INDIA ENERGY AND CLIMATE REPORT

India Energy and Climate Report 2026

CO_2 Coalition

October 2026

Contents

Executive Summary

1. Development Context and Energy Access

1.1 Population and growth
1.2 Energy poverty and access

2. Energy Supply Overview

2.1 Total primary energy supply
2.2 Import dependence
2.3 Investment and credit flows

3. Fossil Fuels

3.1 Coal
3.2 Oil
3.3 Natural gas

4. Electricity

4.1 Generation and capacity
4.2 Peak demand and reliability
4.3 Outlook to 2035–36

5. Non-Fossil Sources

5.1 Nuclear power
5.2 Hydropower
5.3 Wind and solar

6. Weather and Climate: The Observational Record

6.1 Temperature
6.2 Monsoon rainfall
6.3 Rainfall benefits
6.4 El Niño and the monsoon
6.5 Tropical cyclones
6.6 Extreme weather and mortality
6.7 Himalayan glaciers
6.8 Sea-level rise
6.9 Wildfires
6.10 Climate models and policy

7. Agriculture and Food Security

7.1 Record harvests
7.2 Harvest details by crop and sector
7.3 Resilience in El Niño years
7.4 Carbon dioxide and greening
7.5 Fossil fuels and food

8. Forests, Wildlife, and Conservation

8.1 Forest and tree cover
8.2 Greening and the carbon sink
8.3 Wildlife recovery
8.4 Conservation successes

9. Policy Implications

9.1 International commitments
9.2 Recommendations

10. Conclusions

Annex: Abbreviations and Units

References

About the Author

Executive Summary

India is the world's most populous country and its fastest-growing major energy market. This report reviews the state of India's energy system and the observational record of its weather and climate, using the most recent statistics of the Government of India. The main source of information on energy is *Energy Statistics India 2026*, published by the Ministry of Statistics and Programme Implementation (MoSPI) in March 2026 and covering fiscal year (FY) 2024–25. These data are supplemented by releases from the Central Electricity Authority (CEA), the Central Electricity Regulatory Commission (CERC), the Ministries of Coal, Power, Petroleum and Natural Gas, and Agriculture and Farmers Welfare, and the India Meteorological Department (IMD).

Fossil fuels underpin the Indian economy. Coal, oil, and natural gas met about 96% of India's total primary energy supply (TPES) of 932,816 thousand tonnes of oil equivalent (ktoe) in FY2024–25. Coal alone accounted for 59%. Renewable sources, including large hydropower, contributed 3.8% [1].

Coal production has entered the billion-ton era. Output reached 1,047.5 million metric tons (Mt) in FY2024–25, 64% more than a decade earlier, and net imports fell 8%. Proved coal reserves of 220 billion metric tons are sufficient for roughly two centuries at current production rates [1].

Thermal generation provides the bulk of electricity and nearly all firm supply. Thermal plants, overwhelmingly coal-fired, held 52% of utility capacity but produced 74.5% of the 1,830 terawatt-hours (TWh) generated in FY2024–25. Wind, solar, and other renewables held 36% of capacity but produced 14% of generation [1; 2]. At the record peak demand of 270.8 gigawatts (GW) on May 21, 2026, coal units supplied 171.7 GW [3]. The government plans at least 97 GW of new coal- and lignite-fired capacity by 2034–35 [4].

Oil and gas import dependence is the main structural vulnerability. Crude oil import dependence reached a record 88.7% in FY2025–26 as domestic output declined to 28.0 Mt, and natural gas import dependence was 49.7% in FY2024–25 [1; 5]. In July 2026 the government approved the US$8.83 billion Samudra Manthan offshore exploration scheme to reverse this trend [6].

The observational climate record shows no crisis. India's annual mean temperature has risen at 0.68°C per century since 1901 [7]. All-India monsoon rainfall shows no statistically significant long-term trend [8], and 2025 rainfall was 110% of the long-period average. The annual frequency of tropical cyclones over the Bay of Bengal declined from 1951 to 2018 [9]. Cyclone deaths in Odisha fell from more than 10,000 in 1999 to

45 in 2013 as forecasting, warning, and evacuation improved [10]. In 2025, heat waves caused approximately 35 deaths nationwide [7].

Rainfall has been abundant and beneficial. Summer monsoon rainfall over northwest India has risen by about 40% compared with the weak-monsoon 1980s, and century-long records show rising rainfall in the Thar Desert districts of Rajasthan [54; 55; 56]. The Thar has become about 38% greener since 2001, with higher monsoon rainfall supporting an expansion of cropland [57].

Agricultural output is at an all-time high. India's food grain harvest set a record in each of the past ten years, reaching 376.6 Mt in 2025–26, 54% above 2010–11 [11; 12]. El Niño years have not interrupted the long-run trend: the 2023 El Niño monsoon produced a record crop, and the 2014–15 drought years reduced output by only about 5% before a record rebound.

The harvest record is broad-based. Rice, maize, groundnut, rapeseed-mustard, and sugarcane all reached record output in 2025–26 [58]. Horticultural output reached an estimated 377.8 Mt, milk 247.9 Mt, and fish about 19.8 Mt, and India supplies about 38% of world rice exports [59; 60; 61; 62].

India's forests and wildlife are expanding. Forest and tree cover was 827,357 square kilometers (km²), 25.17% of the country's area, in 2023, and India ranks third in the world for annual net gain in forest area [63; 64]. India's tiger population rose from 1,411 in 2006 to 3,682 in 2022, about three-quarters of the world's wild tigers, and Asiatic lions increased from 327 in 2001 to 891 in 2025 [65; 66; 67].

India's international climate commitments do not constrain fossil fuel use. India's Nationally Determined Contribution (NDC) for 2031–2035 sets intensity and capacity-share targets, contains no coal phase-out, and states that implementation depends on finance and technology from developed countries [13].

The evidence supports an energy strategy centered on secure, affordable, and dispatchable supply, with continued expansion of domestic coal, intensified oil and gas exploration, and growth in nuclear power. It does not support restrictions on fossil fuel use on the basis of climate risk.

Notes. Indian fiscal years (FY) run from April 1 to March 31. Unless otherwise stated, FY2024–25 energy data are provisional figures from *Energy Statistics India 2026*. Quantities are expressed in metric units; "tons" denotes metric tons. Numbers in square brackets refer to the numbered reference list at the end of the report.

1. Development Context and Energy Access

> **Key points India's** per-capita energy and electricity use remain low by international standards, despite rapid progress in increasing access to both. Universal village electrification was achieved in 2018, and more than 100 million low-income households have obtained connections to liquefied petroleum gas (LPG). Demand growth over the next two decades will be driven by rising incomes, urbanization, and cooling needs.

1.1 Population and growth

India's population is estimated at about 1.46 billion in 2025, the largest of any country [14]. The economy has sustained one of the highest growth rates among large economies, and energy demand has grown in step. India is the world's third-largest oil consumer, third-largest consumer of LPG, fourth-largest importer of liquefied natural gas (LNG), and fourth-largest refiner [1, p. 1].

1.2 Energy poverty and access

Energy consumption per person remains modest. Per-capita primary energy consumption was 18,096 megajoules (MJ) in FY2024–25, an increase of only 19% over ten years. Per-capita electricity consumption rose from 780 kilowatt-hours (kWh) in FY2015–16 to 1,153 kWh in FY2024–25, an increase of 48% [1, p. xii]. India's per-capita greenhouse gas emissions are approximately one-third of the world average [13].

Access has improved substantially. All 597,464 census villages were declared electrified in April 2018, with Leisang in Manipur the last to be connected [15]. Under the Saubhagya program and related plans, 28.6 million households were subsequently electrified [16]. According to the Ministry of Power, average rural power supply rose from 12.5 hours a day in FY2013–14 to 22.6 hours in FY2025–26, and urban supply reached 23.4 hours [17].

Clean cooking has advanced on the back of fossil fuels. Under the Pradhan Mantri Ujjwala Yojana program, 106 million low-income families had received subsidized LPG connections by November 2025. The natural gas pipeline network exceeded 25,000 kilometers, 15.6 million homes were connected to piped natural gas, and 8,340 compressed natural gas (CNG) stations were operating [18]. These gains replaced traditional use of dried dung and wood for cooking, with large benefits for indoor air quality and women's health.

The overall demand is broadening. Total final consumption reached 608,578 ktoe in FY2024–25, about 30% above FY2015–16. In FY2024–25, consumption grew fastest in the residential sector (8.0%), followed by commercial and public services (5.1%), transport (4.4%), and industry (2.7%). Energy use in agriculture and forestry rose at a compound annual rate of 4.1% over ten years [1, p. xii]. Overall energy intensity improved to 0.1329 MJ per rupee of GDP [1, pp. xii–xiii].

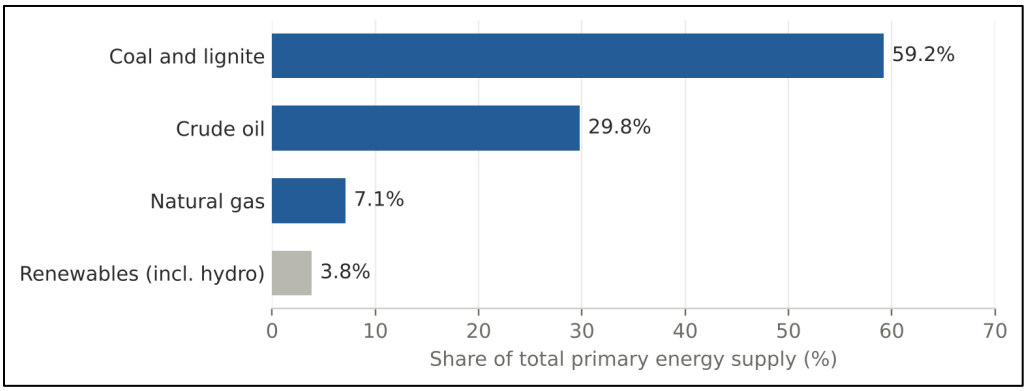
2. Energy Supply Overview

Key points Coal, crude oil, and natural gas supplied about 96% of India's primary energy in FY2024–25. Renewables, including large hydropower, supplied 3.8%. Import dependence is low for coal (23.5%) but high for natural gas (49.7%) and crude oil (89.4%).

2.1 Total primary energy supply

India's total primary energy supply (TPES) reached 932,816 ktoe in FY2024–25, up 2.95% from the previous year [19]. Coal, including lignite, accounted for 59.2%, crude oil for 29.8%, and natural gas for 7.1% [1, p. xi]. Coal accounted for nearly 79% of the energy supplied from domestic production [1, p. xi].

Figure 2.1 Total primary energy supply by source, FY2024–25



Note: Renewables include large hydropower. Shares follow MoSPI's accounting conventions. Source: [1].

Renewable energy supply grew from 16,281 ktoe in FY2015–16 to 35,847 ktoe in FY2024–25, a compound annual growth rate (CAGR) of 9.2%. Solar, wind, and other non-hydro renewables reached 23,032 ktoe, about 2.5% of TPES [1, pp. xi–xii].

2.2 Import dependence

In FY2024–25, India's import dependence was 89.4% for crude oil, 49.7% for natural gas, and 23.50% for coal [1, p. xiii]. Crude oil imports rose to 243.2 Mt from 234.2 Mt the year before; net natural gas imports increased 12.3% to 35.7 billion cubic meters (bcm); and net coal imports fell 8.1% to 241.7 Mt [1, p. xii]. Coal is the only major fuel for which India is largely self-sufficient.

2.3 Investment and credit flows

Commercial bank lending reflects the dominance of conventional energy. In March 2025, outstanding bank credit to petroleum, coal products, and nuclear fuel industries was US$16.18 billion, nearly double the 2021 level and about 15 times the US$1.085 billion lent to renewable energy. Outstanding credit to the power sector stood at US$71.76 billion [1, pp. 20–22].

3. Fossil Fuels

Key points Coal production exceeded 1,000 Mt for the first time in FY2024–25, and reserves are sufficient for roughly two centuries. Domestic oil and gas output is declining, raising import dependence. New offshore exploration programs and Andaman Sea gas discoveries offer the principal upside for domestic hydrocarbons.

3.1 Coal

Production. Coal production grew 5.0% to 1,047.5 Mt in FY2024–25, from 997.8 Mt the previous year, and was 408 Mt (64%) higher than in FY2015–16. Non-coking coal accounted for 93.7% of output [1, p. xi]. Coal India Limited remains the dominant producer, while captive and commercial mines allocated through auctions are growing quickly: they produced 210.5 Mt in FY2025–26, up 10.2% year on year, and twelve newly operational blocks added more than 86 Mt per year of capacity [20].

Reserves. Estimated coal resources stood at 400.7 billion metric tons on April 1, 2025, an increase of 11.3 billion metric tons in one year. Proved reserves were 220.4 billion metric tons, equivalent to about 210 years of FY2024–25 production. The neighboring states of Odisha (25.2%), Jharkhand (23.3%), and Chhattisgarh (21.3%) hold about 70% of the total. Lignite resources were 47.4 billion metric tons, 79% of them in Tamil Nadu [1, pp. xi, 7, 11].

Quality and processing. Indian coal generally has high ash content. Installed coal cleaning capacity doubled from 131 Mt per year in 2016 to 262 Mt per year in March 2025 [1, p. xi].

Imports. Net imports of 241.7 Mt in FY 2024–25 consisted largely of coking coal for steelmaking, which domestic deposits cannot fully supply, and thermal coal for coastal power plants designed for imported fuel [1, p. xii].

Power plant pipeline. The Ministry of Power reported in March 2026 that 39,545 MW of coal- and lignite-based capacity were under construction, 22,920 MW had been contracted, and 24,020 MW were in planning. The government projects a requirement of about 307 GW of thermal capacity by 2034–35 and plans at least 97 GW of additions [4]. Coal plants held 41.4 Mt of stock in mid-July 2026, about 13 days of consumption [17].

3.2 Oil

Production and reserves. Domestic crude oil production fell from 29.7 Mt in FY2021–22 to 28.0 Mt in FY2025–26 as mature fields declined. The government reports that the

decline rate from these fields has been held to about 2% a year, compared with a global average of 6% [5]. Estimated crude reserves were 672.1 Mt on April 1, 2025, about 24 years of current production. The Western Offshore region holds 31%, followed by Assam (21.5%), Rajasthan (20.3%), and Gujarat (18.0%) [1, pp. xi, 12].

Refining. India's 23 refineries had capacity of 258.1 Mt per year in March 2025 and processed 268.6 Mt of crude in FY2024–25, an average utilization of 104.6%. Public sector refineries account for more than 61% of capacity [1, pp. 15, 24]. India is a major exporter of refined products.

Imports. Crude import dependence rose from 85.5% in FY2021–22 to a record 88.7% in FY2025–26 [5]. With most imports sourced from the Middle East, India is exposed to disruptions in the Strait of Hormuz and to price shocks.

Exploration. On July 31, 2026, the Union Cabinet approved Samudra Manthan, the National Offshore Exploration Scheme, with an outlay of US$8.83 billion. It funds seismic surveys, 60 deepwater and ultra-deepwater exploration wells, and shared offshore infrastructure, with the aim of adding more than 600 million tons of oil equivalent of reserves [6]. Oil India Limited announced natural gas discoveries in the Andaman offshore basin in September 2025 and again in June 2026 at the Vijayapuram-3 well [21]. These are early-stage results; commercial volumes remain to be appraised.

3.3 Natural gas

Domestic gas production peaked at 35.7 bcm in FY2023–24 and fell to 34.3 bcm in FY2025–26 [5]. Estimated reserves declined 1.94% to 1,073.01 bcm, concentrated in the Western Offshore (32.5%) and Eastern Offshore (25.2%) [1, p. xi]. Net imports, mainly as LNG, rose to 35.72 bcm in FY2024–25, bringing import dependence close to 50% [1, p. xii].

Shale gas development is in its early stages and limited by water scarcity and complex geology. Oil India Limited announced natural gas discoveries in the Andaman offshore basin in September 2025 and again in June 2026 at the Vijayapuram-3 well [21]. These are early results; commercial volumes remain to be appraised.

Natural gas is a critical industrial feedstock. It is the principal input for nitrogen fertilizer production and therefore for India's food supply (Chapter 7). City gas distribution has expanded rapidly, as noted in Section 1.2.

4. Electricity

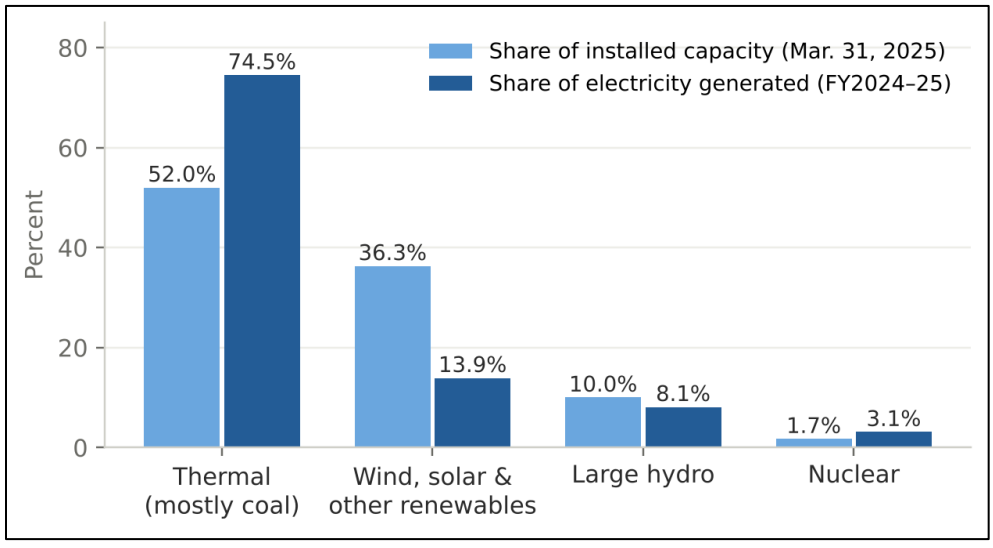
Key points Installed capacity overstates the contribution of variable renewables. In FY2024–25, thermal plants generated 74.5% of electricity from 52% of capacity, while wind, solar, and other renewables generated 13.9% from 36% of capacity. Coal remains decisive at times of peak demand, particularly after sunset.

4.1 Generation and capacity

Gross electricity generation rose from 747 TWh in FY2008–09 to 1,830 TWh in FY2024–25, a compound annual growth rate of about 5.8% [2]. In FY2024–25, thermal stations generated 1,363.9 TWh (74.5%), wind, solar, biomass, and small hydro 255.0 TWh (13.9%), large hydro 148.6 TWh (8.1%), and nuclear 56.7 TWh (3.1%) [2].

Utility installed capacity was 475.2 GW on March 31, 2025: thermal 246.9 GW (52.0%), renewables excluding large hydro 172.4 GW (36.3%), large hydro 47.7 GW (10.0%), and nuclear 8.2 GW (1.7%). Renewable capacity grew 20% during the year, while thermal capacity grew 1.5% [1, p. 25].

Figure 4.1 Share of utility capacity and share of generation by source



Note: Capacity as of March 31, 2025; generation for FY2024–25. Other renewables include biomass and small hydro. Sources: [1]; [2].

The difference reflects capacity factors. Coal plants can operate around the clock, while solar output is confined to daylight hours and wind output varies by season. The government reported in 2025 that non-fossil sources had reached 50% of installed capacity, five years ahead of the 2030 target [22]. Their share of generation remained far lower.

Transmission and distribution losses were 17.5% in FY2024–25, and net electricity available for supply grew 5.3% to 1,725 TWh [1, p. xi].

4.2 Peak demand and reliability

Peak demand reached 249.9 GW in FY2024–25 [2] and set an all-time high of 270.8 GW on May 21, 2026. Coal-fired units supplied 171.7 GW at the time of the peak, and the grid recorded shortfalls of 2.57 GW during non-solar hours that day [3]. The Ministry of Power informed Parliament that coal and lignite plants supplied 69.54% of electricity in April–June 2026 and about three-quarters of generation during non-solar peak hours. It also reported that the national energy shortage fell from 4.2% in FY2013–14 to zero in FY2025–26 [17].

