food security and jobs for a country with a growing population of more than 1.3 billion people.

FORESTED AREA AND CARBON STORAGE

Forests cover 25% of India with a steady increase in recent decades. According to recent calculations by the Ministry of Environment Forest and Climate Change, the total carbon stock of Indian forests is over 7 gigatonnes of carbon (of which over 20% in Himalayan forests). Indian forests are a crucial carbon sink.

1990

64 Mln ha
Million hectares
Forested area

95 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

72 Mln ha
Million hectares
Forested area

100 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.42

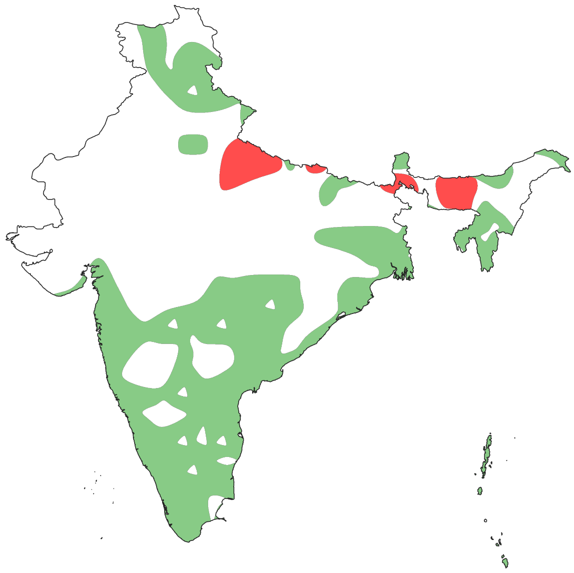
+0.23

A slight increase is possible especially in southern areas.

+ Fertilizing effect of increasing atmospheric CO_2 and rising temperatures promotes productivity

Decrease expected in some sub-Himalayan areas.

+ Increasing risk of drought stress due to modifications in the water regime reduces productivity



KEY SPECIES UNDER CLIMATE CHANGE

XERIFICATION
HIMALAYA
Most forests types, particularly Himalayan forests, are turning xeric

REDUCTION
SAL TREE
Decline of sal tree in central India

REDUCTION
TEAK
Decline of teak from very moist and moist forests

LOW VULNERABILITY
TROPICAL AND MONTANE FORESTS
Less vulnerability shown by tropical rain and montane wet temperate forests

FIRES IN INDIA

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total forest area affected by fire was approximately 58.6 million hectares.

BURNING
58.6 MILLION HECTARES

EMITTING
12.5 TERAGRAMMES OF CARBON PER YEAR

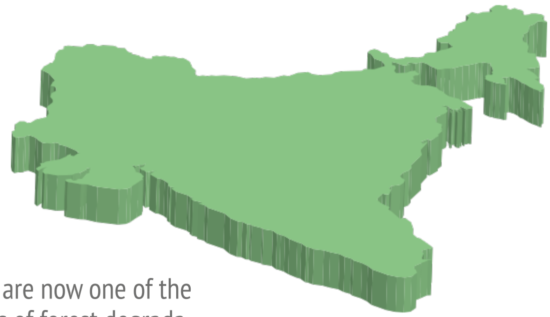
FOREST FIRE EMISSIONS CONTRIBUTED TO 47.5% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING
164 MILLION USD PER YEAR IN ANNUAL DAMAGES

WHERE DO FIRES OCCUR?

Forest fires affect dry deciduous broadleaved forests in particular due to abundant fuel load and low moisture content in soil.

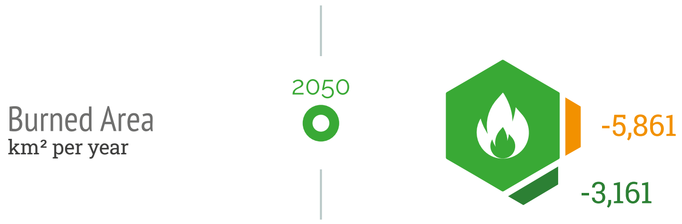
In the north-east, forest fires are mainly associated with traditional practices of shifting cultivation.

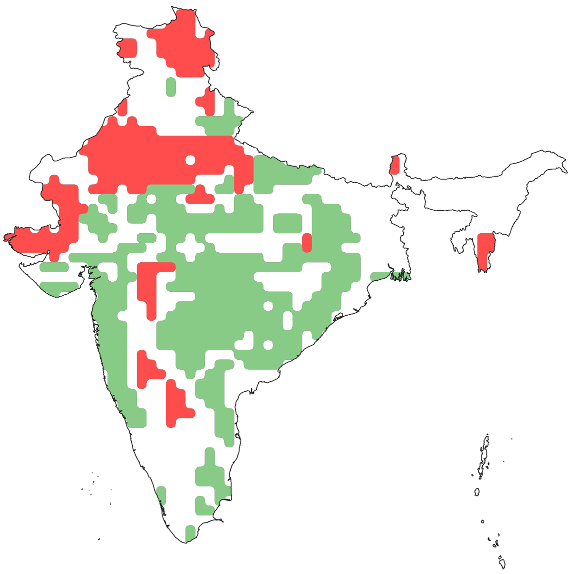


Forest fires are now one of the main causes of forest degradation in India, particularly in the regions of Madhya Pradesh, Odisha, and Chhattisgarh.

FUTURE BURNED AREA

By 2050, under both low and medium emission scenarios, a decrease in burned area is expected in tropical and subtropical broadleaf forests over central India. However, a slight increase in burned area is expected over north and north-western areas dominated by xeric shrublands, decidous forests and alpine steppes.





Decrease in burned areas for a low emissions scenario

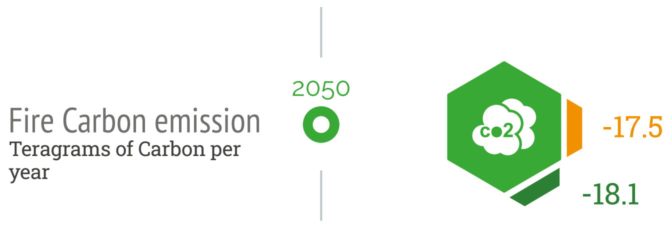
Increase in burned areas for a low emissions scenario
+ Increasing temperatures and decreasing rainfall over largely forested Indian states

CASE STUDY: AIR QUALITY

Due to a prolonged dry spell, 2021 was the worst year out of the last 15 in terms of forest fires in northern India. Uttarakhand's forest fires emitted nearly 0.2 teragrammes of carbon, a record that had gone unchallenged since 2003. On top of forest fires, post-monsoon agricultural fires further affected the already high concentrations of urban air pollution in the Indo-Gangetic Plain. During the period from 2012-2016, their contribution ranged from 7% to 78% of the maximum observed PM2.5 increments in Delhi, suggesting that changes in farming practices that reduce agricultural fires could produce significant health benefits. Another challenge related to forest fires is the threat to protected areas and biodiversity conservation. In eastern India's Similipal Biosphere Reserves, approximately 10-30% of the territory burns each year. In march 2014 a large fire burned in the Sri Venkateshwara National Park, which is home to a wide range of uncommon species.

FUTURE FIRE EMISSIONS

Fire emissions might follow similar spatial patterns to burned areas. A slightly potential increase is expected in eastern subtropical forests and rainforests, particularly under a medium emissions scenario.



INDIA
URBAN

OVERVIEW

India's urbanization rate is expected to grow from 35% in 2020 to more than 50% in 2050. Migration from rural areas due to climate impacts is expected to contribute substantially to this increase in urban population.

Smaller urban areas with less than 300,000 inhabitants have a predominant role in terms of share of the urban population. However, megacities with more than 10 million inhabitants are home to one fifth of the urban population. Urbanization rates are growing rapidly, and urban areas are growing faster than rural areas. India's urban population is expected to grow from 340 million in 2008 to 590 million by 2030, an increasing trend which is expected to continue until 2050 in all types of cities, but in particular in megacities.

Built up areas cover 2.27% of India (67,385.25 square kilometers).

Population in Urban Areas

2020 — 483,098,640

2050 — 876,613,025

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 — 34.9%

2050 — 52.8%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Indian cities are exposed to multiple climate impacts connected to heat stress and flooding, which amplify the challenges caused by other factors such as poverty and rapid growth combined with scarcely managed urbanization.

HEATWAVES AND HEAT STRESS

Between 1965 and 2010, heat waves increased by an average of 0.23 cases per decade and their duration extended by 0.71 days per decade. Regular heatwave events occur almost every year over most of the country, in particular in the northwest and the south-eastern parts. Average duration of heatwaves over northwest India is between 5 to 7 days per season.

Between 1960 and 2009, mean temperatures in India increased by 0.5% and heat related mortality also rose. In 2010, more than 1,300 people died in the city of Ahmedabad due to heatwaves, with subsequent heatwaves in 2013 and 2015 killing more than 1,500 and 2,500 people across the country. During the intense heatwave of 2016, temperatures reached 52.4°C in the city of Jaisalmer. Heatwaves will become more frequent and prolonged, extending the periods of overheating in urban areas.

2050 — Cooling Degree Days
% of change
+54.1%
+20.9%
+13.2%

2050 — Heatwave frequency
% of change
+97.4%
+55.4%
+32.1%

2050 — Heatwave duration
% of time
+2,515%
+525%
+160%

HEAT, POVERTY AND AIR POLLUTION

Indian cities are among the world's most polluted and put city dwellers at risk throughout the country, exacerbating the impacts of heatwaves in urban areas. The entire urban population of India is constantly exposed to unsafe levels of air pollution which exceed the WHO's threshold values.

Mortality from heat waves is higher in low-income groups with no access to electricity and those that depend on outdoor work.