4.3 Outlook to 2035–36

The Central Electricity Authority's Long-Term National Resource Adequacy Plan, released in April 2026, projects peak demand of 458.7 GW and energy requirement of 3,365 TWh by 2035–36, each roughly 1.8 times FY2024–25 levels. Meeting this demand would require 1,121 GW of installed capacity, including 174 GW and 888 GWh of battery and pumped storage [23]. The scale of storage required illustrates the cost of relying on variable sources. Dispatchable coal, nuclear, and hydro capacity will remain essential to system adequacy.

5. Non-Fossil Sources

Key points Nuclear power provides firm low-emission electricity and is set to expand under new legislation permitting private participation. Hydropower is constrained by monsoon variability and siting. Wind and solar capacity is growing rapidly but contributes far less to energy supply than to installed capacity.

5.1 Nuclear power

India's installed nuclear capacity was 8.78 GW in April 2026, and nuclear plants generated 56.7 TWh in FY2024–25. Capacity is projected to reach 22.4 GW by 2031–32, and the government has set a target of 100 GW by 2047. The Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India (SHANTI) Act, 2025 permits limited private participation under regulatory oversight. The Union Budget 2025–26 provided US$2.10 billion for a Nuclear Energy Mission focused on small modular reactors, with at least five indigenous units targeted by 2033. The 500 MW Prototype Fast Breeder Reactor at Kalpakkam achieved first criticality on April 6, 2026, marking the start of the second stage of India's three-stage thorium-oriented program [24].

5.2 Hydropower

Large hydro capacity was 47.7 GW in March 2025, about one-third of the estimated large hydro potential of 133.4 GW [1, pp. 9, 25]. Output varies with monsoon rainfall, and many projects face long gestation periods, geological risk, and land and rehabilitation constraints. The CEA has issued a roadmap for pumped storage capacity to support grid balancing [25].

5.3 Wind and solar

Grid-connected renewable capacity reached 172.4 GW in March 2025, of which solar accounted for 61% and wind 29% [1, p. 18]. By January 31, 2026, solar capacity was 140.6 GW and wind 54.7 GW [23]. The estimated technical potential is very large, at 3,343 GW for solar and 1,164 GW for wind [1, p. 13].

Variable output limits the system value of this capacity. Solar generation is unavailable during the evening peak, and wind output is concentrated in the monsoon months. As Section 4.2 shows, coal continued to supply around three-quarters of non-solar peak generation in 2026. The large storage requirement projected by the CEA, together with additional transmission, raises the full system cost of high renewable penetration.

6. Weather and Climate: The Observational Record

Key points India's long-term warming has been modest, at 0.68°C per century. Monsoon rainfall for the entire country shows no significant long-term trend. Tropical cyclone frequency over the Bay of Bengal has declined. Odisha state experiences the most cyclone landfalls by far, and cyclone deaths there fell by more than 99% between 1999 and 2013 as warning and evacuation improved. Heat waves caused about 35 deaths in 2025. There is no evidence in the observational record of a climate crisis in India. Rainfall has increased markedly over northwest India and the Thar Desert, greening arid land and expanding cropland, and winter cold stress in north India has eased. Sea level along India's coast has risen by about 1.3–1.7 mm a year over the long tide-gauge record, and the highest local rates reflect land subsidence. Forest fires are overwhelmingly human-caused; satellite fire detections have fallen from their 2020–21 peak, and the area burned in 2023–24 was less than 5% of forest cover.

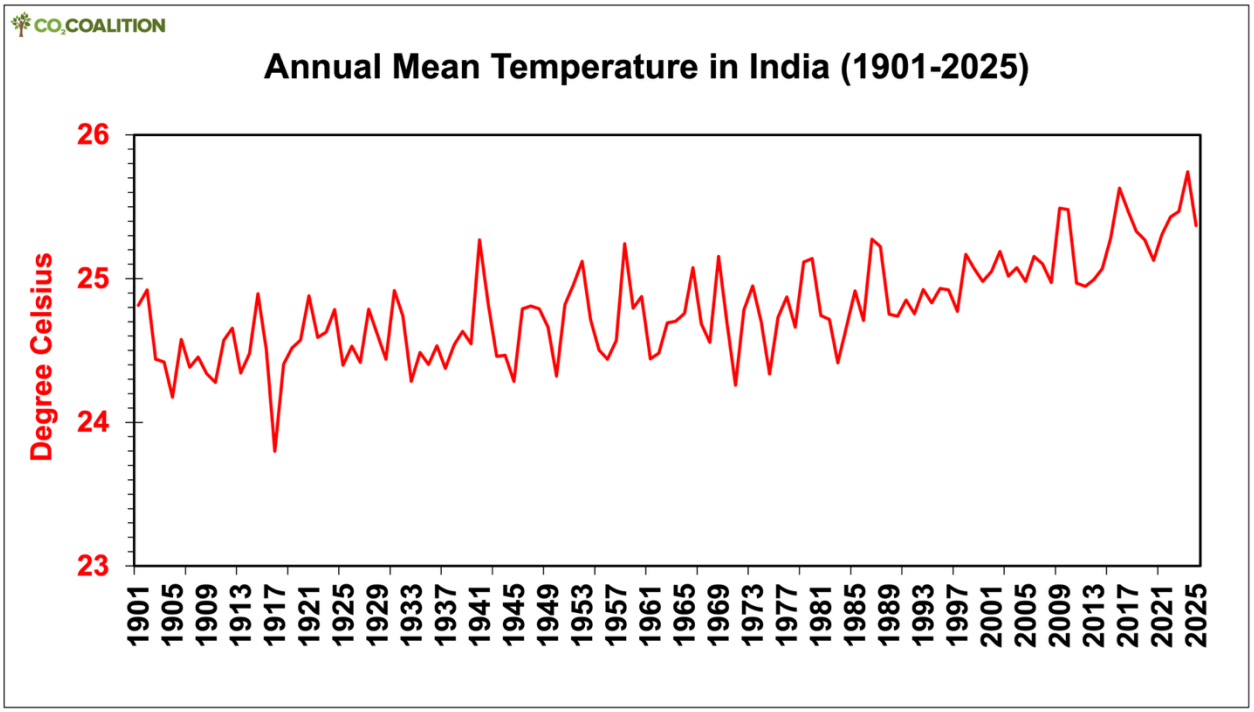
6.1 Temperature

The India Meteorological Department (IMD) reports that India's annual mean temperature has risen at a rate of 0.68°C per century since 1901 [7]. This is equivalent to less than 0.07°C per decade. The year 2024 was the warmest on record, at 0.65°C above the long-period average, while 2025 ranked eighth warmest, at 0.28°C above the 1991–2020 average [7; 26]. Since 1901, maximum and minimum temperatures also showed similar warming trends, increasing at rates of 0.89°C and 0.47°C per 100 years, respectively [95].

A substantial part of the warming recorded at urban stations has been linked to land-use change and the urban heat island effect, which is examined in detail later in this section.

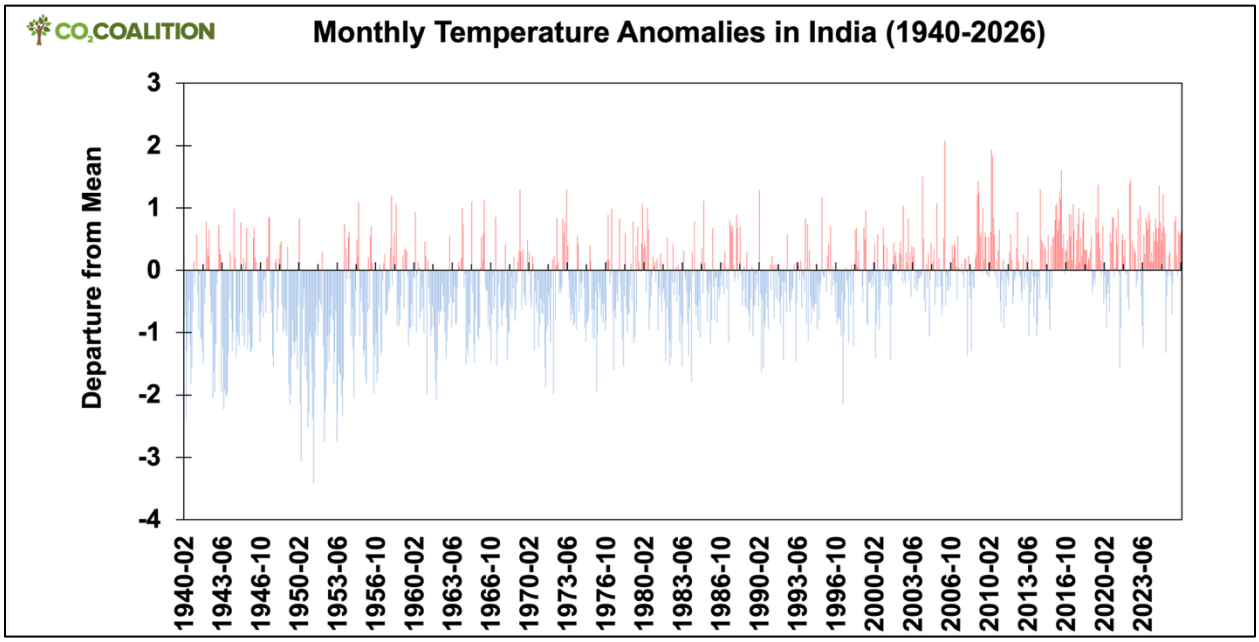
In 2025, the average seasonal mean temperature was above normal during the winter season (January–February), which experienced the highest anomaly on record since 1901 at +1.17°C. The anomaly was +0.29°C in the pre-monsoon season (March–May) and +0.09°C in the southwest monsoon season (June–September), while the post-monsoon season (October–December) was slightly below normal at −0.10°C [95]. Figure 6.1 shows the annual mean temperature series since 1901, and Figure 6.2 shows monthly temperature anomalies since 1940.

Figure 6.1 Annual mean temperature in India, 1901–2025



Note: All-India annual mean surface air temperature in degrees Celsius. Source: IMD, All India Time Series of Temperature [96].

Figure 6.2 Monthly temperature anomalies in India, 1940–2026



Note: Monthly temperature anomalies in degrees Celsius. Source: Ritchie, Rosado, and Samborska [97], using Copernicus Climate Change Service data.

Early assessments by Indian meteorologists found no systematic climate change over India during most of the 20th century. Thapliyal and Kulshrestha [27] concluded that,

apart from year-to-year fluctuations and epochal variations in rainfall and temperature, "there appears to be no systematic climate change or trend over India."

A significant part of the recent warming recorded at many stations reflects local land-use change rather than global greenhouse effects (Box 6.1). IMD notes that the recent rise is most pronounced in minimum (nighttime) temperatures, particularly in winter and the post-monsoon season [26], consistent with the urban heat island effect.

Box 6.1 Urban heat islands and India's temperature record

Most long-running meteorological stations are in or near towns that have grown rapidly. Concrete, asphalt, and loss of vegetation raise local temperatures, especially at night, and this warming can be difficult to separate from regional climate signals.

In the National Capital Region, an analysis of four stations found that annual mean maximum temperatures showed no specific trend, while annual mean minimum temperatures increased consistently, particularly after 1990, a pattern the authors linked to urbanization [28]. Satellite measurements of winter surface temperatures across Indian metropolitan areas found urban heat island intensities of 8.9–10.3°C in Mumbai, Nagpur, and Hyderabad, with hot spots expanding in built-up and barren land [29]. In Odisha, 25–50% of the warming observed between 1981 and 2010 was associated with land-use and land-cover change, rising to 40–50% in the cities of Bhubaneswar and Cuttack [30].

Station-based temperature trends should therefore be interpreted with care. Urban warming is a local planning challenge, not evidence of a national climate emergency.

Artificial influence on measurement instruments

A significant source of anthropogenic bias in temperature measurement is the urban heat island (UHI) effect. Over recent decades it has been consistently observed that temperatures recorded in urban environments tend to be higher than those in nearby rural or undeveloped areas. This disparity is primarily attributed to the thermal properties of construction materials, such as concrete and asphalt, used extensively in buildings, roads, and other urban infrastructure, which absorb and retain heat. The loss of vegetation and natural landscapes in cities further increases local warming by limiting evaporative cooling and increasing surface heat retention. According to the U.S. Environmental Protection Agency, "As urban areas develop, changes occur in their landscape. Buildings, roads, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and moist become impermeable and dry. These changes cause urban regions to become warmer than their rural surroundings, forming an 'island' of higher temperatures in the landscape" [122].

The UHI effect is a globally recognized and empirically verifiable phenomenon, evident in major cities worldwide, including those in India. During the European heat wave of June 2019, NASA's ECOSTRESS instrument found that early-morning surface

temperatures in Rome, Paris, Madrid, and Milan were still 25–30°C, indicating that "much of the heat from previous days was stored by surfaces with high heat capacity (such as asphalt, concrete and water bodies) and unable to dissipate before the next day. The trapped heat resulted in even higher midday temperatures" [123]. While the UHI effect is not the sole driver of temperature increases, it contributes substantially to regional warming. In eastern China, urbanization accounted for 36–68% of total regional summer warming in the Yangtze River Delta and 12–24% of winter warming in the Beijing–Tianjin–Hebei region over 1979–2008 [124]. In Hong Kong, an urban station ran on average 0.865°C warmer than a rural station over two decades, an artificial warming bias that inflates urban temperature trends [125]. Because accurate temperature data are essential to sound climate policy, such biases matter.

The India Meteorological Department (IMD) is the government agency responsible for weather observation and forecasting in India, and international bodies such as the World Meteorological Organization, the UNFCCC, and the IPCC rely on its records for India's temperature history. Many of IMD's long-running observatories, some with records exceeding a century, are in towns and cities that have grown rapidly, particularly since economic liberalization in 1991. Studies of major Indian cities consistently find UHI intensities of several degrees Celsius, far larger than the national warming of about 0.7°C per century [7]. In several major cities, a large part of the observed rise in land surface temperature (LST) is likely to reflect the UHI effect rather than regional or global climate change. The following examples cover cities in the north, south, east, west, and centre of India.

Delhi and the National Capital Region (north India). A field campaign in Delhi in May 2008 found that the heat island was strongest in densely built-up and commercial areas, with intensities of up to 8.3°C in both afternoon and night hours [126]. Analysis of station records showed that night-time temperatures in urban areas rose markedly with changing land-use patterns [28]. Satellite data for 2000–2014 showed that the intensity of Delhi's heat island varies from 3°C to 8°C and is highest in summer compared with the monsoon and winter seasons [127]. The National Capital Region adjoining Delhi includes the fast-growing cities of Noida and Gurugram. A study of Noida combining Landsat thermal data, field data, and meteorological observations found that built-up area grew from 28.2 km² in 2000 to 88.4 km² in 2013, and that temperature was positively correlated with built-up area and negatively with vegetation, with the temperature change mainly due to the spread of impervious surfaces [128]. In 2026, the Centre for Science and Environment reported that 75.8% of Delhi was persistently heat-stressed in summer and that the dense core cools 3.8°C less at night than peri-urban areas [138].

Mumbai (west India). A comparative satellite study found Mumbai's heat island to be stronger than Delhi's, reflecting its lower green cover and denser high-rise development, and found a strong negative correlation between vegetation and surface temperature [129].

Lucknow (north-central India). Spatio-temporal analysis of LST in Lucknow between 2002 and 2014 found the highest surface temperatures in the central part of the city, with densely built-up areas warmer than open land and vegetated areas and water bodies cooler [130]. A 2025 study found that built-up area in Lucknow rose from 10.9% to 25.5% of the city between 2001 and 2021 as vegetation fell from 71.6% to 45.3%, and that mean LST rose from 25.3°C to 29.8°C [141]. Surface heat islands were also observed in five cities of neighbouring Bihar (Bhagalpur, Gaya, Patna, Purnea, and Muzaffarpur), where the intensity showed a significant increasing trend over 2001–2014 [131].

Bengaluru (south India). Bengaluru is a prime example of the UHI effect in south India. TERI found in 2014 that dense urban pockets were about 2°C warmer than nearby rural areas [132], and earlier field measurements found mean air temperatures in the city centre 0.8–2°C higher than on the outskirts [133]. The Energy and Wetlands Research Group at the Indian Institute of Science found that urban area in Greater Bangalore grew by 632% between 1973 and 2009, while vegetation cover declined by 76% and water bodies by 79%, and that the resulting heat island contributed to an increase of about 2–2.5°C in local temperatures over the preceding decade [134]. A 2025 study reported that built-up area rose from 8% of the city in 1973 to 93% in 2023, that LST rose by 7.9°C between 1992 and 2017, and that average air temperature has risen by 0.23°C per decade since 1975 [139].

Chennai (south India). Chennai also shows a pronounced heat island whose strength varies by season and time of day. Measurements at 30 fixed sites found a positive night-time heat island of 3.6°C in summer and 4.1°C in winter in the early-morning hours, while the urban core was cooler than its rural surroundings in the afternoon [135]. A 2024 study of the Chennai Metropolitan Area for 2013–2022 found a strong negative association between vegetation and LST, with weak heat islands only where green cover remains [140].

Ahmedabad and Jaipur (west India). A strong surface heat island has been documented at night over both cities, while daytime heat islands were weak or even reversed; the authors attribute the pattern to differences in how built-up surfaces and the surrounding soil and vegetation heat and cool [136]. A 2024 analysis of 141 Indian cities placed Ahmedabad and Jaipur among the cities with the largest urbanization-driven warming [137].

Odisha and Hyderabad (east and south-central India). A study combining ground observations, remote sensing, and reanalysis products for Odisha over 1981–2010 found that 25–50% of the observed warming in the state was associated with land-use change, as green spaces gave way to buildings [30]. A 2024 modelling study of heat waves in Bhubaneswar and Hyderabad found that urbanization raised air and surface temperatures by about 4–6°C, mainly at night [142].

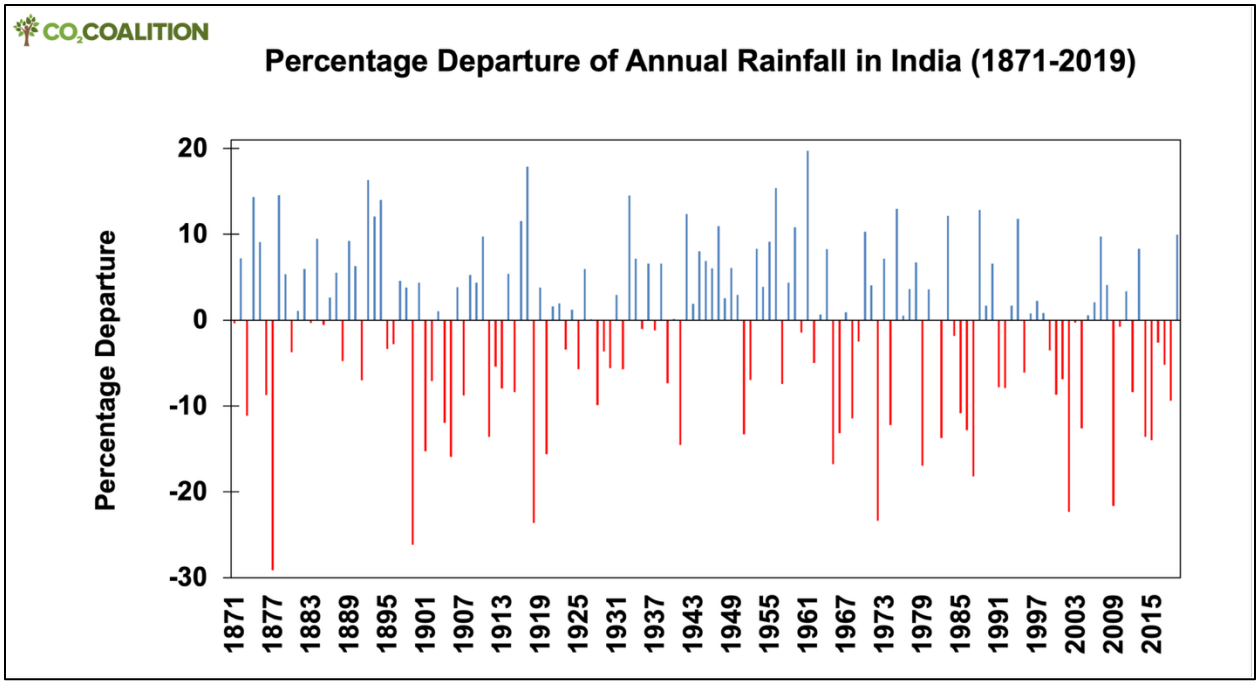
Pan-Indian studies. Satellite analyses at the national level confirm the presence of multiple heat islands in every major city and their growth over time. Winter heat island intensities were highest in Mumbai, Nagpur, and Hyderabad (8.9–10.3°C), and hot spots were expanding in both built-up areas and land that had lost vegetation [29]. The most comprehensive recent study, covering 141 cities over 2003–2020, found that urbanization alone accounted for about 38% of the night-time warming observed in Indian cities, equivalent to a 60% enhancement of warming relative to surrounding non-urban areas, with the urban contribution highest in the developing cities of eastern and central India [137].