2017

Population exposed to air pollution

100.0%

COASTAL FLOODING

Three of India's five mega-cities (Kolkata, Mumbai and Chennai) are situated in low-lying coastal areas which are exposed to regular tropical typhoons. Intense rainfall during the monsoon season is also among the key challenges for most other Indian cities, alongside increasing drought events during the dry season.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

FLOODING

Intense rainfall during the monsoon season causes regular traffic break downs and hinders urban activities such as going to school, as well as flooding low-lying slums for days. In 2005 an exceptional storm surge with heavy rainfall in Mumbai left killed over 1,000 people, of which most lived in slum areas. The widespread flooding throughout the city, had a strong impact on economic activities and caused the national stock exchange and banking system, including ATMs, to shut down.

Despite reduced rainfall quantities, both rainfall events and storm surges will become more intense. Under a changing climate, a one in 100 years flood event in Kolkata could cost up to 6.8 billion USD due to damage and losses to business interruptions, health care facilities etc. A case similar to the one which occurred in Mumbai in 2005, which corresponds to a one in 100 year event, could increase total losses from 700 to 2,305 million USD.

2050

Runoff increase
% of area

+43%

+33%

+17%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

UNCONTROLLED URBANIZATION

Risks arising from climate change will add to existing risk drivers in Indian cities, which are commonly due to poverty, ecosystem degradation, and poorly governed, rapid urbanization which resulted in the growth of unplanned settlements and slums, frequently situated in highly exposed areas such as flood plains or steep hills.

35% of urban households live in slums with scarce access to safe drinking water and sanitation, inadequate housing and lack of drainage

2010

% of urban population
Population living in slums

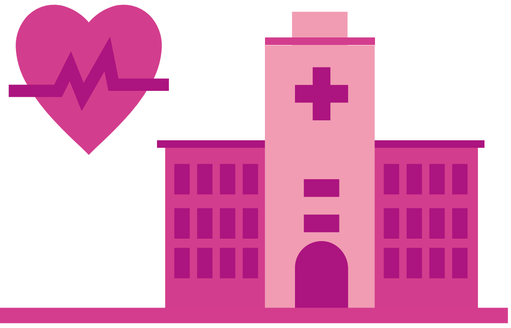
35.2%

2018

% of total population
Urban population living in areas where elevation is below 5 meters

1.1%

INDIA
HEALTH



OVERVIEW

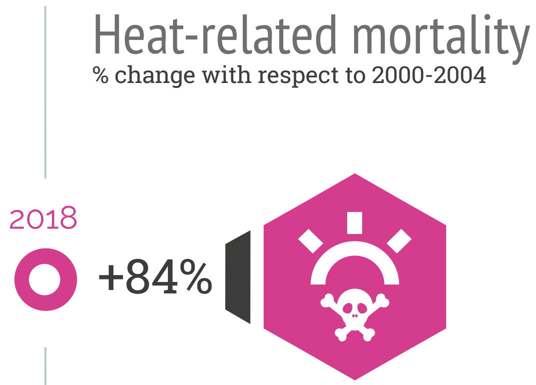
With a population of 1.4 billion and increased climate change risks due to coastal and inland river flooding, increased heat stress, water and food insecurity, and changes in the occurrence of climate-sensitive diseases, India's decades of advancement in health and social development may be threatened. Extremely hot days (temperatures higher than 35°C) are expected to increase from approximately five per year in 2010, to around 42 per year in 2100. As a result, the death rate due to climate change is projected to increase by 10% - equivalent to 60 deaths per 100,000 people by the end of the century. By 2100, around 1.5 million additional deaths due to climate change are expected in India.

HEAT RELATED MORTALITY

India reported over 31,000 heat-related deaths of people older than 65 in 2018.

Between 1960 and 2009, an increase of 0.5°C in summer mean temperatures increased the probability of mass heat-related mortality by 146%. Under a high emissions scenario, excess mortality will increase by 10% by 2100.

This is equivalent to 1.54 million excess deaths per year due to climate change by 2100 under a high emissions scenario. However, under a medium emissions scenario, this number is projected to decline by 80%. In 2018, there was an 84% increase in heat-related deaths in India compared to the 2000 to 2004 baseline.