The abundant evidence of urban heat islands in Indian cities, which have developed rapidly in recent decades, needs further study to establish how much of the warming recorded in India's long-term temperature series reflects local urbanization rather than regional or global climate change.

6.2 Monsoon rainfall

The southwest monsoon (June–September) delivers most of India's annual rainfall. MoSPI's statistical compendium states that "all India summer monsoon season (June to September) rainfall as well as the all India rainfall for all the four monsoon months does not show any significant trend," despite theories that warming would increase Asian rainfall [8].

India’s area-weighted mean summer monsoon rainfall (AISMR), based on a homogeneous rainfall data set of 306 rain gauges in India, developed by the Indian Institute of Tropical Meteorology, is widely considered as a reliable index of summer monsoon activity over the Indian region.



India Summer Monsoon Rainfall (1871-2019). Source: (IITM, 2024)

Monsoon variability is dominated by multidecadal epochs. For example, the 44 years from 1921 to 1964 included only three drought years, whereas 1965–1987 included 10 drought years in 23. The strength of the link between the monsoon and the El Niño–Southern Oscillation (ENSO) has itself varied over time [31]. After a weak phase in the late twentieth century, summer monsoon rainfall over India has strengthened since 2002 [32].

Recent years confirm abundant rainfall. In 2025, monsoon rainfall and annual rainfall were 108% and 110%, respectively, of the long-period average [7]. The 2026 monsoon was below normal at 87% of the long-period average, coinciding with a strong El Niño [33], which is consistent with the historical pattern of ENSO-driven variability.

IMD's annual report gives further detail on 2025. The annual rainfall over the country was 110% of the long-period average (LPA) for 1971–2020, and rainfall during the southwest monsoon season was 108% of its LPA. Among the four homogeneous regions of the country, South Peninsular India, Central India, and Northwest India received above-normal rainfall (110%, 115%, and 127% of LPA, respectively), while East and Northeast India received below-normal rainfall (80% of LPA). During the season, out of 36 meteorological subdivisions, 2 received large excess rainfall, 12

received excess rainfall, 19 received normal rainfall, and the remaining 3 received deficient rainfall [95].

6.3 Rainfall benefits

While all-India monsoon rainfall shows no significant long-term trend, its regional distribution has shifted in ways that have benefited some of the country's driest areas. A study of 1979–2022 found that summer monsoon rainfall over northwest India has increased by about 40% compared with the 1980s [54]. That baseline falls in the weak-monsoon phase of the late twentieth century described in Section 6.2, so part of the increase represents a recovery from an unusually dry epoch rather than a departure from the long-term record. The authors link the increase to an expansion of the Hadley circulation and warming of the Indian Ocean, which strengthened the moisture-bearing winds reaching the northwest [54]. Whatever the balance of natural variability and warming behind it, the observed outcome has been a wetter northwest, which is a benefit rather than a hazard for an arid region. A review of reanalysis data for 1959–2021 found a significant increase in atmospheric moisture during the monsoon season over most of India in 2002–2021, together with a higher share of steady, stratiform rainfall [68].

Rainfall has also become less erratic in parts of central India. Over 2005–2020, extreme daily rainfall events over central India became less frequent, while low and moderate rain events increased. The authors link the change mainly to natural drivers, including the Atlantic Zonal Mode, rather than to warming [69]. Moderate, well-distributed rain is generally more useful to farmers than intense downpours, which run off quickly.

Box 6.2 A wetter Thar Desert

Rajasthan, India's driest state, has become wetter. In Jaisalmer district, in the heart of the Thar Desert, 121 years of rainfall data show an upward trend in annual rainfall across all 16 grid cells studied, with a marked increase after 1992 [55]. In Churu district of northeast Rajasthan, precipitation over 1901–2022 shows a rising trend that, the authors note, can help to mitigate the severity of drought [56].

Satellite records show the result. Greenness across the Thar Desert rose by 38% between 2001 and 2023. Increased precipitation accounted for about 45% of the greening and groundwater-fed irrigation for about 55%; during the summer monsoon season, precipitation accounted for about two-thirds [57]. A separate study of 2001–2020 found that surface greenness rose by 28.4%, vegetation productivity by 22.9%, and cropland area by 23.5%, and attributed 60.7% of the greening to climatic factors, chiefly higher rainfall and soil moisture associated with a westward extension of the monsoon [70].

Both studies note pressures on groundwater, traditional pastoralism, or native biodiversity, but the second concludes that the greening could improve socio-economic conditions and food security in the region [70]. The two parts of the greening should be distinguished. The rainfall-driven part is a clear benefit of the observed climate. The irrigation-driven part depends on drawing down aquifers that

rainfall does not fully replace: satellite gravity measurements showed groundwater beneath Rajasthan, Punjab, and Haryana declining by about 17.7 km³ a year over 2002–2008, a net loss of 109 km³ [143], and in 2025 Rajasthan extracted 147% of its annual extractable groundwater, Punjab 156%, and Haryana 137% [72]. More rain over arid land is a benefit, not a symptom of crisis; sustaining the irrigated share of the gains will require better groundwater management.

Rainfall is also the largest single source of groundwater recharge, supplying about 61% of the annual total [71]. India's 2025 groundwater assessment put annual recharge at 448.5 billion cubic meters (bcm) and extraction at 247.2 bcm, a stage of extraction of 60.6%. Of the 6,762 assessment units, 73.1% were classified as safe and 10.8% as over-exploited [72]. Between 2017 and 2024, recharge increased by about 15 bcm while extraction fell by 3 bcm, and the share of over-exploited units fell from 17.2% to 11.1%. The government credits much of this improvement to tanks, ponds, and other water-conservation structures that capture monsoon runoff [73].

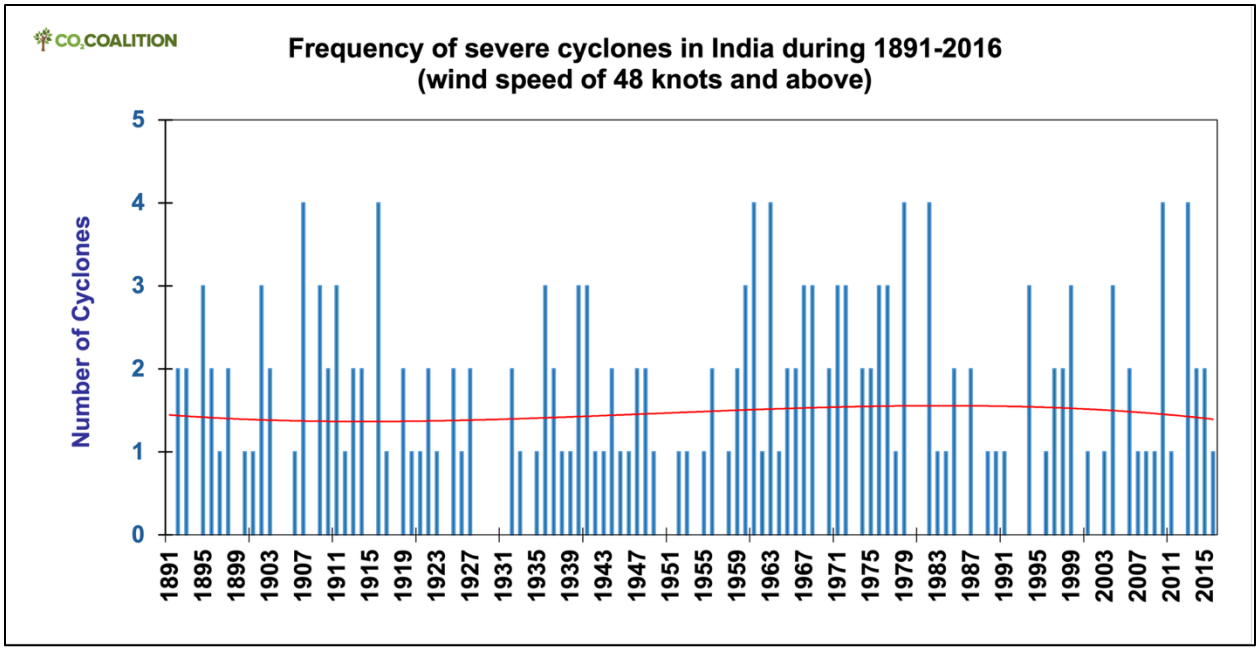
Rainfall gains translate into crop output. In Tamil Nadu, rainfall exceeded 500 mm in every year from 1990 to 2023, and the production of most major crops was strongly associated with rainfall and yield, with coefficients of determination (R^2) of 0.7–0.96 [74]. Chapter 7 shows that national harvests have reached record levels.

6.4 El Niño and the monsoon

El Niño events, in which the eastern tropical Pacific warms, tend to weaken the Indian monsoon. In 2023, weak El Niño conditions developed in July and became moderate in August and September, and monsoon rainfall was 94% of the long-period average. A positive Indian Ocean Dipole offset part of the El Niño effect [34]. In 2026, a weak El Niño developed in June and became strong by the end of the season [33]. These events are part of natural climate variability with a long historical record. Their consequences for agriculture are examined in Chapter 7.

6.5 Tropical cyclones

The Ministry of Earth Sciences' assessment of climate change over India found that the annual frequency of tropical cyclones over the North Indian Ocean declined by 0.23 per decade between 1951 and 2018, and by 0.26 per decade over the Bay of Bengal. The same assessment reports an increase in very severe cyclonic storms in the post-monsoon season over 2000–2018, a short period relative to natural multidecadal variability [9]. In 2025, four cyclonic storms formed over the North Indian Ocean; cyclones Montha and Ditwah caused nine and two deaths in India, respectively [7].



Frequency of severe cyclones (maximum wind speed of 48 knots and above) over the Bay of Bengal (BOB), Arabian Sea (AS) and land surface of India during 1891-2016

The human toll of cyclones has fallen dramatically, and the main reason is adaptation. The 1999 Odisha super cyclone killed more than 10,000 people. Cyclone Phailin, a very severe cyclone that struck the same coast in 2013, killed 45 people after the evacuation of 1.2 million residents [10]. Cyclone Fani killed 64 people in Odisha in May 2019 [35]. The storms have not disappeared; Odisha has become far better prepared for them. Improved forecasting, early warning, cyclone shelters, evacuation planning, and sturdier housing, all made possible by economic development, account for the reduction in deaths. A hazard that once killed thousands now typically kills dozens. That record shows a manageable and increasingly well-managed hazard, which is difficult to reconcile with claims that cyclones represent a growing crisis for India.

6.6 Extreme weather and mortality

IMD attributed approximately 2,760 deaths in 2025 to extreme weather. Lightning and thunderstorms caused more than 1,310 deaths and floods, heavy rain, and landslides more than 1,370, while heat waves caused approximately 35 deaths [7]. In a country of 1.46 billion people, these figures correspond to about two deaths per million inhabitants per year. However, some estimate that these figures are not accurate. For instance, the EM-DAT 2024 report, published by the Centre for Research on the Epidemiology of

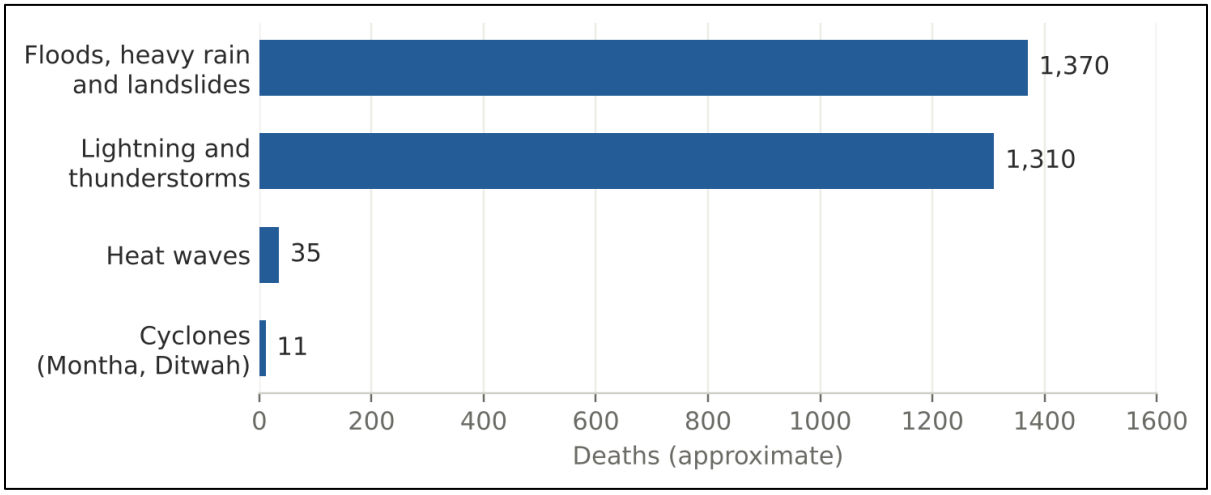
Disasters (CRED), reports that India recorded 733 heatwave deaths in 2024. Some papers, like "*Impact of heatwaves on all-cause mortality in India: A comprehensive multi-city study"* from 2024, claim India is undercounting deaths. But there has been no revision of the figures by the IMD. NCRB's Accidental Deaths & Suicides in India 2024 report goes even further to claim that heat wave deaths are higher than those of cold weather deaths. So, there is a discrepancy in the values, but no amendments have been made to the official data from the Indian government.

India's temperature-related mortality debate often focuses almost exclusively on heatwaves. Yet epidemiological research presents a more complicated picture. A nationally representative study published in *PLOS Medicine* in 2018, examining mortality data from 2001 to 2013, found that moderately cold temperatures accounted for a substantially greater share of attributable deaths than extremely hot temperatures.

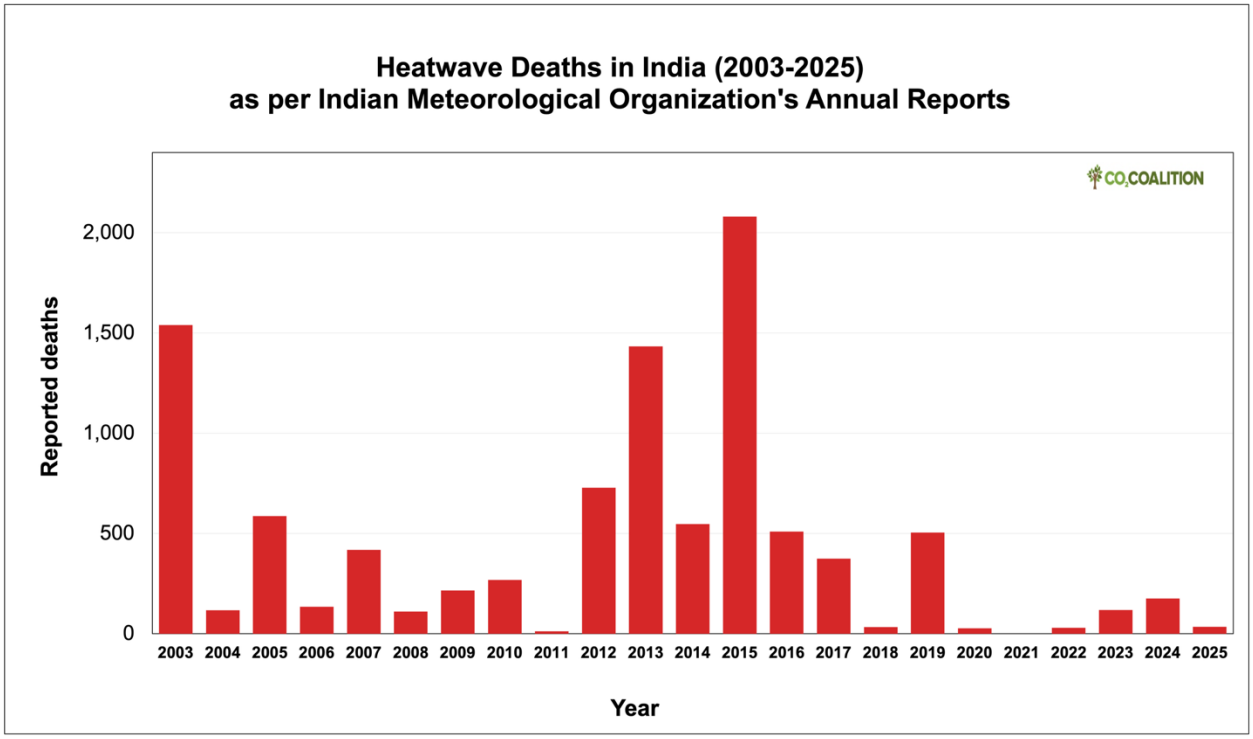
The researchers estimated that moderately cold temperatures accounted for 6.3% of all medical deaths, compared with 0.5% attributable to hot temperatures. Their modelling further estimated 584,000 medical deaths across all age groups attributable to moderately cold temperatures in 2015. Among people aged 30–69, 197,000 deaths from stroke, ischemic heart disease and respiratory diseases were attributed to moderate cold exposure. This was approximately 42 times the estimate associated with extremely hot temperatures. A separate 2015 study published in *The Lancet*, covering multiple countries, also found that cold temperatures accounted for a much larger proportion of temperature-attributable mortality than heat.

A study of official accidental death statistics for 2001–2014 found that deaths from extreme precipitation and tropical cyclones declined over the period, while lightning was the single largest cause of weather-related deaths. Deaths from lightning and temperature extremes rose over the period, reflecting exposure and limited adaptation rather than changes in the hazards themselves [36]. Lightning deaths are largely preventable through public warnings and basic protective measures.

Figure 6.3 Deaths from extreme weather events in India by cause, 2025, according to IMD



Note: Approximate values as reported by IMD. Source: [7].



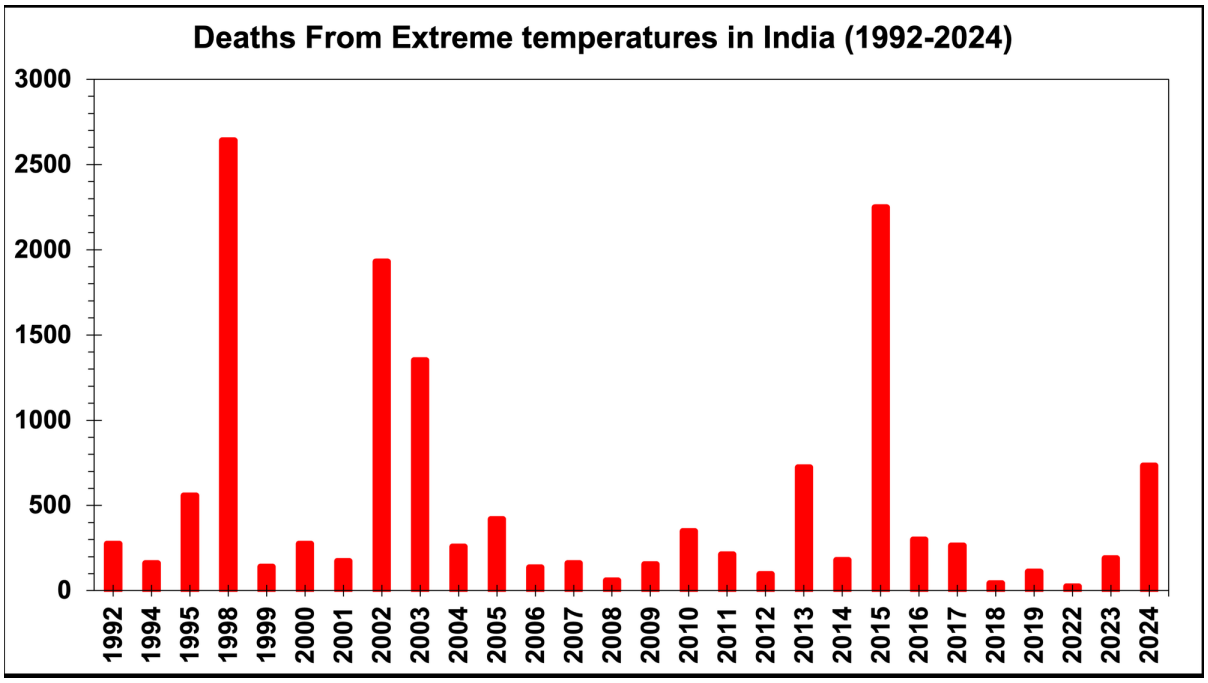
A global study of 2000–2019 attributed 8.52% of all deaths to cold and 0.91% to heat [37]. Worldwide, death rates from natural disasters have fallen by more than 90% over the past century, as societies have become more resilient [38].

These findings expose a weakness in public discussions that treat heat as the sole temperature-related mortality concern. Public-health planning must account for both ends of the temperature distribution, including the substantial burden associated with

moderately cold conditions. The evidence also reinforces the need to distinguish direct heatstroke fatalities from statistical estimates of temperature-attributable mortality.

Recorded deaths from extreme temperatures in India show no upward trend (Figure 6.4). In the EM-DAT international disaster database, the highest annual totals were in 1998 (about 2,650), 2002 (1,930), and 2015 (2,248). Between 2016 and 2023, recorded deaths ranged from 25 to 300 in years with reported events, before rising to 733 in 2024 [98].

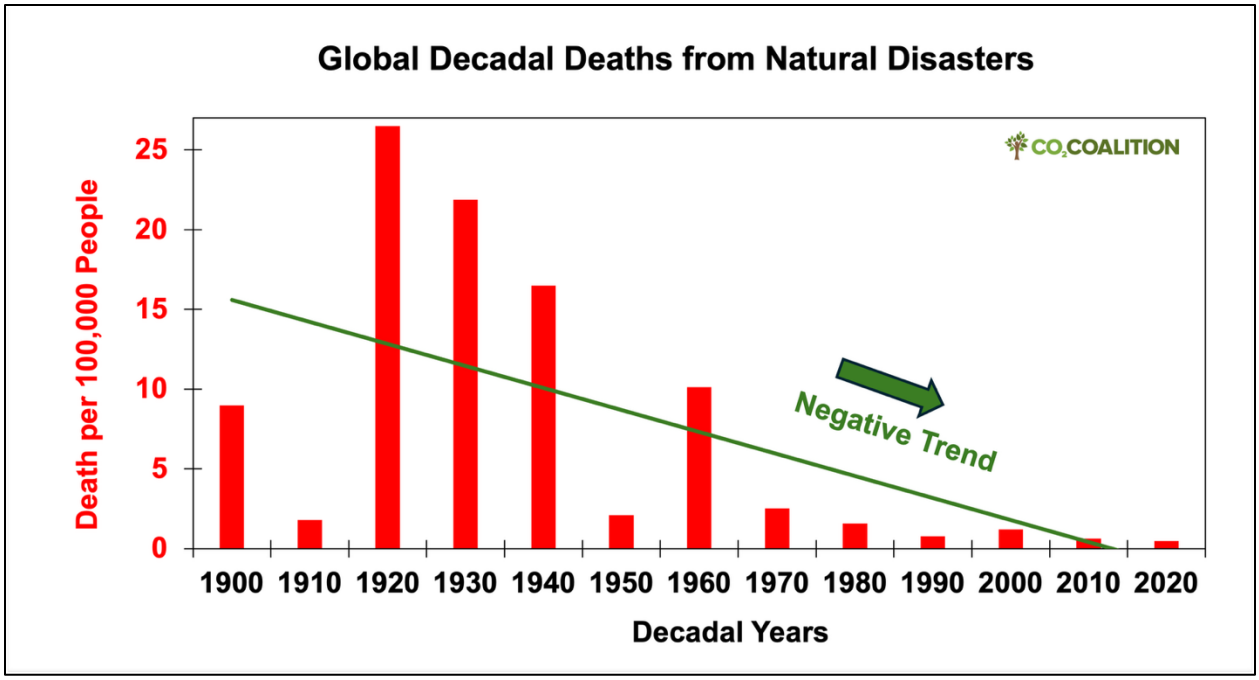
Figure 6.4 Deaths from extreme temperatures in India, 1992–2024



Note: Years with no recorded deaths in EM-DAT are not shown. Source: Ritchie, Rosado, and Roser [98], using EM-DAT data.

Deaths from Natural Disasters are Declining

Globally, deaths from natural disasters have fallen sharply since the 1960s, even as population has grown, thanks to better warning systems, stronger buildings and infrastructure, and other forms of adaptation. Whatever trends exist in individual hazards, people today are far less likely to die from extreme weather than earlier generations were. The record does not support the claim that a warming-driven disaster crisis is under way.

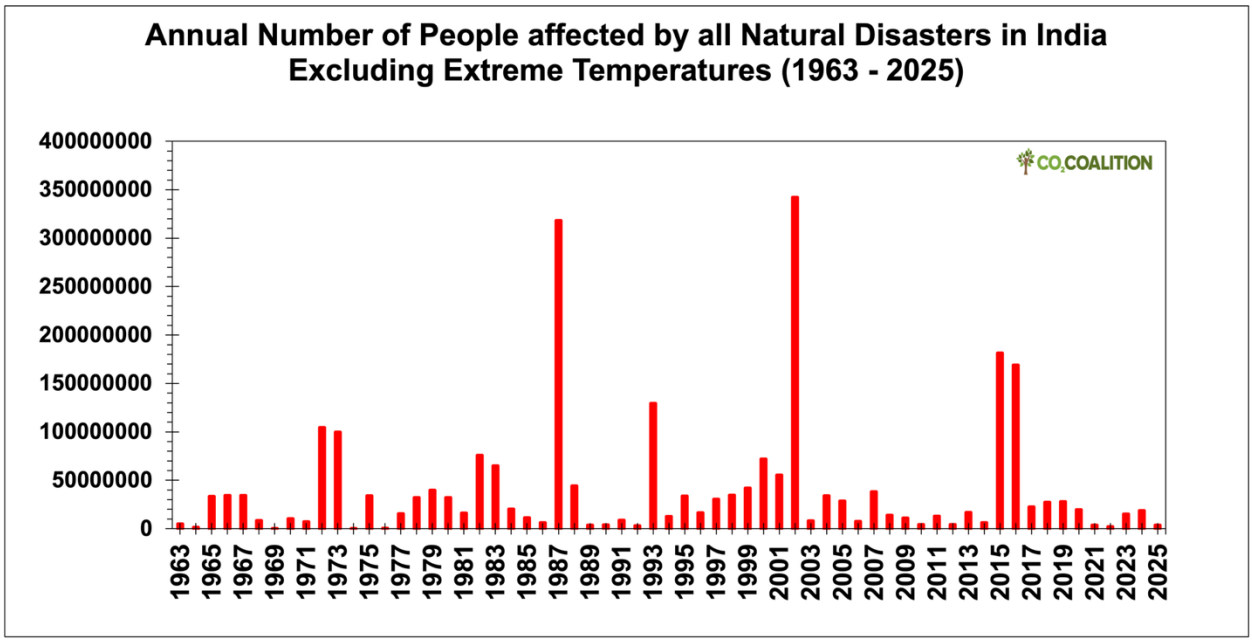


Note: Decadal averages of global annual deaths from all natural disasters per 100,000 people; the 2020s cover 2020–2025 only.
Source: Ritchie, Rosado, and Roser [99], using EM-DAT data.

In India, floods and cyclones have been the major cause of deaths from natural disasters. However, as illustrated in the section on climate, frequency of severe cyclones has remained at average levels. Flood damage, meanwhile, has been predominantly from poor urban planning and destruction of natural water reservoirs in urban centers.

The number of people affected by natural disasters in India has also fallen. Excluding extreme temperatures, the largest annual totals in the EM-DAT record were in the drought years of 1987 and 2002, when more than 300 million people were affected, and in the drought years of 2015 and 2016. Since 2017, the annual total has not exceeded about 28 million, and in 2025 it was about 3.8 million, even as India's population has grown (Figure 6.5) [100].

Figure 6.5 People affected by natural disasters in India, excluding extreme temperatures, 1963–2025



Note: Annual number of people affected, as defined by EM-DAT. Source: Ritchie, Rosado, and Roser [100], using EM-DAT data.

6.7 Himalayan glaciers

Himalayan glaciers feed the rivers of northern India. Early alarm about them was overstated. In January 2010, the Intergovernmental Panel on Climate Change (IPCC) acknowledged that its 2007 claim that Himalayan glaciers could disappear by 2035 "refers to poorly substantiated estimates" and that its evidence standards "were not applied properly" [40]. A 2009 review for the Ministry of Environment and Forests, drawing on Geological Survey of India glacier records, concluded that "it is premature to make a statement that glaciers in the Himalayas are retreating abnormally because of the global warming" [39].

The satellite record since then gives a fuller picture, and it shows that glaciers in the region are losing mass. The most complete assessment of the world's glaciers found that they lost 267 ± 16 gigatonnes (Gt) of ice a year over 2000–2019, with the loss accelerating by 48 ± 16 Gt a year per decade [144]. A 2025 international intercomparison put global glacier loss at 273 ± 16 Gt a year over 2000–2023, about 5% of global glacier ice, with the annual rate 36% higher in 2012–2023 than in 2000–2011 [145]. The Karakoram, where glaciers showed a slight mass gain of +0.11 meters water equivalent (m w.e.) a year over 1999–2008 [41], is no longer an exception. The 2021 global assessment reported the apparent end of the "Karakoram anomaly" [144], and

the International Centre for Integrated Mountain Development (ICIMOD) found a slight loss of −0.09 ± 0.04 m w.e. a year in the Karakoram over 2010–2019, while mass loss across the Hindu Kush Himalaya as a whole was 65% faster in the 2010s than in the 2000s [146].

These losses need to be seen against the region's climate history. Tree-ring records from the Karakoram and Tien Shan indicate that the warmest decades since AD 618 occurred between AD 800 and 1000, and that twentieth-century growing conditions, though above the long-term average, did not approach the peak around AD 1000 [147]. A millennium-long carbon-isotope record from the Karakoram likewise found 1990s temperatures substantially below those of the Medieval Warm Period, although the authors caution that this result depends on the correction applied to the record [148]. A synthesis of quantitative temperature records from the Tibetan Plateau found the plateau warm during 600–1400 CE, with medieval temperatures that reached or exceeded those of the twentieth century in the plateau-wide composite [149]. Evidence for a Roman-era warm phase in the region is thinner: one summer-temperature composite shows a warm interval at 0–185 CE, about 0.22°C above the 2,000-year average, but most records indicate a relatively cool first half of the first millennium [149]. Karakoram glaciers then advanced during the Little Ice Age, and much of the retreat observed between about 1910 and the 1960s removed ice stored during that cold period [150].

Glacier change in the region is therefore real and, since 2000, predominantly negative. It is also gradual, follows the end of the Little Ice Age, and occurs within a long history of large natural fluctuations, including medieval warmth comparable to or greater than today's in regional proxy records. It does not indicate an imminent threat to India's water supply.

6.8 Sea-level rise

Tide gauges provide India's best and longest direct record of sea level. The Ministry of Earth Sciences' national climate assessment estimates that sea level in the north Indian Ocean rose by about 1.06–1.75 mm a year between 1874 and 2004, while satellite altimetry indicates about 3.3 mm a year over 1993–2015, close to the global rate [102]. The assessment also cautions that only two tide gauges in the Indian Ocean, at Mumbai and Fremantle, extend back to the nineteenth century, and that multidecadal oscillations mean 50–60 years of data are needed to establish a robust long-term trend. Satellite altimetry, available only since the early 1990s, is too short on its own for that purpose [102].

The government's replies to Parliament have consistently put the long-term rise along the Indian coast at well under 2 mm a year. A 2013 reply cited Indian estimates of about 1.3 mm a year over the previous 40–50 years [103], and a 2020 reply, based on INCOIS analysis of tide-gauge records at ten ports, gave an average of about 1.7 mm a year (Table 6.1) [104]. At these rates, sea level rises by roughly 13–17 centimeters a century.

Table 6.1 Long-term sea-level trends at Indian tide gauges

Station	Rate (mm a year)	Period
Chennai	0.33	1916–2005
Mumbai	0.74	1878–2005
Visakhapatnam	0.97	1937–1988
Paradeep	1.03	1966–2005
Kochi	1.30	1939–2005
Okha	1.50	1964–1991
Port Blair	2.20	1916–1964
Haldia	2.89	1972–2005
Kandla	3.18	1950–2005
Diamond Harbour	5.16	1948–2005

Note: Relative sea-level trends, which include vertical movement of the land at each gauge. Stations are ordered by rate. Source: [104].

The stations with the highest rates are in areas where the land is sinking. Because no long-term data on land subsidence or emergence were available, the 2020 reply notes, the measured trends combine land movement with changes in the ocean itself. It attributes the high rate at Diamond Harbour, on the Hooghly estuary south of Kolkata, to larger land subsidence and suggests that the same may apply to Kandla, Haldia, and Port Blair [104]. By contrast, the long records at Chennai and Mumbai show some of the lowest rates on the coast, at 0.33 and 0.74 mm a year.

Satellite altimetry measures the height of the sea surface itself rather than the level of the sea against the land, and it shows higher trends for the shorter period 1993–2020: 4.59 ± 0.19 mm a year off Mumbai, 4.30 ± 0.17 mm off Mormugao, 4.10 ± 0.16 mm off Kochi, 4.31 ± 0.26 mm off Chennai, 4.27 ± 0.33 mm off Visakhapatnam, and 4.43 ± 0.36 mm off Paradip [105]. The highest of these amounts to less than 5 centimeters a decade. Because tide-gauge and satellite trends cover different periods and measure different quantities, they cannot be compared directly, and the national assessment's caution about short records applies to the satellite figures [102].

In India's largest coastal cities, the movement of the land matters as much as the movement of the sea. A satellite radar study of 2015–2023 found that parts of all five of

India's largest cities are subsiding, mainly because of groundwater extraction. Average subsidence was 0.8 ± 1.2 mm a year in Mumbai and 2.2 ± 1.8 mm a year in Kolkata, but local hotspots reached 26.1 mm a year in Mumbai and 16.4 mm a year in Kolkata [106]. In those hotspots, the ground is falling several times faster than the sea is rising. The remedy, regulating groundwater pumping, lies with local authorities rather than with global emissions policy.

Mumbai has managed its relationship with the sea through engineering for more than two centuries. The modern city was formed by joining seven islands through successive reclamations, which the district administration records as completed in 1845 [107]. Later schemes reclaimed land along Back Bay for Marine Drive in the early 20th century and, after Independence, for Nariman Point and Cuffe Parade [108]. Much of the city's low-lying land is therefore man-made, and waterlogging during monsoon downpours that coincide with high tides reflects drainage capacity and land-use decisions as well as sea level.

Kolkata and the Sundarbans lie on the soft, compacting sediments of the Ganges–Brahmaputra delta. The Ministry of Earth Sciences has told Parliament that river mouths along the coast are subject to deltaic subsidence and that it "has not been established" that coastal erosion is caused only by sea-level rise [103].

Shoreline records describe a coast in dynamic balance rather than in retreat. The National Centre for Coastal Research found that between 1990 and 2018, 33.6% of the Indian coastline was eroding, 26.9% was accreting, and 39.6% was stable [109]. Erosion on some stretches and accretion on others reflect sediment supply, waves, currents, and coastal structures as well as changes in sea level.

Projections of future sea level depend on emissions scenarios and model assumptions. INCOIS's 2025 interim report projects relative mean sea-level rise by 2100, compared with 1995–2014, of 0.40 m at Visakhapatnam to 0.63 m at Bhavnagar under the intermediate SSP2-4.5 scenario, and of 0.62 m to 0.87 m under the high-emission SSP5-8.5 scenario (Table 6.2) [110]. The report notes that its projections rely on coarse global models, that the lack of coastal land-motion observations adds uncertainty, and that its vulnerability maps show land at or below projected extreme sea levels rather than predicted flooding [110].

Table 6.2 Projected relative mean sea-level rise by 2100 at selected locations

Location	SSP2-4.5 (cm)	SSP5-8.5 (cm)
Visakhapatnam	40.1	62.7
Chennai	42.2	66.0
Mumbai	42.4	66.6
Paradip	43.8	66.1
Kochi	52.9	76.9
Diamond Harbour	57.6	79.8
Bhavnagar	62.9	87.0

Note: Median projections relative to the 1995–2014 average. Source: Nidheesh et al. [110], Tables 3a and 3b.

These projections assume a marked acceleration. Even the intermediate scenario implies an average rise of about 4–7 mm a year from the 1995–2014 baseline to 2100, several times the long-term tide-gauge rates in Table 6.1 and at or above the recent satellite trends. By comparison, a continuation of the satellite-era rate of about 4.5 mm a year would raise sea level by about 34 centimeters between 2025 and 2100, and the long-term tide-gauge average of 1.7 mm a year by about 13 centimeters.

Either outcome is gradual enough to be met through planning. The government has published Coastal Vulnerability Index maps at a scale of 1:100,000, including for Mumbai, Chennai, and Kolkata [111]; carried out multi-hazard vulnerability mapping at 1:25,000 to identify low-lying areas; and delineated a hazard line along the entire coast [112]. Coastal Regulation Zone notifications govern development near the shore [105]. India's coastal cities face a manageable engineering and planning task, centered on drainage, groundwater control, and protection of low-lying land, and not an existential threat from climate-driven sea-level rise.

6.9 Wildfires

Forest fires in India are a seasonal feature of dry forests, and they are overwhelmingly started by people. A Forest Survey of India (FSI) technical study found that more than 95% of fire incidents are of human origin [113]. Fires are set to clear forested land, prepare soil for growing crops, and to encourage fresh grass for fodder, and other fires are initiated accidentally [114]. The Ministry of Environment, Forest and Climate Change's National Action Plan on Forest Fire encourages forest-fringe communities to work with forest-management departments in reducing the vulnerability of forests to fire and strengthening firefighting capabilities [115].

Most forest fires are originate with the burning of fallen leaves, twigs, pine needles, and undergrowth rather than the crowns of trees. The government attributes them to a combination of natural and human factors.

Satellite monitoring covers a fire season that runs from November to June [116] and shows no upward trend (Table 6.3). Detections by the SNPP-VIIRS sensor peaked at 345,989 in the 2020–21 season [116] and then fell in each of the next three seasons, to 203,544 in 2023–24 [63]. They rose to 238,309 in 2024–25, which was still about 31% below the 2020–21 peak [114].

Table 6.3 Forest fire alerts detected by satellite, 2018–19 to 2024–25

Fire season (November–June)	SNPP-VIIRS detections
2018–19	210,286
2019–20	124,473
2020–21	345,989
2021–22	223,333
2022–23	212,249
2023–24	203,544
2024–25	238,309

Note: Counts include repeated detections of large and continuous fires and are not counts of separate fires. Sources: [116]; [63]; [114].

These counts overstate the number of fires. FSI alerts include large, continuous, and repeated fires, so a single fire can be detected many times [116]. A parliamentary standing committee reported in 2026 that only about 12.5% of FSI fire alerts in Uttarakhand corresponded to actual fires [117].

The area burned is relatively small. FSI's first national burnt-area assessment put the area affected by fire in 2023–24 at 34,562 km² [114], less than 5% of the 715,343 km² of forest cover recorded in 2023 [63]. The largest burnt areas were in Andhra Pradesh (5,287 km²), Maharashtra (4,095 km²), and Telangana (3,983 km²) [114]. Forest cover, nonetheless, continued to grow (Section 8.1).