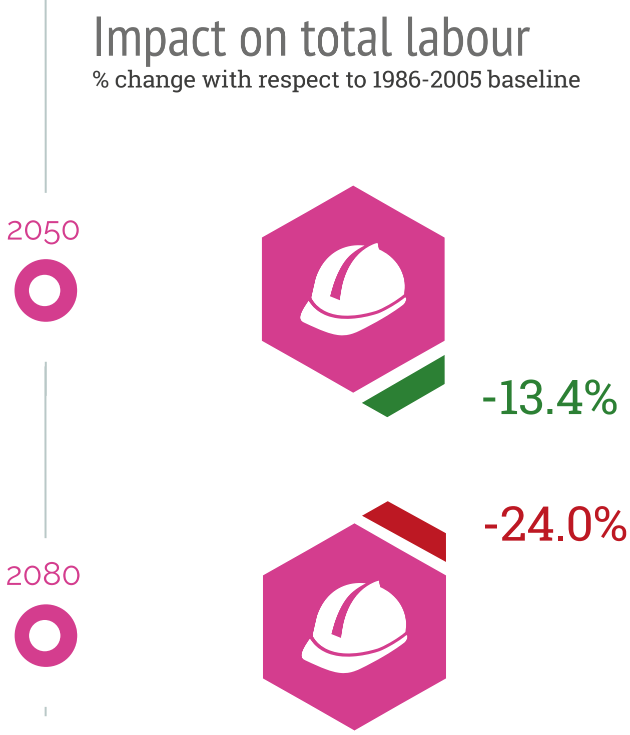


IMPACTS ON LABOUR

Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

The effects of climate change on the livelihoods of vulnerable workers engaged in subsistence farming, the informal economy, and the tourism sector has been increasing. 1°C increase in annual temperatures leads to a 2% decline in industrial productivity in India. Total labour is expected to decline by 13.4% under a low emissions scenario, and by 24% under a medium emissions scenario.



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

Epidemiological risks from dengue and Zika will increase due to future climate change in India.

Under a medium emissions scenario, 98.1% of the population will be at risk of transmission-suitable mean temperatures for dengue by 2050, whereas 97% will be at risk under a high emissions scenario. In the case of Zika, 97.2% of the population will be at risk by 2050 under medium emissions.

CLIMATE CHANGE AND MALARIA

Malaria presents a significant public health challenge in India, with more than one million reported annual cases. 76.7% of the Indian population will be at risk of malaria under a low emissions scenario in 2050, whereas 73.7% will be at risk under a high emissions scenario.

POLLUTION AND PREMATURE MORTALITY

1.67 million deaths were attributable to air pollution in 2019, accounting for 17.8% of total deaths in the country. By 2060, 2,039 deaths will be caused by outdoor air pollution per year per million people, compared to 508 in 2010.

Dengue suitability

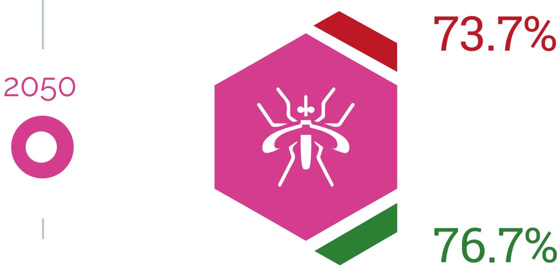
% of population at risk

Zika suitability

% of population at risk

Malaria suitability

% of population at risk



INDIA ENERGY

ENERGY SYSTEM IN A NUTSHELL

India's energy demand has grown fast, tripling over the last 30 years, and increasing by 60% in per capita terms. Energy consumption is the world's third highest (908 million tonnes of oil equivalent). India claims over 10% of the global increase in energy demand since 2000. Per capita energy use and emissions are still less than half the global average.

Within India's energy mix, coal and oil shares grew, while biomass dropped. India is highly dependent on coal, which covers half of energy demand.

0.11
ktoe/US$
Energy intensity

17.8%
AC Share in electricity consumption

37.8%
Import dependence ratio

CLIMATE CHANGE TODAY

WATER

In India, 40% of thermal power plants are in areas of high water stress and hence have a capacity factor 21% lower relative to plants with better water availability. In 2013-2016, 14 of the 20 largest utilities faced at least one shutdown due to water shortages. In 2016 alone, 14 terawatt-hours were lost due to insuffcient water availiability.

EXTREME EVENTS

IN 2019, UNSEASONAL PRECIPITATION AND STORMS DAMAGED SEVERAL SOLAR PLANTS. RISING HEAT STRESS AFFECTED HIMALAYAN GLACIERS AND LED TO INCREASED RISKS OF DROUGHTS AND FLOODS. IN 2021, A GLACIAL LAKE OUTBURST CAUSED FLASH FLOODS IN THE HIMALAYAN REGION DESTROYING TWO HYDROELECTRIC DAMS.

ENERGY SUPPLY

The current (2019) energy mix of total primary energy supply in India is dominated by coal (45%), oil (25.6%) and biofuels (20%). Natural gas accounted for 5.7% of total primary energy supply and hydro, solar and wind together accounted for 2.5%. India is dependent on imports for both coal and oil. Despite having rich coal reserves, domestic production cannot keep pace with demand. A lack of domestic oil reserves leaves India highly reliant on crude oil imports.

ENERGY DEMAND

Energy is used by the industrial sector (34% of final demand, mostly in the iron and steel industry), and by the residential (29%) and transport sectors (17%, mostly for road transport). The tertiary sector claims about 4% of final demand. Air conditioning accounts for 17.8% of residential electricity demand (2017). Energy demand largely exceeds domestic supply; hence imports are needed and shortages occasionally occur.