Most forests face low fire risk. An FSI analysis of fire detections over 2004–2021 classified 2.8% of forest cover as extremely fire-prone, 7.9% as very highly fire-prone, and 11.61% as highly fire-prone, while 64.54% was less fire-prone [115]. Where fires are frequent, local land use is the main driver. In the western Himalaya, the spread of chir pine into oak forests is linked to nearly 57% of fire incidents, and in Manipur shifting cultivation is linked to close to two-thirds of verified fires [117].

Firefighting response has improved. The share of major fires extinguished within 24 hours rose from 33% in 2022–23 to 67% in 2023–24 [118]. FSI now issues pre-fire alerts a week in advance as well as near-real-time alerts, a 24-hour control room in the Ministry monitors incidents nationally, and 150 personnel from three National Disaster Response Force battalions have been trained to tackle large forest fires [119; 120]. In

2024–25, US$3.05 million was sanctioned under the Centrally Sponsored Forest Fire Prevention and Management Scheme and US$15.44 million under compensatory afforestation funds [120].

Climate is at most a secondary factor to wildfires. The government has noted that rising temperatures, erratic rainfall, and accumulated dry fuel can heighten fire risk [121], but the parliamentary committee observed that no dedicated study in India has established a link between climate change and forest fires [117]. Emissions from fires are also small. The government reports that methane and nitrous oxide from forest fires amounted to 1.055 million tons of CO_2 equivalent in 2020, about 0.03% of India's total greenhouse gas emissions [120].

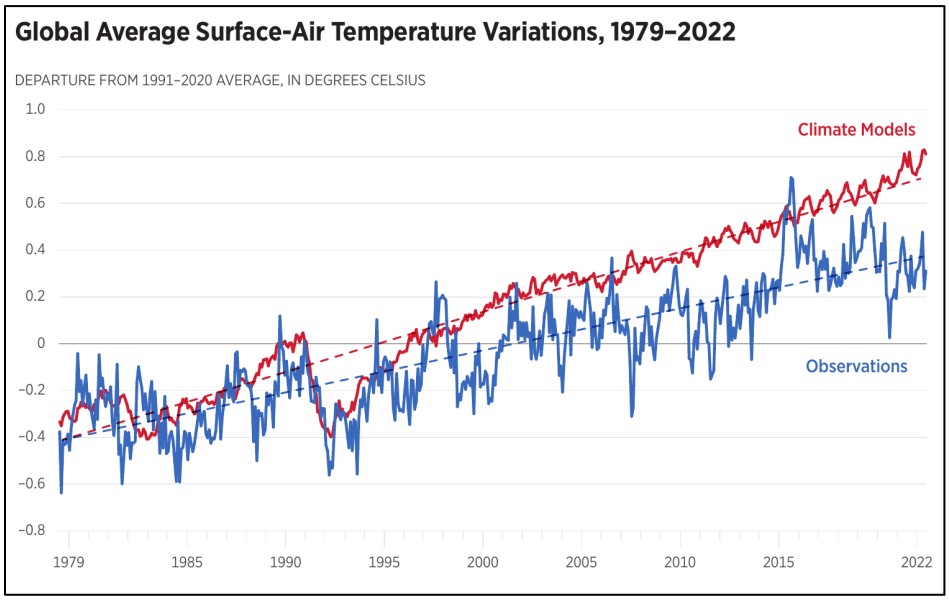
India's forest fires are a land-management problem driven by human ignition and seasonal dry fuel, not a climate-driven crisis. Detections have fallen from their 2020–21 peak, the area burned is a small share of the growing forests, and response times have improved. Community incentives, fuel management, and enforcement against deliberate burning, rather than emissions policy, are the effective remedies.

6.10 Climate models and policy

Projections used to justify emissions restrictions rely on climate models whose sensitivity to carbon dioxide remains uncertain. The IPCC assesses equilibrium climate sensitivity to lie likely between 2.5°C and 4°C [42]. Leading modelers have acknowledged that a subset of the latest generation of models is "too hot" and that "these high-sensitivity models do a poor job of reproducing historical temperatures" [43]. An analysis of the CMIP6 model ensemble found that all model runs warmed the lower and mid-troposphere faster than observations over 1979–2014, both globally and in the tropics [44]. Models also did not reproduce the slower rate of surface warming observed in the early 2000s [45].

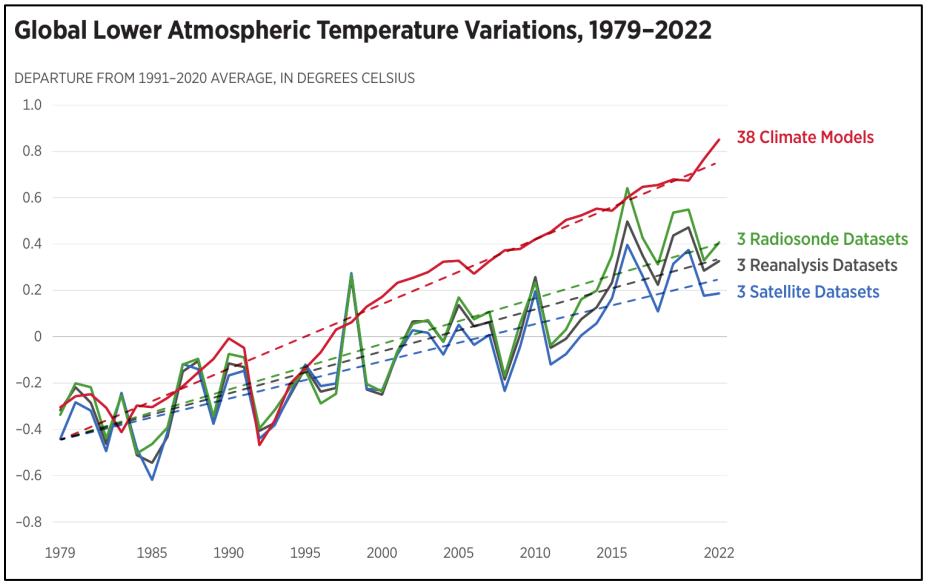
A 2024 analysis by Spencer illustrates the gap between models and observations. Over 1979–2022, the average of 36 climate models in the sixth phase of the Coupled Model Intercomparison Project (CMIP6) warmed global average surface air temperature 43% faster than the average of five observation-based datasets (Figure 6.6). In the lower atmosphere, the average of 38 models warmed 43% faster than weather-balloon (radiosonde) datasets, 55% faster than reanalysis datasets, and 75% faster than satellite datasets (Figure 6.7) [101].

Figure 6.6 Global average surface air temperature: climate models versus observations, 1979–2022



Note: Departures from the 1991–2020 average, in degrees Celsius. Figures have been adjusted to align trends starting in 1979. Average of five observation-based datasets and 36 CMIP6 models. Source: Spencer [101], Chart 1.

Figure 6.7 Global lower-atmosphere temperature: climate models versus observations, 1979–2022



Note: Departures from the 1991–2020 average, in degrees Celsius. Figures have been adjusted to align trends starting in 1979. Source: Spencer [101], Chart 3, based on data from McKitrick and Christy [44] and the American Meteorological Society's *State of the Climate in 2022*.

For India, these uncertainties matter because model projections of future heat, rainfall, and crop losses are often presented as forecasts. The observational record reviewed in this chapter, rather than model scenarios, should anchor policy.

Summary of Physical Science Basis

Apart from a modest rise in temperatures, part of which reflects urban heat islands and land-use change, India's climate record shows no dangerous or worrying trends. All-India monsoon rainfall varies in multidecadal epochs without a significant long-term trend, and the recent rise in rainfall over northwest India has benefited one of the country's driest regions. Tropical cyclones over the Bay of Bengal have become less frequent, and deaths from cyclones and other extreme weather have fallen sharply because of adaptation. India's glaciers have lost mass since 2000, but the losses are gradual and occur within a long history of natural fluctuations, including medieval warmth comparable to or greater than today's in regional proxy records.

7. Agriculture and Food Security

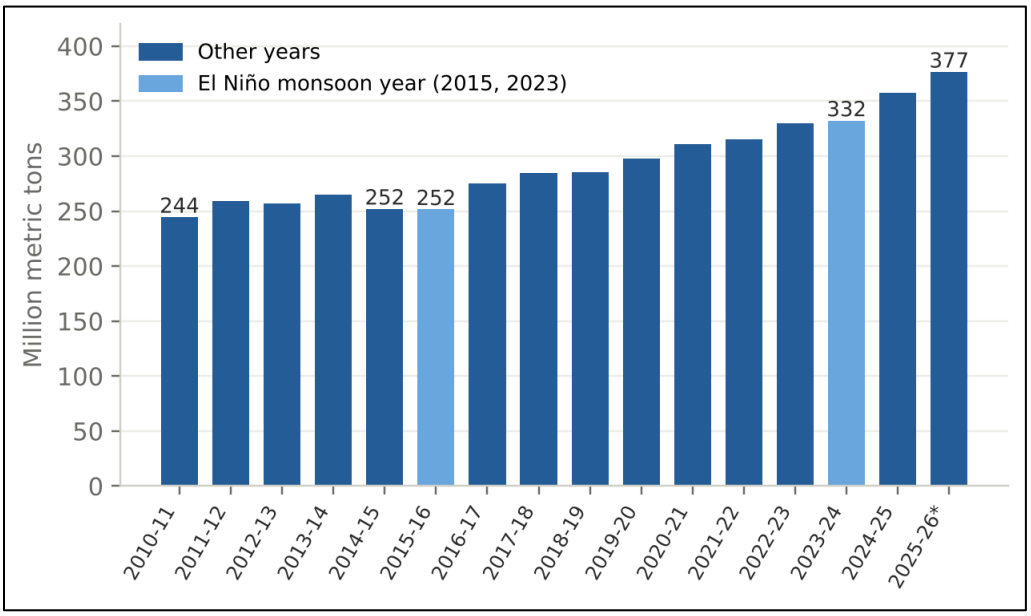
Key points India's output of food grain has set a record in each of the past 10 years, reaching 376.6 Mt in 2025–26. El Niño years have caused only shallow, temporary dips. Rising CO_2 concentrations, fertilizer, and irrigation have all contributed to higher yields and greener croplands. Rice, maize, oilseeds, sugarcane, horticulture, milk, and fish production are also at or near record levels. Studies that projected climate-driven yield declines have been contradicted by rising yields.

7.1 Record harvests

India's food grain production reached a record 376.56 Mt in 2025–26 according to the Third Advance Estimates, 18.8 Mt (5.3%) above the previous record of 357.7 Mt in 2024–25 [12; 46]. Rice reached a record 154.0 Mt, wheat 120.7 Mt, and maize 55.1 Mt. Oilseed production was 43.1 Mt and sugarcane 500.1 Mt [46].

Production has risen steadily since 2010–11, when it was 244.5 Mt, an increase of 54% [11; 12]. Foodgrain output has set a new record every year for ten consecutive years, from 275.1 Mt in 2016–17 to 376.6 Mt in 2025–26 [12]. Oilseed output rose from 25.3 Mt in 2015–16 to 43.1 Mt in 2025–26 [12].

Figure 7.1 Food grain production in India, 2010–11 to 2025–26



Note: 2025–26 is the Third Advance Estimate. El Niño monsoon years per [34] and [47] Sources: [11]; [12].

7.2 Harvest details by crop and sector

The 2025–26 record was broad-based. According to the Third Advance Estimates, rice output rose by 3.8 Mt to 154.0 Mt and maize by 11.7 Mt to 55.09 Mt, both records. Wheat production increased to 120.7 Mt from 117.9 Mt. Gram (chickpea), the largest pulse crop, rose to 12.5 Mt from 11.1 Mt, while tur (pigeon pea) was almost unchanged at 3.6 Mt. Among oilseeds, groundnut (13.1 Mt) and rapeseed-mustard (13.8 Mt) set records, and total oilseed output was 43.1 Mt. Millets (Shree Anna) reached 17.6 Mt, cotton 29.0 million bales of 170 kg, and sugarcane a record 500.1 Mt, 45.45 Mt more than a year earlier (Table 7.1) [58].

Table 7.1 Production of major crops, 2024–25 and 2025–26

Crop	2024–25	2025–26	Change
Foodgrains	**357.73**	**376.56**	**+5.3%**
Rice	150.18	154.02	+2.6%
Wheat	117.94	120.66	+2.3%
Maize	43.41	55.09	+26.9%
Gram (chickpea)	11.11	12.51	+12.6%
Tur (pigeon pea)	3.62	3.59	−0.9%
Groundnut	11.94	13.07	+9.5%
Rapeseed and mustard	12.67	13.77	+8.7%
Sugarcane	454.61	500.06	+10.0%

Note: Million metric tons. 2025–26 figures are Third Advance Estimates; 2024–25 figures are as reported in the same release.
Source: [58].

Beyond field crops, horticultural production—the business of growing and selling fruits, vegetables, flowers, and other high-value plants for consumers and industries—reached a record estimated 377.8 Mt in 2025–26, up from 370.7 Mt in 2024–25, including 121.5 Mt of fruit and 221.0 Mt of vegetables [59]. India is the world's largest milk producer: output reached 247.9 Mt in 2024–25, up 3.6% in a year, and per-capita availability rose to 485 grams a day [60; 76]. Fish production more than doubled, from about 9.5 Mt in 2013–14 to about 19.8 Mt in 2024–25, making India the world's second-largest producer [61].

Abundant harvests have made India a major food exporter. Rice exports reached 20.2 Mt in FY2024–25, up 23.4% from the previous year, giving India about 38% of world rice exports. In November 2025, public stocks of rice held by the Food Corporation of India were more than three times the buffer norm [62].

Actual outcomes have repeatedly outperformed climate projections. A review of Indian studies found that most had projected climate-driven declines in crop yields by 2020

and beyond, yet actual yields of various crops continued to rise, a result the authors attribute to new varieties, irrigation, fertilizer, and mechanization [77]. In the Kinnaur district of Himachal Pradesh, climate fluctuations over 1990–2020 favored apples, walnuts, and grapes, although they reduced yields of apricots, plums, pears, and almonds [78].

7.3 Resilience in El Niño years

The 2023 El Niño monsoon delivered 94% of normal rainfall [34], yet the 2023–24 harvest set a record of 332.30 Mt [12]. The 2014 and 2015 monsoons were both weak, the latter during one of the strongest El Niño events on record [47]. Food grain output fell from 265.04 Mt in 2013–14 to 252.02 Mt in 2014–15 and 251.54 Mt in 2015–16, a decline of about 5% [11; 12]. The following year output rose 9.4% to a record 275.11 Mt, beginning the current series of annual records [12].

The 2026 monsoon is the most recent test. Despite rainfall at 87% of normal and a strong El Niño [33], kharif (monsoon-season) crops had been sown on 108.6 million hectares by September 4, 2026, 1.6% less than a year earlier, with acreage for pulse crops higher [48]. Official production estimates for 2026–27 have not yet been released. Historical experience indicates that weak monsoons cause modest and temporary reductions in output rather than food crises.

7.4 Carbon dioxide and greening

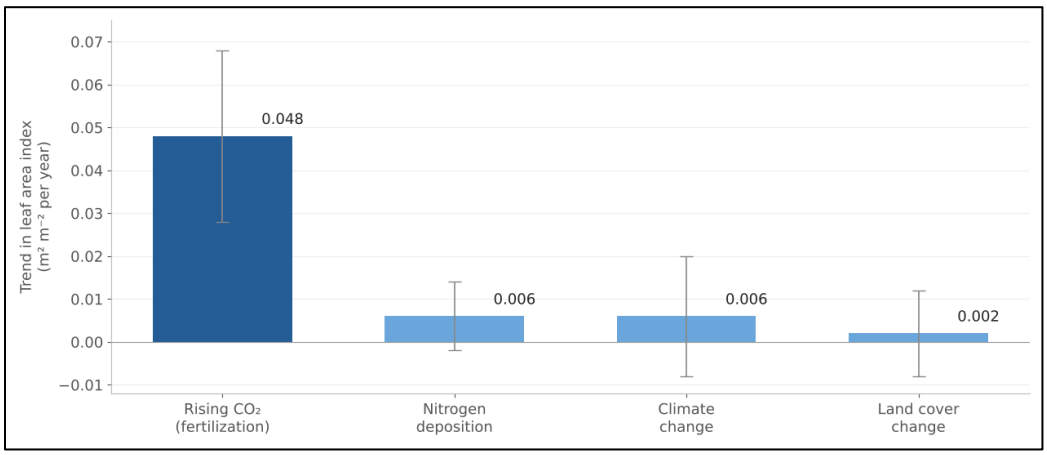
Higher atmospheric CO_2 enhances photosynthesis and water-use efficiency in most crops. Satellite records show significant greening over 25–50% of the world's vegetated land between 1982 and 2009, of which 70% was attributed to CO_2 fertilization [49]. A later analysis for 2000–2017 found that India and China lead global greening; in India, 82% of the gain came from croplands, driven by multiple cropping supported by fertilizer and irrigation [50].

The supplementary analysis of Zhu and colleagues quantifies the effect. Atmospheric CO_2 rose from 341 to 387 parts per million (ppm) between 1982 and 2009, an increase of 13.5%. A leaf-scale model estimated that this raised photosynthesis by about 9.7–11.7% (21–25% per 100 ppm) and the water-use efficiency of photosynthesis by about 12.3%. Ecosystem models gave increases in global leaf area of 4.7–9.5%, and the results of free-air CO_2 enrichment (FACE) experiments implied increases in net primary production of 6.1–9.4% [49, Supplementary Information].

Across 10 ecosystem models, the trend in leaf area attributable to rising CO_2 was eight times the trend attributable to climate change or to nitrogen deposition, and 24 times that attributable to land cover change (Figure 7.2). Satellite data show statistically

significant greening over 35% of the global vegetated area during 1982–2014, against significant browning over 4% [49, Supplementary Information].

Figure 7.2 Drivers of the global trend in leaf area, 1982–2009



Note: Multi-model ensemble mean trends in growing-season leaf area index, with error bars showing ±1 standard deviation across models. CO_2 and climate effects are from ten models, land cover change from seven, and nitrogen deposition from two. Source: Zhu et al. [49], Supplementary Information, Table S3.

Crop-level studies confirm the CO_2 benefit. Across the 12 largest wheat producers, including India, the rise in CO_2 between 1961 and 2019 increased wheat yields by about 7%, more than offsetting the reductions of about 3% attributed to 1.2°C of warming and about 1% to drought [79]. A global modeling study of rice found that rising CO_2 raised rice productivity by about 30%, while warming reduced production by about 7%; expansion of planted and irrigated area was the largest driver of higher output [80].

7.5 Fossil fuels and food

Modern Indian agriculture depends on fossil energy. Natural gas is the main feedstock for urea and other nitrogen fertilizers, diesel powers tractors and pumps, and coal-based electricity runs irrigation pumps. Restrictions on fossil fuels would raise input costs and put at risk the productivity gains that have given India its food security.

8. Forests, Wildlife, and Conservation

Key points India's forest and tree cover has expanded to a quarter of the country's area, and India ranks third in the world for annual net gain in forest area. Forest carbon stocks are rising. Populations of tigers, leopards, Asiatic lions, one-horned rhinoceros, and gharials have grown under sustained protection, and several reintroduced populations are breeding.

8.1 Forest and tree cover

The Forest Survey of India (FSI) reports in its biennial *India State of Forest Report* (ISFR) that forest cover reached 715,343 km² (21.8% of the geographical area) in 2023, and tree cover outside forests a further 3.4%, for combined forest and tree cover of 827,357 km² (25.2%). Combined cover increased by 1,445.81 km² between 2021 and 2023, and the area bearing bamboo increased by 5,227 km² [63; 81].

Forest cover has grown steadily across the comparable assessments of the past decade and more, from 692,027 km² (21.05%) in 2011 to 715,343 km² in 2023 [82; 63]. The gain of more than 23,000 km² is larger than the state of Mizoram. Assessments before 2011, beginning in 1987, used coarser methods and are not directly comparable [83].

Between 2021 and 2023, combined forest and tree cover increased most in Chhattisgarh (684 km²), Uttar Pradesh (559 km²), Odisha (559 km²), and Rajasthan (394 km²) [81]. The ISFR counts as forest cover all land of more than one hectare with a tree canopy density above 10%, irrespective of ownership or legal status, so the figures include plantations and orchards as well as natural forest [63].