FUTURE ENERGY DEMAND

In India, higher cooling needs are projected to require additional installed power generation capacities of 36 gigawatts by mid century and 136 gigawatts by the end of the century under a high emissions scenario. Energy demand is predicted to increase, as the small drop in heating demand is going to be more than compensated by the vast increase in cooling needs, resulting in a net increase of energy demand of about 1,714 PJ (475 billion Kwh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in HDD/CDD
Billion KWh

2050

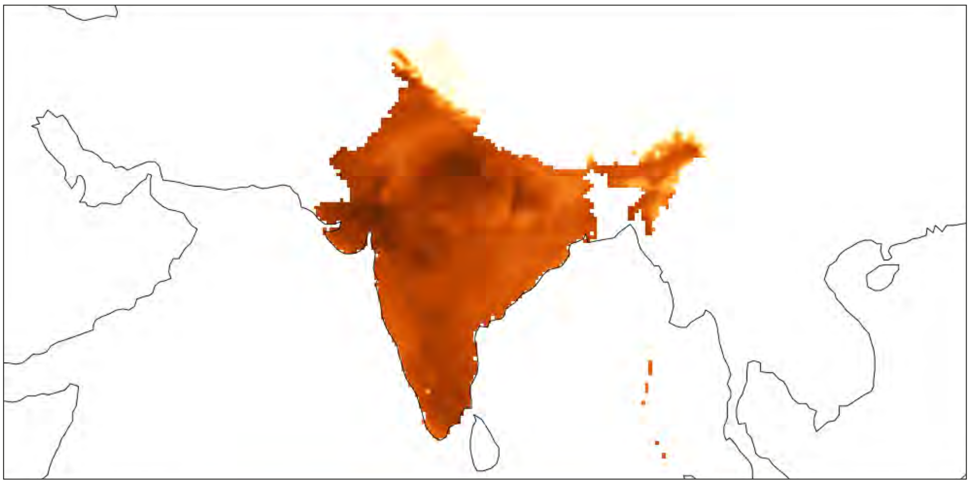
+ 476.07

COOLING NEEDS

It is expected that India will face an increasing number of extreme heat spells. Very strong increase in cooling needs are expected all over the country, particularly in the southern and in the central states, where the capital New Delhi and the largest cities are located. Moderate increases are expected only near the northern border. This may result in increasing pressure on already constrained energy infrastructure assets.

COOLING DEGREE DAYS

0 600

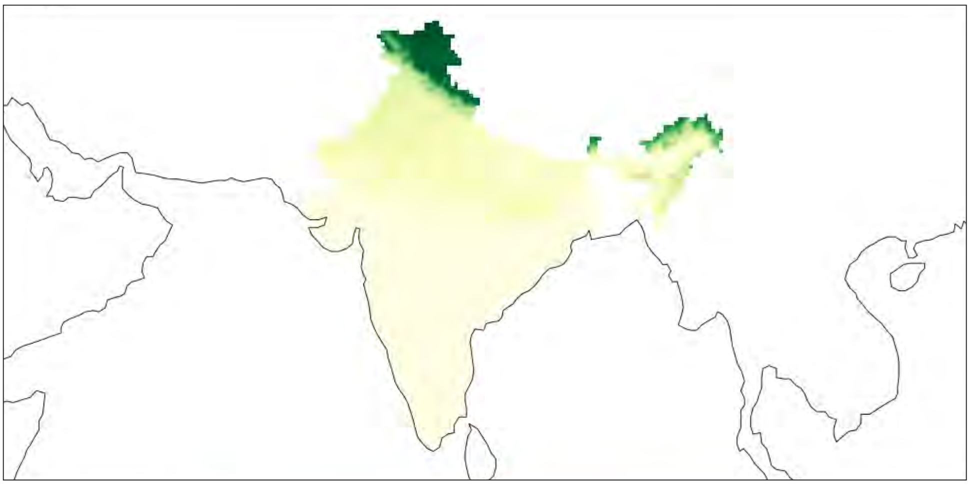


HEATING NEEDS

Heating degree days are of almost no relevance in the peninsular part of India. Heating needs are expected to decrease strongly in the states and territories closer to the northern mountain ridges (Ladakh, Jammu and Kashmir, Himachal Pradesh, Uttarakhand and Arunachal Pradesh), which are however not as densely populated as the rest of India.

HEATING DEGREE DAYS

-827 0



FUTURE ENERGY SUPPLY

The future Indian energy mix is likely to be determined by energy policies and hence is outside the scope of this report. The government set ambitious coal and renewable energy targets, and most energy models expect coal to dominate. India aims to quadruple renewable energy capacity by 2030 and to more than double the share of natural gas. India's NDC include a 40% target for clean-energy installed power-generation capacity and up to a 35% reduction in emissions intensity of GDP by 2030.

Change in Hydropower generation
% of change

2050

-3.60%

-2.62%

EXPECTED IMPACTS OF CLIMATE CHANGE

As water availability is predicted to decrease, most of India's power plants become vulnerable. A large share of fossil fuel infrastructure is located in areas highly vulnerable to climate hazards, such as ports, which will be increasingly threatened by more frequent and severe cyclones and storms.

New projects like Udupi Power Plant (Udupi), Tata Power, Adani Power (Mundra) will be vulnerable. Himalayan glaciers are predicted to shrink fast. This will pose significant threats to hydropower generation.