8.2 Greening

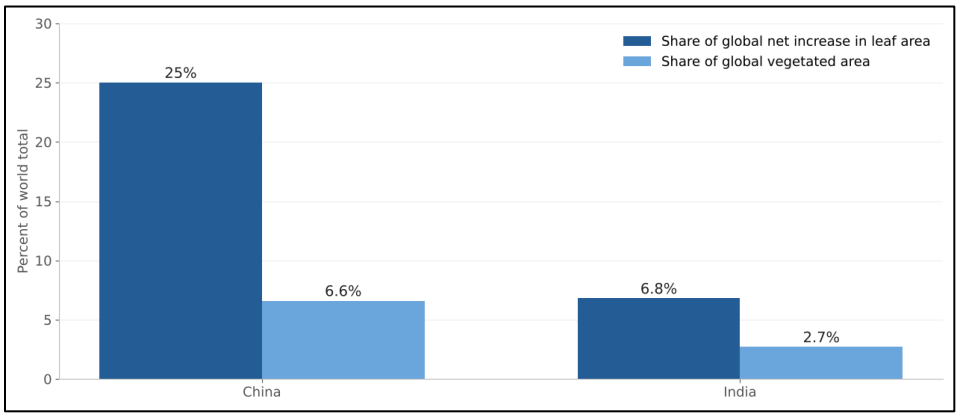
International assessments confirm the trend. In the Food and Agriculture Organization's (FAO) *Global Forest Resources Assessment 2025*, India ranked third in the world for annual net gain in forest area, and ninth for total forest area (about 72.7 million hectares), and fifth for carbon sinks.

Greening extends well beyond forests. India and China have led the world in greening since 2000, mostly through croplands in India's case [50], and the Thar Desert has become markedly greener as rainfall has increased (Box 6.2).

Satellite data show how large India's contribution has been. Between 2000 and 2017, global leaf area increased by 2.3% a decade, equivalent to adding 5.4 million km² of new leaf area. India accounted for 6.8% of this net increase while holding only 2.7% of

the world's vegetated area, while respective numbers for China 25% and 6.6% (Figure 8.1). India's leaf area increased by 11% over the period. Croplands contributed 82% of India's greening and forests 4.4%, and India's cereal production rose by 26%, from 235 Mt to 295 Mt [50].

Figure 8.1 China and India: share of global greening and of global vegetated area, 2000–2017

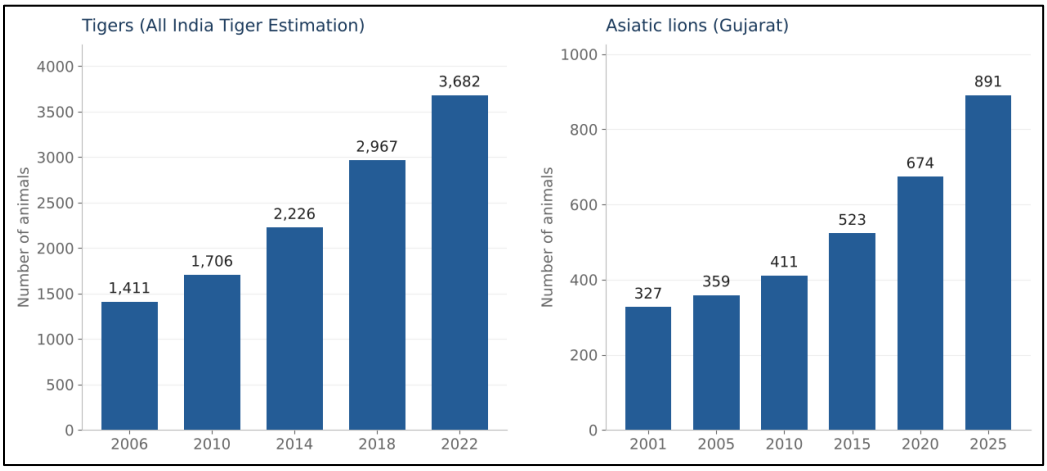


Note: Greening is measured as the net increase in leaf area from MODIS satellite data. Source: Chen et al. [50].

8.3 Wildlife recovery

India's tiger population has risen in every national assessment since 2006, from 1,411 to 3,682 in 2022, growing about 6% a year in consistently sampled areas (Figure 8.2). India holds about 75% of the world's wild tigers [65]. A peer-reviewed analysis of two decades of monitoring found that tiger-occupied range expanded by about 30%, or roughly 2,929 km² a year, to about 138,200 km², and that tigers have colonized habitats shared with about 60 million people [84].

Figure 8.2 Tiger and Asiatic lion populations in India



Note: Tiger figures are national estimates from the All India Tiger Estimation; results of the 2026 cycle are expected in 2027. Lion figures are Gujarat Forest Department estimates. Sources: [65]; [66]; [67].

Leopard numbers rose from 12,852 in 2018 to 13,874 in 2022, about 1.1% a year in commonly sampled areas. The largest gains were in central India and the Eastern Ghats, although numbers fell in the Shivalik hills and Gangetic plains [85; 86]. The Asiatic lion numbered 891 in 2025, up from 674 in 2020 and 523 in 2015. Its distribution area expanded by 59% over 10 years, and 497 lions now live in nine satellite populations beyond the Gir forest [66].

The greater one-horned rhinoceros has recovered strongly in Assam. The 2022 count recorded 2,895 rhinos in the state, including 2,613 in Kaziranga National Park, about 200 more than four years earlier [87]. In Ladakh, a comprehensive survey estimated 477 snow leopards across 47,572 km², one of the largest contiguous populations in the world [88]; the first national assessment estimated 718 snow leopards in India [89].

The critically endangered gharial, a fish-eating crocodilian, has recovered in the Chambal River. A survey of 22 rivers in the Ganga basin recorded 3,037 gharials, including at least 2,097 in the Chambal, where numbers have grown by about 7% a year since 1979 under protection and a captive rearing and release program. The authors caution that conditions elsewhere in the basin are less favorable [90].

8.4 Conservation successes

Targeted reintroductions show that lost populations can be restored (Box 8.1).

Box 8.1 Reintroduction and wetland successes

Tigers in Panna. Tigers had been lost from Panna Tiger Reserve, Madhya Pradesh, by 2009. After reintroduction that year, 18 females produced 120 cubs, and the population reached 59 by 2021, growing about 26% a year [91].

Rhinos in Manas. Poaching had wiped out the rhinos of Manas National Park, Assam. Translocated and rehabilitated rhinos produced 35 calves between 2012 and 2021, and the first locally born generation has begun to breed [92].

Swamp deer in Satpura. Ninety-eight hard-ground swamp deer (barasingha), a subspecies once confined to Kanha Tiger Reserve, were moved to Satpura Tiger Reserve between 2015 and 2023. The new population had grown to 172 animals by 2023 [93].

Wetlands. India had designated 26 Ramsar sites (wetlands of international importance) by 2014. In 2026, the Jai Prakash Narayan Bird Sanctuary in Uttar Pradesh became the country's 100th [94].

The record of the past two decades is one of expanding forest cover and recovering wildlife, achieved alongside rapid growth in energy use and incomes. These healthy ecosystems are not experiencing climate-driven collapse.

9. Policy Implications

> **Key points** India's international climate commitments are conditional, non-binding on fossil fuel use, and dependent on external finance that is becoming less certain. Energy policy should give priority to security, affordability, and reliability.

9.1 International commitments

India’s Nationally Determined Contribution (INDC) is ambiguous at best, with more focus on installation of renewable technology, than on reducing its consumption of fossil fuel. Here are some key highlights from India’s original INDC (2015).

“*In order to secure reliable, adequate and affordable supply of electricity,* ***coal will continue to dominate power generation in future.”***

- The most important commitment, according to India, is its aim to achieve a renewable target of 40% in the total installed capacity by 2030. But this proposed installation of renewables is contingent upon international aid, especially that from the Green Climate Fund, which was established within the United Nations Framework Convention on Climate Change (UNFCCC) to assist developing countries in climate adaptation and mitigation. India emphatically asserts that meaningful contribution to emission reduction cannot happen without economic development, which is still facing a lot of challenges. “*Our efforts to avoid emissions during our development process are also tied to the availability and level of international financing and technology transfer since India still faces complex developmental challenges.”*
- India estimates that at least $2.5 trillion is required to meet climate change actions until 2030. “*Preliminary estimates indicate that India would need around USD 206 billion (at 2014-15 prices) between 2015 and 2030 for implementing adaptation actions. Estimates by NITI Aayog (National Institution for Transforming India) indicate that the mitigation activities for moderate low carbon development would cost around USD 834 billion through 2030 at 2011 prices. A preliminary estimate suggests that at least USD 2.5 trillion (at 2014-15 prices) will be required for meeting India's climate change actions between now and 2030.*” **But with the abrupt stoppage of funds from the U.S. towards the Green Climate Fund (GCF) and other green funds makes the GCF funding source volatile and subject to closure, a factor that allows India to supports its decision to not push the Net Zero agenda.**

- India says that its responsibility in addressing climate change is not necessarily determined by the global emission reduction achievements and the progress made in temperature control.
- India asserts that it is not responsible for the GHG emissions associated with the industrial era of the West and that India's contribution will solely depend on and be contingent upon the climate fund that is provided to it by the developed countries. "*The successful implementation of INDC is contingent upon an ambitious global agreement including additional means of implementation to be provided by developed country parties, technology transfer and capacity building following Article 3.1 and 4.7 of the Convention.*
- The INDC also categorically states that a meaningful effort towards climate change would be possible only when the developing countries become developed countries, eliminating poverty as a hurdle in solving many environmental problems. "*It must be understood that poverty is a big polluter*," reads the INDC. "*India's contribution takes into account its commitment to conservation of nature as well as the imperatives of meeting the competing demand of resources for addressing the challenges of poverty eradication, food security and nutrition, universal access to education and health, gender equality and women empowerment, water and sanitation, energy, employment, sustainable urbanization and new human settlements and the means of implementation for enhanced action for achieving among others, the sustainable development goals for its 1.2 billion people*."
- India will adopt a strategy which enables development and environmental simultaneously: "*India believes that development and environment are not adversaries but can go hand in hand, if environmental sensibilities can be imbibe…. India's development plans will continue to lay a balanced emphasis on economic development and environment."*
- The most definite blow to the Paris agreement from India comes in the form of its INDC declaration that the Paris agreement does not restrict the country from sector specific developmental goals and targets. ***"India's INDC do not bind it to any sector specific mitigation obligation or action, including in agriculture sector. India's goal is to reduce overall emission intensity and improve energy efficiency of its economy over time and at the same time protecting the vulnerable sectors of economy and segments of our society."***

As an update to this, India submitted its INDC for 2031–2035 in April 2026. It commits to reducing the emissions intensity of GDP by 47% from 2005 levels by 2035, reaching about 60% non-fossil installed power capacity, and creating an additional carbon sink of 3.5–4.0 billion tons of CO_2 equivalent through forest and tree cover [13]. The INDC contains no commitment to cap or phase out coal, oil, or gas. It states that "the effective implementation of India's INDC depends on provision of additional support such as financial resources, technology transfer, and capacity-building by developed countries" [13]. India has consistently defended its right to use coal. At the 2021 Glasgow climate conference, the final text was amended at India's request to call for a "phasedown" rather than a "phase-out" of unabated coal power [51; 52]. External support for climate policies is diminishing. The United States has exited the Paris Agreement, and in January 2026 it ordered withdrawal from 66 international organizations, including the United Nations Framework Convention on Climate Change (UNFCCC) and the IPCC [53].

9.2 Recommendations

1. **Prioritize energy security and affordability.** National energy planning should be judged by its ability to deliver reliable, low-cost electricity and fuels to households and industry.
2. **Expand domestic coal production and dispatchable generation.** Continue commercial coal auctions, mine modernization, and the planned 97 GW of coal and lignite capacity, and evaluate all capacity on its contribution to peak and evening demand.
3. **Accelerate oil and gas exploration.** Implement the Samudra Manthan offshore oil exploration scheme promptly, appraise the Andaman discoveries, and streamline approvals to arrest declining domestic production.
4. **Scale up nuclear power.** Use the SHANTI Act to attract private investment and deliver the 22 GW of capacity planned for 2031–32 and the 100 GW goal for 2047. Expand avenues for small and medium-scale modular reactors.
5. **Assign integration costs to variable sources.** Wind and solar projects should bear the costs of storage, balancing, and transmission that their variability imposes on the system. Subsidies for wind and solar projects should be stopped immediately, as it is not the Government’s burden to support inferior energy systems that cannot compete with the efficiencies and reliability that thermal units offer.
6. **Secure fertilizer feedstocks.** Ensure long-term natural gas supply for fertilizer production to protect food security.

7. **Base climate policy on Indian observations.** Fund independent national assessments of temperature, rainfall, and extreme-event trends that correct for urban heat island effects, rather than relying on model projections.
8. **Treat international pledges as conditional.** India has no obligation to curtail fossil fuel use, and it should state this clearly in international forums.

Withdrawal from Paris Agreement: Physical Science Basis

The recommendation for India to withdraw from the Paris agreement stems from the fundamental flaw in the interpretation of climate system, the scientific conclusions made in the agreement, and policy recommendations based on those erroneous conclusions.

- Climate models—used by IPCC and as the basis for Paris Agreement—continue to fail in the predictions of real-world temperatures due to false assumptions (especially of a very high temperature sensitivity to greenhouse gas emissions).
- The average of the models departs markedly from measured temperatures: since 1979, the CMIP6 average has warmed 43% faster than surface observations and 43–75% faster than observations of the lower atmosphere [101]. The models are therefore not accurate enough to serve as a basis for forecasting temperature and climate trends or for making policy decisions.
- The urban heat island effect has a measurable influence on city temperatures across the globe, and urban warming is difficult to separate from regional climate signals in station records. Numerous studies show marked contrasts between temperatures measured in Indian cities and those of their less-developed surroundings, and a recent analysis of 141 cities attributed about 38% of their night-time warming to urbanization [137]. Part of the warming recorded at urban stations is therefore a local effect of development rather than a signal of global climate change.

10. Conclusions

The Government of India's statistics describe an energy system built on coal, oil, and natural gas. Fossil fuels supply about 96% of primary energy and three-quarters of electricity. Coal production has passed 1,000 Mt a year, reserves are sufficient for two centuries, and coal-fired plants carry the system at peak demand. Oil and gas import dependence is the principal vulnerability, and new exploration programs are the appropriate response, and not a pivot towards renewables.

The observational climate record does not indicate a crisis. Warming has been modest and is partly attributable to local land-use change in urban areas. Monsoon rainfall shows no significant long-term trend. Cyclones have become less frequent over the Bay of Bengal, and deaths from them have fallen by more than 99% in Odisha since 1999 and adaptation methods has reduced cyclone deaths in general. Heat waves caused about 35 deaths in 2025 as per Indian government’s IMD. Though heat wave numbers are claimed to be more as per other estimates, multiple global level studies show cold is a bigger killer than heat. Food production has set 10 consecutive annual records, and El Niño years have caused only brief, shallow dips. In short, there is no climate crisis.

The broader environmental record is also positive. Monsoon rainfall has increased over northwest India and the Thar Desert. It greened arid land, and expanded cropland. Harvests of rice, maize, oilseeds, sugarcane, horticultural crops, milk, and fish are at or near record levels. Forest and tree cover has reached a quarter of India's land area, and populations of tigers, lions, rhinoceros, and gharials have increased.

India's 1.46 billion people need more energy. The evidence (of a lack of climate-induced economic collapse) supports continued expansion of coal, oil, gas, and nuclear power to meet that need reliably and affordably and does not support restrictions on fossil fuels.

Annex: Abbreviations and Units

bcm	billion cubic meters
CAGR	compound annual growth rate
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CMIP6	Coupled Model Intercomparison Project, Phase 6
CNG	compressed natural gas
CO_2	carbon dioxide
crore	10 million
DES	Directorate of Economics and Statistics
ENSO	El Niño–Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
FSI	Forest Survey of India
FY	fiscal year (April 1–March 31)
GDP	gross domestic product
Gt	gigatonne (billion metric tons)
GW	gigawatt
GWh	gigawatt-hour
IMD	India Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
ISFR	India State of Forest Report
km^2	square kilometer
ktoe	thousand tons of oil equivalent
kWh	kilowatt-hour
lakh	100,000
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LST	land surface temperature
MJ	megajoule
MoSPI	Ministry of Statistics and Programme Implementation
m w.e.	meters water equivalent
Mt	million metric tons
MW	megawatt
NDC	Nationally Determined Contribution
R^2	coefficient of determination
TPES	total primary energy supply

TWh	terawatt-hour
UHI	urban heat island
UNFCCC	United Nations Framework Convention on Climate Change

References

[1] MoSPI (Ministry of Statistics and Programme Implementation). *Energy Statistics India 2026*. 33rd ed. New Delhi: National Statistics Office, 2026. https://www.mospi.gov.in/uploads/publications_reports/publications_reports1774859128428_05e8ebb5-0598-4112-844c-bbe00e04aab8_33rd_Edition_of_ES-2026_Final.pdf.

[2] CERC (Central Electricity Regulatory Commission). "Chapter I: Overview of Power Sector." In *Report on Short-Term Power Market in India, 2024–25*. New Delhi: CERC, 2025. https://www.cercind.gov.in/2025/market_monitoring/Annual-2024-25/Chapter%20I.pdf.

[3] Goyal, Kushagra. "Power Demand Tracker: India Meets All-Time High Demand of 270.8 GW, Renewable Energy Share 34%." *Down To Earth*, May 22, 2026. https://www.downtoearth.org.in/amp/story/energy/power-demand-tracker-india-meets-all-time-high-power-demand-of-2708-gw-renewable-energy-share-34.

[4] Business Standard. "Over 24,000 MW Coal, Lignite-Based Power Capacity in Planning Stages: Govt." March 9, 2026. https://www.business-standard.com/industry/news/over-24-000-mw-coal-lignite-based-power-capacity-in-planning-stages-govt-126030900563_1.html.

[5] Bubna, Udit. "India's Crude Import Dependence Rises to Record 88.7% as Domestic Output Continues to Decline." *ThePrint*, July 27, 2026. https://theprint.in/economy/indias-crude-import-dependence-rises-to-record-88-7-as-domestic-output-continues-to-decline/2998114/.

[6] PIB (Press Information Bureau). "Samudra Manthan: The National Offshore Exploration Scheme." Backgrounder, July 31, 2026. https://static.pib.gov.in/WriteReadData/specificdocs/documents/2026/jul/doc2026731939901.pdf.

[7] IMD (India Meteorological Department). "Statement on Climate of India during 2025." Press release, January 1, 2026. https://mausam.imd.gov.in/Forecast/marquee_data/Statement_climate_of_india_2025.pdf.

[8] MoSPI (Ministry of Statistics and Programme Implementation). "Rainfall." Chap. 34 in *Statistical Year Book India*. New Delhi: MoSPI, n.d. Accessed October 6, 2026. https://mospi.gov.in/sites/default/files/Statistical_year_book_india_chapters/Rainfall.pdf.

[9] Vellore, R. K., N. Deshpande, P. Priya, B. B. Singh, J. Bisht, and S. Ghosh. "Extreme Storms." In *Assessment of Climate Change over the Indian Region: A Report of the Ministry of Earth Sciences (MoES), Government of India*, edited by R. Krishnan, J. Sanjay, Chellappan Gnanaseelan, Milind Mujumdar, Ashwini Kulkarni, and Supriyo Chakraborty, 155–73. Singapore: Springer, 2020. https://doi.org/10.1007/978-981-15-4327-2_8.

[10] Ray-Bennett, Nibedita S. "Learning from Deaths in Disasters: The Case of Odisha, India." Middle East Institute, June 9, 2016. https://mei.edu/publication/learning-deaths-disasters-case-odisha-india/.

[11] DES (Directorate of Economics and Statistics). *Fourth Advance Estimates of Production of Foodgrains for 2016–17*. New Delhi: Ministry of Agriculture and Farmers Welfare, 2017. https://desagri.gov.in/wp-content/uploads/2021/04/4th_Adv2016-17Eng.pdf.

[12] DES (Directorate of Economics and Statistics). *Time Series: Third Advance Estimates of Production of Foodgrains, Oilseeds and Other Commercial Crops, 2025–26*. New Delhi: Ministry of Agriculture and Farmers Welfare, 2026. https://desagri.gov.in/wp-content/uploads/2026/06/Time-Series-3rd-AE-2025-26-English.pdf.

[13] GOI (Government of India). *India's Nationally Determined Contribution (2031–2035)*. Submitted to the United Nations Framework Convention on Climate Change, April 2026. https://unfccc.int/sites/default/files/2026-04/INDIA%20NDC%202031-35.pdf.

[14] UN DESA (United Nations Department of Economic and Social Affairs, Population Division). *World Population Prospects 2024*. New York: United Nations, 2024. https://population.un.org/wpp/.

[15] Indian Infrastructure. "Central Government Achieves Electrification of All Villages." May 11, 2018. https://indianinfrastructure.com/2018/05/11/central-government-achives-electrification-of-all-villages/.

[16] PIB (Press Information Bureau). "Annexure: Number of Households Electrified since the Launch of SAUBHAGYA Scheme Including Additional Households Achievement under DDUGJY." August 2025. https://static.pib.gov.in/WriteReadData/specificdocs/documents/2025/aug/doc2025818615601.pdf.

[17] CW Team. "Coal Remains Backbone of India's Power Supply." *Construction World*, July 29, 2026. https://www.constructionworld.in/energy-infrastructure/coal-and-mining/coal-remains-backbone-of-indias-power-supply/95119.

[18] IANS. "Number of Poor Families Getting Cheap LPG under Ujjwala Scheme Rises to 10.6 Crore." November 21, 2025. https://ianslive.in/number-of-poor-families-getting-cheap-lpg-under-pms-scheme-rises-to-106-crore--20251121145704.

[19] MoSPI (Ministry of Statistics and Programme Implementation). "Energy Statistics India 2026." Press release, March 30, 2026. https://www.mospi.gov.in/uploads/latestReleases/latest_release_1774858925751_4d9a81ae-3de8-4756-97ed-cf19d69e2588_ES_2026_Press_release.pdf.

[20] MoC (Ministry of Coal). Press release on coal production and dispatch from captive and commercial mines, FY2025–26. April 2, 2026. https://coal.nic.in/sites/default/files/2026-04/Press020426.pdf.

[21] Deccan Herald. "OIL Makes Second Natural Gas Discovery in Andaman Offshore Region; Hardeep Puri Shares Video." June 5, 2026. https://www.deccanherald.com/india/oil-makes-second-natural-gas-discovery-in-andaman-offshore-region-hardeep-puri-shares-video-4029114.

[22] News On AIR. "India Achieves 50% Non-Fossil Power Capacity, Five Years Ahead of Target." All India Radio, December 8, 2025. https://www.newsonair.gov.in/india-achieves-50-non-fossil-power-capacity-five-years-ahead-of-target.

[23] Energetica India. "CEA Unveils Long Term National Resource Adequacy Plan, Sees 458.7 GW Peak Demand by 2035–36." April 2026. https://www.energetica-india.net/news/cea-unveils-long-term-national-resource-adequacy-plan-sees-4587-gw-peak-demand-by-203536.

[24] PIB (Press Information Bureau). "A New Chapter in India's Nuclear Journey." Factsheet, April 7, 2026. https://www.pib.gov.in/FactsheetDetails.aspx?Id=150617.

[25] Indian Infrastructure. "CEA Issues Roadmap to 100 GW of Pumped Storage Projects by 2035-36." February 4, 2026. https://indianinfrastructure.com/2026/02/04/cea-issues-roadmap-to-100-gw-of-pumped-storage-projects-by-2035-36/.

[26] Tribune. "2024 Was the Warmest Year since 1901: IMD." *The Tribune* (Chandigarh), January 2025. https://www.tribuneindia.com/news/nation/2024-was-the-warmest-year-since-1901-imd.

[27] Thapliyal, V., and S. M. Kulshrestha. "Climate Changes and Trends over India." *Mausam* 42, no. 4 (1991): 333–38.

[28] Mohan, Manju, Anurag Kandya, and Arunachalam Battiprolu. "Urban Heat Island Effect over National Capital Region of India: A Study Using the Temperature Trends." *Journal of Environmental Protection* 2 (2011): 465–72.

[29] Sultana, Sabiha, and A. N. V. Satyanarayana. "Urban Heat Island Intensity during Winter over Metropolitan Cities of India Using Remote-Sensing Techniques: Impact of Urbanization." *International Journal of Remote Sensing* 39, no. 20 (2018): 6692–6730. https://doi.org/10.1080/01431161.2018.1466072.

[30] Gogoi, Partha Pratim, V. Vinoj, D. Swain, G. Roberts, J. Dash, and S. Tripathy. "Land Use and Land Cover Change Effect on Surface Temperature over Eastern India." *Scientific Reports* 9 (2019): 8859. https://doi.org/10.1038/s41598-019-45213-z.

[31] Kothawale, D. R., and Jayashree Revadekar. "Interannual Variations of Indian Summer Monsoon." Indian Institute of Tropical Meteorology, n.d. Accessed October 6, 2026. https://www.tropmet.res.in/~kolli/MOL/Monsoon/Historical/air.html.

[32] Jin, Qinjian, and Chien Wang. "A Revival of Indian Summer Monsoon Rainfall since 2002." *Nature Climate Change* 7, no. 8 (2017): 587–94. https://doi.org/10.1038/nclimate3348.

[33] IMD (India Meteorological Department). "Salient Features of Southwest Monsoon 2026." September 30, 2026. https://mausam.imd.gov.in/Forecast/marquee_data/Salient_Features_SW_MONSOON%20_2026_30_sep.pdf.

[34] IMD (India Meteorological Department). "End of Season Report: Southwest Monsoon 2023." Press release, September 30, 2023. https://internal.imd.gov.in/press_release/20230930_pr_2553.pdf.

[35] Deccan Herald. "Cyclone Fani: Death Toll Increases to 64." May 13, 2019. https://www.deccanherald.com/india/cyclone-fani-death-toll-increases-to-64-733650.html.

[36] Mahapatra, Bidhubhusan, Monika Walia, and Niranjan Saggurti. "Extreme Weather Events Induced Deaths in India 2001–2014: Trends and Differentials by Region, Sex and Age Group." *Weather and Climate Extremes* 21 (2018): 110–16.

[37] Zhao, Qi, Yuming Guo, Tingting Ye, et al. "Global, Regional, and National Burden of Mortality Associated with Non-optimal Ambient Temperatures from 2000 to 2019: A Three-Stage Modelling Study." *Lancet Planetary Health* 5, no. 7 (2021): e415–25. https://doi.org/10.1016/S2542-5196(21)00081-4.

[38] Ritchie, Hannah, Pablo Rosado, and Max Roser. "Natural Disasters." Our World in Data. Last updated May 2026. https://ourworldindata.org/natural-disasters.

[39] Raina, V. K. *Himalayan Glaciers: A State-of-Art Review of Glacial Studies, Glacial Retreat and Climate Change*. MoEF Discussion Paper. New Delhi: Ministry of Environment and Forests, Government of India, 2009.

[40] MIT Technology Review. "Climate Change Authority Admits Mistake." January 21, 2010. https://www.technologyreview.com/2010/01/21/122816/climate-change-authority-admits-mistake/.

[41] Gardelle, Julie, Etienne Berthier, and Yves Arnaud. "Slight Mass Gain of Karakoram Glaciers in the Early Twenty-First Century." *Nature Geoscience* 5 (2012): 322–25. https://doi.org/10.1038/ngeo1450.

[42] IPCC (Intergovernmental Panel on Climate Change). "Summary for Policymakers." In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by V. Masson-Delmotte et al. Cambridge: Cambridge University Press, 2021. https://www.ipcc.ch/report/ar6/wg1/.

[43] Hausfather, Zeke, Kate Marvel, Gavin A. Schmidt, John W. Nielsen-Gammon, and Mark Zelinka. "Climate Simulations: Recognize the 'Hot Model' Problem." *Nature* 605 (2022): 26–29. https://doi.org/10.1038/d41586-022-01192-2.

[44] McKitrick, Ross, and John Christy. "Pervasive Warming Bias in CMIP6 Tropospheric Layers." *Earth and Space Science* 7, no. 9 (2020): e2020EA001281. https://doi.org/10.1029/2020EA001281.

[45] Fyfe, John C., Gerald A. Meehl, Matthew H. England, Michael E. Mann, Benjamin D. Santer, Gregory M. Flato, Ed Hawkins, et al. "Making Sense of the Early-2000s Warming Slowdown." *Nature Climate Change* 6, no. 3 (2016): 224–28. https://doi.org/10.1038/nclimate2938.

[46] Rural Voice. "Government Estimates Record 376.56 Million Tonnes Foodgrain Production in 2025-26, Up 5.3% from Last Year." May 27, 2026. https://eng.ruralvoice.in/national/government-estimates-record-376.56-million-tonnes-foodgrain-production-in-2025-26-up-5.3pc-from-last-year.html.

[47] NOAA CPC (National Oceanic and Atmospheric Administration, Climate Prediction Center). "Cold & Warm Episodes by Season." n.d. Accessed October 6, 2026. https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php.

[48] ETV Bharat. "Kharif Sowing Area Down 17.69 Lakh Hectares from Last Year as Rice Coverage Falls: MoAFW." September 8, 2026. https://www.etvbharat.com/en/bharat/kharif-sowing-area-down-over-17-lakh-hectares-from-last-year-as-rice-coverage-falls-says-moafw-enn26090804576.

[49] Zhu, Zaichun, Shilong Piao, Ranga B. Myneni, et al. "Greening of the Earth and Its Drivers." *Nature Climate Change* 6 (2016): 791–95. https://doi.org/10.1038/nclimate3004.

[50] Chen, Chi, Taejin Park, Xuhui Wang, Shilong Piao, Baodong Xu, Rajiv K. Chaturvedi, Richard Fuchs, et al. "China and India Lead in Greening of the World through Land-Use Management." *Nature Sustainability* 2, no. 2 (2019): 122–29. https://doi.org/10.1038/s41893-019-0220-7.

[51] S&P Global. "COP26: Nations Strike Deal in Glasgow after Late Watering Down of Coal Phase-Out Clause." S&P Global Commodity Insights, November 13, 2021. https://www.spglobal.com/commodity-insights/en/news-research/latest-news/energy-transition/111321-cop26-nations-strike-deal-in-glasgow-after-late-watering-down-of-coal-phase-out-clause.

[52] UNFCCC (United Nations Framework Convention on Climate Change). *Glasgow Climate Pact*. Decision 1/CMA.3, 2021. https://unfccc.int/documents/310497.

[53] Jurist. "Trump Orders US Withdrawal from 66 International Organizations, Including UN Climate Bodies." January 2026. https://www.jurist.org/news/2026/01/trump-orders-us-withdrawal-from-66-international-organizations-including-un-climate-bodies/.

[54] Joseph, Ligin, Nikolaos Skliris, Dipanjan Dey, Robert Marsh, and Joël Hirschi. "Increased Summer Monsoon Rainfall over Northwest India Caused by Hadley Cell Expansion and Indian Ocean Warming." *Geophysical Research Letters* 51, no. 16 (2024): e2024GL108829. https://doi.org/10.1029/2024GL108829.

[55] Singh, Hajari, and M. P. Choudhary. "Trend and Homogeneity Test Analysis for Rainfall over a 121-Year Time Period in the Desert District of Western Rajasthan, India." *Water Practice & Technology* 18, no. 7 (2023): 1681–95. https://doi.org/10.2166/wpt.2023.100.

[56] Patel, Shahid, Darshan Mehta, Vijendra Kumar, Shakera Patel, and Deepak Kumar Tiwari. "Trend Analysis of Precipitation and Drought Characteristics over Churu District of Northeast Rajasthan, India." *Journal of Water and Climate Change* 15, no. 9 (2024): 4457–75. https://doi.org/10.2166/wcc.2024.144.

[57] Mishra, Vimal, Hiren Solanki, and Ramakrishna Nemani. "Greening of the Thar Desert Driven by Climate Change and Human Interventions." *Cell Reports Sustainability* 2, no. 5 (2025): 100364. https://doi.org/10.1016/j.crsus.2025.100364.

[58] PIB (Press Information Bureau). "Third Advance Estimates Reflect India's Agricultural Strength; Union Minister Shri Shivraj Singh Chouhan Approves Record Crop Projections." Ministry of Agriculture and Farmers Welfare, press release, May 27, 2026. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2265965.

[59] Global Agriculture. "India's Horticulture Production Estimated at Record 377.8 Million Tonnes in 2025-26." June 2026. https://www.global-agriculture.com/india-region/indias-horticulture-production-estimated-at-record-377-8-million-tonnes-in-2025-26/.

[60] DAHD (Department of Animal Husbandry and Dairying). *Basic Animal Husbandry Statistics 2025*. New Delhi: Ministry of Fisheries, Animal Husbandry and Dairying, 2025. https://dahd.gov.in/sites/default/files/2026-02/BAHS2025.pdf.

[61] News On AIR. "Govt Says Fish Production in Country Increased to 198 Lakh Tonnes in 2024-25 from 95 Lakh Tonnes in 2013-14." All India Radio, January 12, 2026. https://www.newsonair.gov.in/govt-says-fish-production-in-country-increased-to-198-lakh-tonnes-in-2024-25-from-95-lakh-tonnes-in-2013-14.

[62] Bubna, Udit. "172 Countries & Counting: India Looks to Hit New Record in Rice Exports, but There's a Flip Side." *ThePrint*, November 24, 2025. https://theprint.in/economy/172-countries-counting-india-looks-to-hit-new-record-in-rice-exports-but-theres-a-flip-side/2790840/.

[63] FSI (Forest Survey of India). *India State of Forest Report 2023*. Dehradun: FSI, Ministry of Environment, Forest and Climate Change, 2024. https://fsi.nic.in/forest-report-2023.

[64] PIB (Press Information Bureau). "India's Expanding Green Footprint." Backgrounder, October 24, 2025. https://static.pib.gov.in/WriteReadData/specificdocs/documents/2025/oct/doc20251024675101.pdf.

[65] Qureshi, Q., Y. V. Jhala, S. P. Yadav, and A. Mallick. *Status of Tigers, Co-predators and Prey in India, 2022*. New Delhi and Dehradun: National Tiger Conservation Authority and Wildlife Institute of India, 2023. https://ntca.gov.in/assets/uploads/Reports/AITM/status_of_tiger-copredators-2022.pdf.

[66] Gujarat Forest Department. *Asiatic Lion Population Estimation 2025*. Gandhinagar: Government of Gujarat, 2025. https://girlion.gujarat.gov.in/Documents/Uploads/NewsUpdates/Lion_Population_Estimation_2025_Report_L.pdf.

[67] Mongabay India. "Asiatic Lion Population Has Grown 172% in 25 Years." June 2025. https://india.mongabay.com/short-article/2025/06/asiatic-lion-population-has-grown-172-in-25-years/.

[68] Amarjeet, Vasubandhu Misra, Arun Chakraborty, Anil K. Gupta, and Vineet Sharma. "A Study of Recent Changes in Moisture Flux Patterns over India: Implications for Indian Summer Monsoon Rainfall." *International Journal of Climatology* 45, no. 11 (2025): e8927. https://doi.org/10.1002/joc.8927.

[69] Bajrang, C., Raju Attada, and B. N. Goswami. "Possible Factors for the Recent Changes in Frequency of Central Indian Summer Monsoon Precipitation Extremes during 2005–2020." *npj Climate and Atmospheric Science* 6 (2023): 120. https://doi.org/10.1038/s41612-023-00450-y.

[70] Kashyap, Rahul, Jayanarayanan Kuttippurath, and Vikas Kumar Patel. "Agriculture Intensification and Moisture-Induced Thar Desert Greening: Implications for Energy Balance, Socio-economy, and Biodiversity." *GIScience & Remote Sensing* 62, no. 1 (2025): 2483458. https://doi.org/10.1080/15481603.2025.2483458.

[71] Factly. "Data: Marginal Decrease in Annual Ground Water Recharge in 2024 with Minimal Increase in Extraction." n.d. Accessed October 9, 2026. https://factly.in/data-marginal-decrease-in-annual-ground-water-recharge-in-2024-with-minimal-increase-in-extraction.

[72] PIB (Press Information Bureau). "Findings of Dynamic Groundwater Resources Assessment." Ministry of Jal Shakti, press release, December 18, 2025. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2206073.

[73] Ministry of Jal Shakti. "India's Groundwater Revival: Making the Invisible Visible." PIB backgrounder, January 6, 2025. https://static.pib.gov.in/WriteReadData/specificdocs/documents/2025/jan/doc202516481601.pdf.

[74] Thirumala Lakshmi, K. "Rainfall Trends and Their Influence on Crop Production in Tamil Nadu, India: A 33-Year Analysis." *Mausam* 77, no. 2 (2026): 579–90. https://doi.org/10.54302/mausam.v77i2.6830.

[75] Athira, K. S., Raju Attada, and Sulekha Komeravelli. "Cold Stress during Winter over North India: Patterns, Trends, and Mortality Risks." *PLOS ONE* 21, no. 6 (2026): e0351740. https://doi.org/10.1371/journal.pone.0351740.

[76] PIB (Press Information Bureau). "National Milk Day: Honouring the White Revolution." Backgrounder, November 25, 2025. https://static.pib.gov.in/WriteReadData/specificdocs/documents/2025/nov/doc20251125706201.pdf.

[77] Kumar, Nalini Ranjan, Shilpi Kapoor, S. K. Srivastava, and Naveen P. Singh. "Observed vis-à-vis Projected Crops Yield in India in the Context of Climate Change." *Current Science* 124, no. 1 (2023): 18–25. https://doi.org/10.18520/cs/v124/i1/18-25.

[78] Bharti, Harish, Aditi Panatu, Priyanka Sharma, S. S. Randhawa, Satpal Dhiman, and R. S. Rana. "Impact of Climatic Variations in Horticulture Sector, Kinnaur, Himachal Pradesh, India." *Mausam* 75, no. 2 (2024): 313–26. https://doi.org/10.54302/mausam.v75i2.827.

[79] Helman, David, and David J. Bonfil. "Six Decades of Warming and Drought in the World's Top Wheat-Producing Countries Offset the Benefits of Rising CO2 to Yield." *Scientific Reports* 12 (2022): 7921. https://doi.org/10.1038/s41598-022-11423-1.

[80] Lin, Tzu-Shun, and Atul K. Jain. "Management Practices and Elevated Atmospheric CO2 Levels Helped to Sustain a High Level of Global Rice Production." *Scientific Reports* 16 (2026): 26872. https://doi.org/10.1038/s41598-026-55973-0.

[81] Outlook. "India's Forest and Tree Cover Grows by 1,445 Sq Km in Two Years, Claims Govt Report." December 21, 2024. https://www.outlookindia.com/national/indias-forest-and-tree-cover-grows-by-1445-sq-km-in-two-years-claims-govt-report.

[82] FSI (Forest Survey of India). *India State of Forest Report 2011*. Dehradun: FSI, Ministry of Environment and Forests, 2011.

[83] Suyal, B. D. "The Dynamics of Forest Cover of India Based on Assessments Done by Forest Survey of India from 1987 to 2015." *Indian Forester* 143, no. 9 (2017): 931–38. https://doi.org/10.36808/if/2017/v143i9/118900.

[84] Jhala, Yadvendradev, Ninad Mungi, Rajesh Gopal, and Qamar Qureshi. "Tiger Recovery amid People and Poverty." *Science* 387, no. 6733 (2025): 505–10. https://doi.org/10.1126/science.adk4827.

[85] Qureshi, Q., Y. V. Jhala, et al. *Status of Leopards in India, 2022*. New Delhi and Dehradun: National Tiger Conservation Authority and Wildlife Institute of India, 2024. https://ntca.gov.in/assets/uploads/Reports/AITM/Leopard_status_2022_ISBN_corrected_1.pdf.