INDIA ECONOMY

OVERVIEW

India ranks 7th in terms of GDP in the G20 group, with one of the largest growth rates. Due to COVID, for the entire 2020/21 financial year, the overall rate of contraction in India was, in real terms 7.3% .

IMPACTS ON GDP

Without any mitigation, climate change could severely undermine the development gains made in India in recent decades. In a moderate climate change scenario, India is projected to potentially lose between 0.8 and 2% of its GDP by mid century.

By the end of the century costs could double, reaching up to almost 10% of GDP (or 237 billion EUR) under a high emissions scenario.

GDP Loss

% change w.r.t baseline

2050

3.62/5.21%

0.81/2%

2100

8.77/9.9%

2.57/5.18%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Natural disasters linked to weather extremes pose significant risks to the population and infrastructure in India. Approximately 12% of land is at risk of river flooding and erosion.

The majority of the coastline, densely populated in particular along the eastern part of the country with cities like Calicut, is prone to cyclones and tsunamis, whereas mountainous regions are at risk from landslides and avalanches.

IMPACTS ON AGRICULTURE

Globally, India is the largest producer of milk, pulses and jute, and is the second largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruit and cotton.

At a national level, the agricultural sector is significant, employing more than 60% of the population, and contributing to 16% of GDP in 2019.

The agricultural sector in India is particularly vulnerable to the effects of climate change such as increasing temperatures and variability in rainfall. This will have significant repercussions for the Indian economy and the country's food security that relies mostly on domestic production to meet the needs of a growing population.

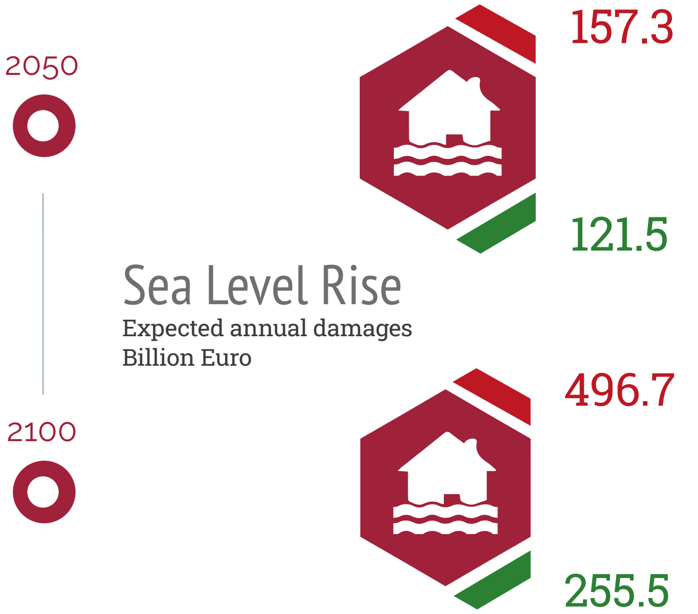
In particular, declines are projected for rice and wheat yields due to climate change, with economic losses by the mid century between 43 and 81 billion EUR(or 1.8-3.4% of GDP).

This is also expected to have substantial effects on Indian farmers' income. It is estimated that in the absence of any adaptation measure, climate change could decrease average farm incomes by 15%, peaking at 25% for unirrigated areas, by the end of the century.

SEA LEVEL RISE DAMAGES

Without any improvement in coastal protection, in a low emissions scenario projected asset losses can amount to 121.5 billion EUR by mid-century and 255.3 billion EUR in the second half of the century.

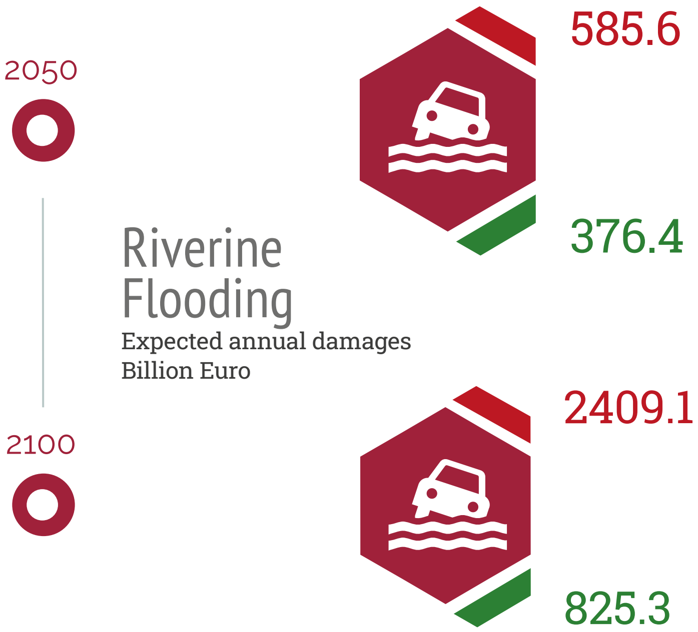
The high emissions scenario features higher losses with potential costs ranging from 157.3 billion EUR in 2050 to 496.7 billion EUR by the end of the century. Sea level rise is also expected to displace many vulnerable coastal communities with an estimated cost from forced migration that, under high emissions, could reach up to 580 million EUR by the end of the century.



RIVER FLOODING DAMAGES

Fluvial flooding is expected to cause substantial losses. The expected annual damages by 2050 are estimated to be 376.4 billion EUR under a low emissions scenario and rise to 585.6 billion EUR under a high emissions scenario.

By the end of the century costs are projected to rise substantially to annual damages of 825.3 billion EUR under a low emissions scenario and may reach 2,409.1 billion EUR under a high emissions scenario.



IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in India will undergo more intense stress due to droughts and extreme events such as typhoons and floods.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of India, there is no demand for heating of any significance in most of the country, and hence the large increase in cooling demand is expected to result in a substantial increase in energy bills.

IMPACTS ON TOURISM

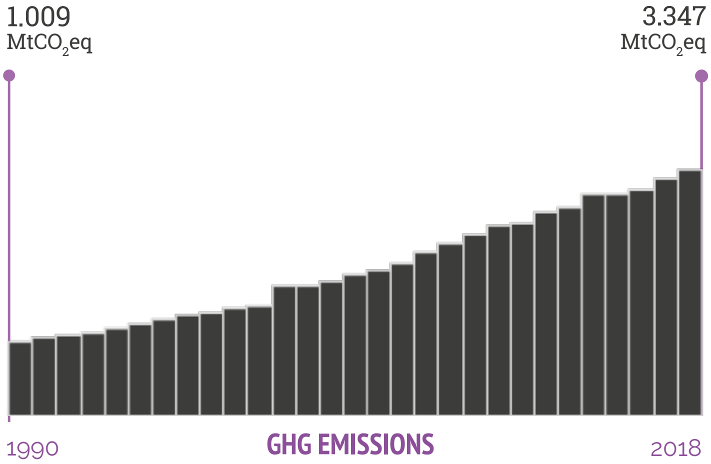
In terms of the tourism sector, to the best of our knowledge no exact costs of climate change have been estimated. However, the occurrence of natural disasters has been linked with a reduction in foreign tourists, but does not seem to affect domestic tourists.

Foreign visitors tend to avoid areas of natural disasters to reduce any risks or disruption, whereas domestic tourists in India mainly travel for religious or social reasons.

INDIA
POLICY

OVERVIEW

Although India is the 2nd most populated country in the world, it has the lowest rate of emissions per capita among G20 countries, accounting for 6.8% of world total GHG emissions in 2018. However, emissions are increasing steadily.



INTERNATIONAL COMMITMENTS

India ratified the Paris Agreement in 2016. Its NDC commits to lower the carbon intensity of each unit of GDP by 33%-35% in 2030 (with reference to 2005 levels), to reach 40% of its power capacity supplied by non-fossil fuels by 2030 and to create additional carbon sink up to 3 billion tCO2eq by 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002 — **KYOTO PROTOCOL - 1ST PERIOD**