[86] Ghai, Rajat. "Prince of the Cats: India Has Nearly 14,000 Leopards, Centre's Report Reveals." *Down To Earth*, February 29, 2024. https://www.downtoearth.org.in/wildlife-biodiversity/prince-of-the-cats-india-has-nearly-14-000-leopards-centre-s-report-reveals-94733.

[87] WWF-India. "The Greater One-Horned Rhino Estimation." n.d. Accessed October 9, 2026. https://wwfindia.org/news_facts/feature_stories/the_greater_one_horned_rhino_estimation.

[88] Raina, Pankaj, Ninad Avinash Mungi, Ujjwal Kumar, Aman Deep Rathi, Niazul H. Khan, Dimpi A. Patel, Anchal Bhasin, et al. "Comprehensive Assessment of Snow Leopard Distribution and Population in the Indian Trans-Himalaya, Ladakh: Standardizing Methods for Evidence-Based Conservation." *PLOS ONE* 20, no. 5 (2025): e0322136. https://doi.org/10.1371/journal.pone.0322136.

[89] Nitnaware, Himanshu. "India Has 718 Snow Leopards; Most of Them Live in Unprotected Areas: Centre." *Down To Earth*, January 30, 2024. https://www.downtoearth.org.in/wildlife-biodiversity/india-has-718-snow-leopards-most-of-them-live-in-unprotected-areas-centre-94174.

[90] Hussain, Syed Ainul, Surya Prasad Sharma, Ashish Kumar Panda, Aftab Alam Usmani, Goura Chandra Das, Neeraj Mahar, Ajay Prakash Rawat, et al. "Recovery of the Critically Endangered Gharial (*Gavialis gangeticus*) amid Escalating Anthropogenic Pressures in the Ganga River Basin." *Frontiers in Conservation Science* 7 (2026): 1920905. https://doi.org/10.3389/fcosc.2026.1920905.

[91] Dutta, Supratim, and Ramesh Krishnamurthy. "Successful Conservation Translocation: Population Dynamics of Tiger Recovery in Panna Tiger Reserve, Central India." *Ecological Solutions and Evidence* 5 (2024): e12337. https://doi.org/10.1002/2688-8319.12337.

[92] Dutta, Deba Kumar, Amal Chandra Sarmah, Amit Sharma, Bibhab Kumar Talukdar, and Anindya Swargowari. "The Recruitment Pattern and Inter-calving Interval of the Reintroduced Greater One-Horned Rhinoceros (*Rhinoceros unicornis*) Population in Manas National Park, Assam, India." *Pachyderm* 66 (2025): 72–84. https://doi.org/10.69649/pachyderm.v66i.1322.

[93] Mongabay. "Rare Swamp Deer Subspecies Thriving in New Home in India." May 2026. https://news.mongabay.com/short-article/2026/05/rare-swamp-deer-subspecies-thriving-in-new-home-in-india/.

[94] PIB (Press Information Bureau). *New India Samachar*, July 1–15, 2026, 42.https://newindiasamachar.pib.gov.in/WriteReadData/flipbook/2026/Jul/1st/English/files/basic-html/page42.html.

[95] IMD (India Meteorological Department). *Annual Report 2025*. New Delhi: Ministry of Earth Sciences, Government of India. Accessed October 13, 2026. https://metnet.imd.gov.in/docs/imdnews/ANNUAL_REPORT2025English.pdf.

[96] IMD (India Meteorological Department), Climate Research and Services, Pune. "All India Time Series of Temperature (1901–2024)." Accessed October 13, 2026. https://imdpune.gov.in/cmpg/Product/allindia_temp.html.

[97] Ritchie, Hannah, Pablo Rosado, and Veronika Samborska. "Monthly Temperature Anomalies." In "Climate Change." Our World in Data, 2024. Data adapted from Copernicus Climate Change Service information. Archived October 13, 2026. https://archive.ourworldindata.org/20261013-084505/grapher/monthly-temperature-anomalies.html.

[98] Ritchie, Hannah, Pablo Rosado, and Max Roser. "Data Page: Annual Number of Deaths from Extreme Temperatures." In "Natural Disasters." Our World in Data, 2022. Data adapted from EM-DAT. Archived October 12, 2026. https://archive.ourworldindata.org/20261012-190130/grapher/natural-disasters-deaths.html.

[99] Ritchie, Hannah, Pablo Rosado, and Max Roser. "Decadal Average: Annual Death Rate from All Natural Disasters." In "Natural Disasters." Our World in Data, 2022. Data adapted from EM-DAT, CRED/UCLouvain. Accessed October 13, 2026. https://ourworldindata.org/grapher/decadal-average-death-rates-from-natural-disasters.

[100] Ritchie, Hannah, Pablo Rosado, and Max Roser. "Data Page: Annual Number of People Affected by All Natural Disasters Excluding Extreme Temperatures." In "Natural Disasters." Our World in Data, 2022. Data adapted from EM-DAT. Archived October 7, 2026. https://archive.ourworldindata.org/20261007-072943/grapher/natural-disasters-people-affected.html.

[101] Spencer, Roy W. *Global Warming: Observations vs. Climate Models*. Backgrounder No. 3809. Washington, DC: The Heritage Foundation, January 24, 2024. https://report.heritage.org/bg3809.

[102] Swapna, P., M. Ravichandran, G. Nidheesh, J. Jyoti, N. Sandeep, and J. S. Deepa. "Sea-Level Rise." In *Assessment of Climate Change over the Indian Region: A Report of the Ministry of Earth Sciences (MoES), Government of India*, edited by R. Krishnan, J. Sanjay, Chellappan Gnanaseelan, Milind Mujumdar, Ashwini Kulkarni, and Supriyo Chakraborty. Singapore: Springer, 2020. https://doi.org/10.1007/978-981-15-4327-2_9.

[103] MoES (Ministry of Earth Sciences). "Rise in Sea Level." Reply to Lok Sabha Starred Question No. 109, December 12, 2013. https://moes.gov.in/sites/default/files/LS109_15_15_2013.pdf.

[104] MoEFCC (Ministry of Environment, Forest and Climate Change). "Increase in Sea-Level in Coastal Areas." Reply to Lok Sabha Unstarred Question No. 3329, March 13, 2020. Accessed October 16,

2026. https://www.datais.info/loksabha/question/Increase+in+Sea-Level+in+Coastal+Areas/49ef5f9e842601b2ddde63ad26e68459/.

[105] PIB (Press Information Bureau). "Parliament Question: Changes in Weather Cycle Due to Climate Change." Ministry of Earth Sciences, March 19, 2026. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2242357.

[106] Sadhasivam, Niteshnirmal, et al. "Building Damage Risk in Sinking Indian Megacities." *Nature Sustainability* 8, no. 12 (2025): 1467–79. https://doi.org/10.1038/s41893-025-01663-0.

[107] Mumbai City District Administration. "History." Government of Maharashtra. Accessed October 16, 2026. https://mumbaicity.gov.in/?p=1532.

[108] Gupta, Sourendu. "History of Land Reclamation in Mumbai." Mumbai/Bombay Pages, Tata Institute of Fundamental Research, 1999. https://theory.tifr.res.in/bombay/history/reclamation.html.

[109] PIB (Press Information Bureau). "Coastal Erosion." Ministry of Environment, Forest and Climate Change, December 4, 2023. https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=1982315.

[110] Nidheesh, A. G., Archit Wadalkar, Abhisek Chatterjee, Aneesh Lotliker, R. S. Mahendra, P. C. Mohanty, Ch. Lakshmi Sravani, et al. *An Interim Report on the Projected Climate Change Induced Extreme Sea Levels and Coastal Vulnerability along the Indian Coasts*. Technical Report ESSO-INCOIS-OMDA-TR-04(2025). Hyderabad: Indian National Centre for Ocean Information Services, July 25, 2025. https://incois.gov.in/documents/Reports/TechnicalReports/TR_ESSO-INCOIS-OMDA-TR-04(2025)_20250725114934.pdf.

[111] PIB (Press Information Bureau). "Parliament Question: Sea-Level Rise and Coastal City Vulnerabilities." Ministry of Earth Sciences, July 31, 2025. https://pib.gov.in/PressReleasePage.aspx?PRID=2150834.

[112] PIB (Press Information Bureau). "Parliament Question: Vulnerability of Coastal Region to Flood and Sea Level Rise." Ministry of Earth Sciences, December 10, 2025. https://pib.gov.in/PressReleasePage.aspx?PRID=2201535.

[113] Srivastava, Kanchan. "Most Forest Fires in India on Account of Human Activity." Mongabay India, January 22, 2020. https://india.mongabay.com/2020/01/most-forest-fires-in-india-on-account-of-human-activity/.

[114] Ground Report. "Forest Fires Burn 34,562 Sq Km Across India, Madhya Pradesh Among Worst Hit." December 9, 2025. https://www.groundreport.in/states-madhya-pradesh/forest-fires-burn-34562-sq-km-across-india-madhya-pradesh-among-worst-hit/.

[115] PIB (Press Information Bureau). "National Action Plan on Forest Fire Empowers All Stakeholders to Reduce Vulnerability of Forests against Fire Hazards." Ministry of Environment, Forest and Climate Change, March 16, 2023. https://pib.gov.in/Pressreleaseshare.aspx?PRID=1907678.

[116] MoEFCC (Ministry of Environment, Forest and Climate Change). "Increase in Forest Fires." Reply to Lok Sabha Unstarred Question No. 1863, July 30, 2021. https://eparlib.sansad.in/bitstream/123456789/939340/1/AU1863.pdf.

[117] PRS Legislative Research. "Forest Fires in the Himalayan Region, Its Adverse Effects and Mitigation Measures." Summary of the report of the Standing Committee on Science and Technology, Environment, Forests and Climate Change, August 2026. https://prsindia.org/policy/report-summaries/forest-fires-in-the-himalayan-region-its-adverse-effects-and-mitigation-measures.

[118] Business Standard. "67% of Major Forest Fires in 2023-24 Doused within 24 Hours, Shows Data." January 2025. Summarized by Vision IAS, January 4, 2025. https://visionias.in/current-affairs/upsc-daily-news-summary/article/2025-01-04/business-standard/environment/67-of-major-forest-fires-in-2023-24-doused-within-24-hours-shows-data.

[119] MoEFCC (Ministry of Environment, Forest and Climate Change). "Prevention of Forest Fires." Reply to Lok Sabha Unstarred Question No. 51, July 22, 2024. https://eparlib.nic.in/bitstream/123456789/2980320/1/AU51_hVtraP.pdf.

[120] MoEFCC (Ministry of Environment, Forest and Climate Change). "Impact of Climate-Driven Wildfires on Greenhouse Gas Emissions." Reply to Rajya Sabha Unstarred Question No. 2299, March 20, 2025. Accessed October 16, 2026. https://toxicslink.org/parliament-q-a/impact-of-climate-driven-wildfires-on-greenhouse-gas-emissions/.

[121] Kashmir Life. "Jammu Kashmir Lost Nearly 440 Sq Km to Forest Fires." December 8, 2025. https://kashmirlife.net/jammu-kashmir-lost-nearly-440-sq-km-to-forest-fires-416155/.

[122] EPA (U.S. Environmental Protection Agency). "Learn About Heat Islands." Heat Island Effect website, January 2017 archived snapshot. Accessed November 9, 2026. https://19january2017snapshot.epa.gov/heat-islands/learn-about-heat-islands_.html.

[123] NASA Jet Propulsion Laboratory. "NASA's ECOSTRESS Maps European Heat Wave from Space." News release, July 2, 2019. https://www.jpl.nasa.gov/news/nasas-ecostress-maps-european-heat-wave-from-space/.

[124] Wu, Kai, and XiuQun Yang. "Urbanization and Heterogeneous Surface Warming in Eastern China." *Chinese Science Bulletin* 58, no. 12 (2013): 1363–73. https://doi.org/10.1007/s11434-012-5627-8.

[125] To, Wai Ming, and Tat Wai Yu. "Characterizing the Urban Temperature Trend Using Seasonal Unit Root Analysis: Hong Kong from 1970 to 2015." *Advances in Atmospheric Sciences* 33, no. 12 (2016): 1376–85. https://doi.org/10.1007/s00376-016-6113-z.

[126] Mohan, Manju, Yukihiro Kikegawa, B. R. Gurjar, Shweta Bhati, Anurag Kandya, and Koichi Ogawa. "Urban Heat Island Assessment for a Tropical Urban Airshed in India." *Atmospheric and Climate Sciences* 2 (2012): 127–38. https://doi.org/10.4236/acs.2012.22014.

[127] Babazadeh, Mina, and Pradeep Kumar. "Estimation of the Urban Heat Island in Local Climate Change and Vulnerability Assessment for Air Quality in Delhi." *European Scientific Journal* 11, no. 10 (2015). https://eujournal.org/index.php/esj/article/view/5712.

[128] Kikon, Noyingbeni, Prafull Singh, Sudhir Kumar Singh, and Anjana Vyas. "Assessment of Urban Heat Islands (UHI) of Noida City, India Using Multi-temporal Satellite Data." *Sustainable Cities and Society* 22 (2016): 19–28. https://doi.org/10.1016/j.scs.2016.01.005.

[129] Grover, Aakriti, and Ram Babu Singh. "Analysis of Urban Heat Island (UHI) in Relation to Normalized Difference Vegetation Index (NDVI): A Comparative Study of Delhi and Mumbai." *Environments* 2, no. 2 (2015): 125–38. https://doi.org/10.3390/environments2020125.

[130] Singh, Prafull, Noyingbeni Kikon, and Pradipika Verma. "Impact of Land Use Change and Urbanization on Urban Heat Island in Lucknow City, Central India: A Remote Sensing Based Estimate." *Sustainable Cities and Society* 32 (2017): 100–114. https://doi.org/10.1016/j.scs.2017.02.018.

[131] Barat, Archisman, Sunny Kumar, Praveen Kumar, and P. Parth Sarthi. "Characteristics of Surface Urban Heat Island (SUHI) over the Gangetic Plain of Bihar, India." *Asia-Pacific Journal of Atmospheric Sciences* 54, no. 2 (2018): 205–14. https://doi.org/10.1007/s13143-018-0004-4.

[132] TERI (The Energy and Resources Institute). "Planning Our Cities Better to Make Our Houses Cooler." Project summary, Urban Planning Characteristics to Mitigate Climate Change in Context of Urban Heat Island Effect, 2017. Accessed November 9, 2026. https://teriin.org/project/planning-our-cities-better-make-our-houses-cooler.

[133] TERI (The Energy and Resources Institute), Bangalore. "Sustainable Urban Development: Minimising Urban Heat Island Effect and Imperviousness Factor." GRIHA news, February 15, 2013. Accessed November 9, 2026. https://grihaindia.org/node/1695.

[134] Ramachandra, T. V., and Uttam Kumar. "Greater Bangalore: Emerging Urban Heat Island." *GIS Development* 14, no. 1 (2010). https://wgbis.ces.iisc.ac.in/energy/paper/Bangalore_heatisland/index.htm.

[135] Amirtham, Lilly Rose. "Urbanization and Its Impact on Urban Heat Island Intensity in Chennai Metropolitan Area, India." *Indian Journal of Science and Technology* 9, no. 5 (2016). https://doi.org/10.17485/ijst/2016/v9i5/87201.

[136] Mathew, Aneesh, Sumit Khandelwal, and Nivedita Kaul. "Analysis of Diurnal Surface Temperature Variations for the Assessment of Surface Urban Heat Island Effect over Indian Cities." *Energy and Buildings* 159 (2018): 271–95. https://doi.org/10.1016/j.enbuild.2017.10.062.

[137] Sethi, Soumya Satyakanta, and V. Vinoj. "Urbanization and Regional Climate Change-Linked Warming of Indian Cities." *Nature Cities* 1 (2024). https://doi.org/10.1038/s44284-024-00074-0.

[138] Down To Earth. "Almost 76 Per Cent of Delhi Is Persistently Heat Stressed in Summers, Says New CSE Report." May 2026. https://www.downtoearth.org.in/climate-change/almost-76-per-cent-of-delhi-is-persistently-heat-stressed-in-summers-says-new-cse-report.

[139] Murali, J., and Arpan Pradhan. "Urban Heat Island in Bengaluru: Built-up Growth and Temperature Trends." *E3S Web of Conferences* 648 (2025): 02019. https://doi.org/10.1051/e3sconf/202564802019.

[140] Gloria, S. Joy, and Shanmuga Priya Gnanasekaran. "Impact of Urban Vegetation Loss on Urban Heat Islands: A Case Study of Chennai Metropolitan Area." *Indian Journal of Science and Technology* 17, no. 2 (2024): 134–41. https://indjst.org/articles/impact-of-urban-vegetation-loss-on-urban-heat-islands-a-case-study-of-chennai-metropolitan-area.

[141] Khan, Danish, and Nizamuddin Khan. "Modelling Urban Future: Integrating CA-ANN Model for Comprehensive Understanding of Land Use, Land Cover Changes, and Temperature Dynamics in Lucknow City, India." *Geology, Ecology, and Landscapes* (2025). https://doi.org/10.1080/24749508.2025.2524207.

[142] Boyaj, A., N. R. Karrevula, P. Sinha, P. Patel, U. C. Mohanty, and D. Niyogi. "Impact of Increasing Urbanization on Heatwaves in Indian Cities." *International Journal of Climatology* (2024). https://doi.org/10.1002/joc.8570.

[143] Rodell, Matthew, Isabella Velicogna, and James S. Famiglietti. "Satellite-Based Estimates of Groundwater Depletion in India." *Nature* 460 (2009): 999–1002. https://doi.org/10.1038/nature08238.

[144] Hugonnet, Romain, Robert McNabb, Etienne Berthier, Brian Menounos, Christopher Nuth, Luc Girod, Daniel Farinotti, Matthias Huss, Ines Dussaillant, Fanny Brun, and Andreas Kääb. "Accelerated Global Glacier Mass Loss in the Early Twenty-First Century." *Nature* 592 (2021): 726–31. https://doi.org/10.1038/s41586-021-03436-z.

[145] The GlaMBIE Team. "Community Estimate of Global Glacier Mass Changes from 2000 to 2023." *Nature* 639 (2025): 382–88. https://doi.org/10.1038/s41586-024-08545-z.

[146] ICIMOD (International Centre for Integrated Mountain Development). "Consequences of Climate Change for the Cryosphere in the Hindu Kush Himalaya." Chapter 2 in *Water, Ice, Society, and Ecosystems in the Hindu Kush Himalaya: An Outlook*. Kathmandu: ICIMOD, 2023. https://lib.icimod.org/record/36324/files/HI-WISE_Report_Chapter2_Consequence_of_Climate_Change_for_the_Cryosphere_in_the_HKH.pdf.

[147] Esper, Jan, Fritz H. Schweingruber, and Matthias Winiger. "1300 Years of Climatic History for Western Central Asia Inferred from Tree-Rings." *The Holocene* 12, no. 3 (2002): 267–77. https://doi.org/10.1191/0959683602hl543rp.

[148] Treydte, Kerstin S., David C. Frank, Matthias Saurer, Gerhard Helle, Gerhard H. Schleser, and Jan Esper. "Impact of Climate and CO_2 on a Millennium-Long Tree-Ring Carbon Isotope Record." *Geochimica et Cosmochimica Acta* 73 (2009): 4635–47. https://doi.org/10.1016/j.gca.2009.05.057.

[149] Li, Xiumei, Yong Zhang, Mingda Wang, Junhui Yan, Baowei Fan, Wei Xing, Yue He, and Juzhi Hou. "Centennial-Scale Temperature Change during the Common Era Revealed by Quantitative Temperature Reconstructions on the Tibetan Plateau." *Frontiers in Earth Science* 8 (2020): 360. https://doi.org/10.3389/feart.2020.00360.

[150] Hewitt, Kenneth. "Understanding Glacier Changes." *The Third Pole* (now Dialogue Earth), n.d. Accessed November 9, 2026. https://dialogue.earth/en/climate/3478-understanding-glacier-changes-1/.

Contributors

Vijay Raj Jayaraj is an environmental scientist and energy analyst. He holds a master's degree in environmental sciences from the University of East Anglia, U.K., a postgraduate degree in energy management from Robert Gordon University, U.K., and a bachelor's degree in engineering from Anna University, India. He has previously worked as a research assistant at the University of British Columbia, studying the impact of climate change on the global fisheries economy.