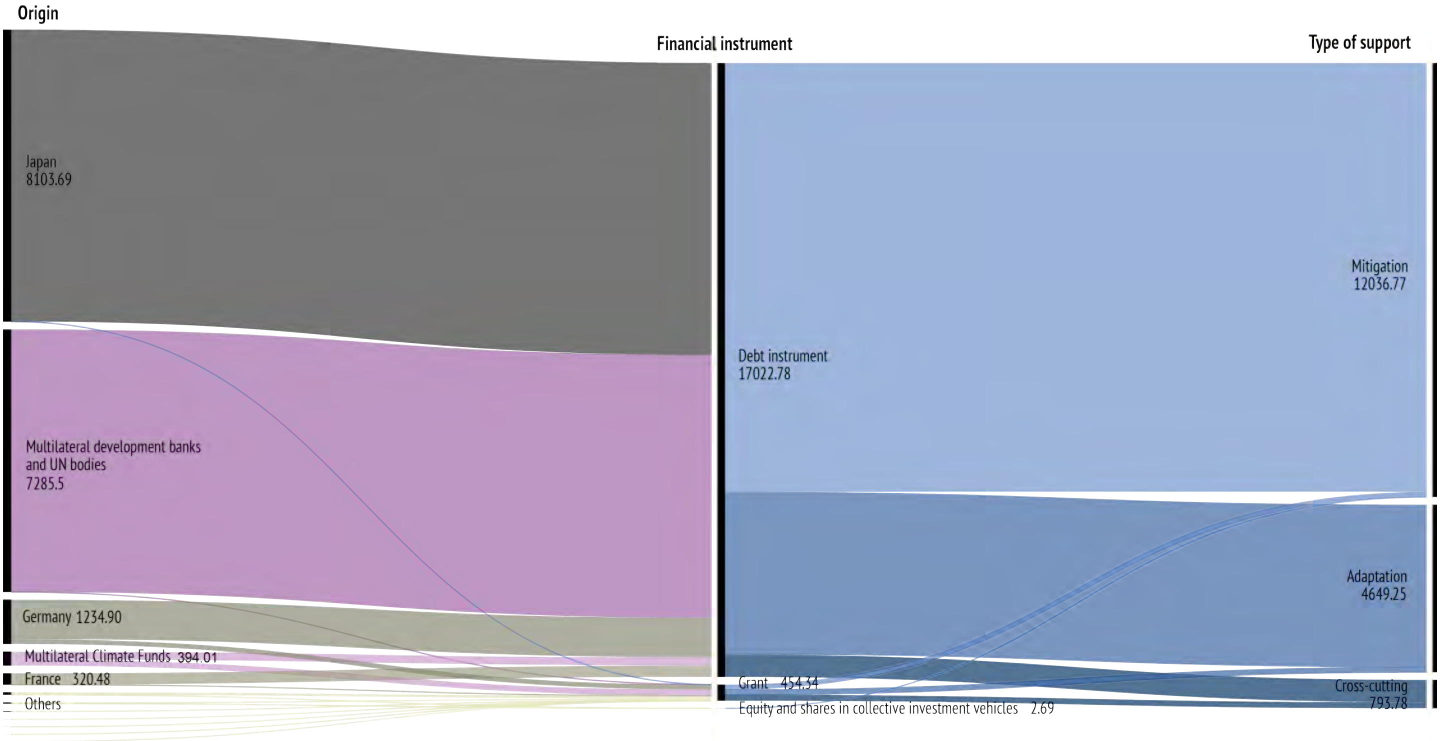
No target

2016 — **PARIS AGREEMENT - 1ST NDC**

33%-35% reduction in GHG emissions per unit of GDP by 2030, with respect to 2005 levels. 40% of power capacity from non-fossil fuel-based resources by 2030. 2.5-3 billion tCO_2eq. of additional carbon sink

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

In 2017-2018, India received 17.5 billion USD in climate-related development finance, according to OECD DAC data. The main sources were bilateral agreements, with Japan as the main donor. Almost all the amount reported is in the form of debt and equity instruments.



SUSTAINABLE RECOVERY POLICY

In 2020, India spent 20.75 billion USD to recover from the sanitary crisis: a fraction of its total expenditure (478,42 billion USD). According to the Global Recovery Observatory, sustainability accounts for 3,6 billion USD.

Total Spending	Recovery Spending	Green Spending
478.43 billion $	20.75 billion $	3.6 billion $

DOMESTIC ADAPTATION POLICY

India has a commitment for adaptation in its NDC. To achieve its targets, India developed an integrated mitigation and adaptation plan. The plan designates sub-national entities and sectoral authorities to provide adaptation plans.

- ○ Domestic Adaptation Policy
  - ● Inclusion of Adaptation in NDCs
  - ● Integrated Adaptation & Mitigation Policy
  - ○ Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ● Subordinate Adaptation Policies
  - ● Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Indian Himalayas Climate Adaptation Programme

The programme aims to enhance the resilience of vulnerable communities in the Indian Himalayas by strengthening Indian institutions in climate science, with a specific focus on glaciology and related areas, as well as planning and policy

NATIONAL INITIATIVES

Modelling of Changing Water Cycle and Climate

Development of hydrological resource assessment and management tools to quantify possible response to climate change and variability

National Water Mission (NWM)

The mission was launched in 2011 to ensure water security and improve access to the resource. It covers the entire water management cycle from water conservation to increasing water use efficiency

SUBNATIONAL INITIATIVES

Climate Change Adaptation in Rainfed Regions of Maharashtra, Madhya Pradesh, and Andhra Pradesh Project (CCA Project)

CCA Project trained local communities to identify and combat climate disasters. It created irrigation models and maps and it maintained springs and canals by clearing lantana and planting bamboo. Where applicable, fish ladders were built to help fish go upstream for breeding

Madurai Action Plan for Blue-Green Infrastructure

The city identified 14 future proofing projects to rehabilitate sewer systems; improve solid waste management; rehabilitate and green infrastructure; manage surface water against floods; balance water supply-demand; plan the future governance system

ENERGY TRANSITION

Among the G20, India is lagging behind in the process of transformation of its energy sector; in particular, the country is at the bottom of the ranking for what regards the Efficiency composite, which takes into account transmission and distribution losses of the electricity grid, the level of energy intensity of the economy and the access to clean cooking services.
India is not progressing much in Emissions, which considers the urban air quality and the level of CO2 emissions. In order to tackle the negative consequences of climate change, there is a lot to do in these two domains. On the contrary, India is quickly moving away from the use of Fossil Fuels and is pushing for their replacement with decarbonized energy sources as also demonstrated by the progress made in the penetration of renewables.
Finally, although the trajectory is encouraging, there is still room for improvement in the Electrification composite, showing the need to improve the quality of electricity supply in terms of readiness, costs, reliability and transparency.

	G20 AVERAGE	COUNTRY
Energy Transition	58.7	52.7
Fossil Fuels	45.3	48.8
Renewables	19.7	25.1
Efficiency	84.9	65.0
Electrification	70.8	67.8
Emissions	72.9	56.7

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.