Journal of Materials and Environmental Science
ISSN : 2028-2508
e-ISSN : 2737-890X
CODEN : JMESCN

J. Mater. Environ. Sci., 2025, Volume 16, Issue 12, Page 2232-2263

http://www.jmaterenvironsci.com

Environment, Climate Change, and Society in India

Arzoo Rana[1]*, Deepak Kumar Saini[2]

[1]*SoS, Sociology, Maharaja Chhatrasal Bundelkhand University, Chhatarpur (M.P.) 471001, India*
[2]*Department of Botany & Microbiology, Govt. Kamla Raja Girls PG College, Gwalior (M.P.) 474001, India*
**Corresponding author, Email address: ranaaarzoo@gmail.com*

Received *16 Sept 2025,*
Revised *26 Oct 2025,*
Accepted *29 Oct 2025*

Keywords:
- ✓ *Climate change;*
- ✓ *India;*
- ✓ *Environment;*
- ✓ *Social vulnerability;*
- ✓ *Adaptation;*
- ✓ *Sustainable development;*
- ✓ *Climate justice*

Citation*: Rana A., Saini D. K., (2025) Environment, Climate Change, and Society in India, J. Mater. Environ. Sci., 16(12), 2232-2263*

Abstract: India faces one of the most complex intersections of environmental degradation, climate change, and social vulnerability in the world. Rapid urbanization, industrialization, population growth, and unsustainable resource use have intensified ecological pressures. Climate change exacerbates these challenges, affecting agriculture, water resources, public health, and urban resilience. Vulnerability is unevenly distributed across regions, genders, castes, and income groups, raising critical issues of climate justice and social equity. This review synthesizes existing research on India's environmental and climate context, societal impacts, policy frameworks, civil society responses, and sustainable development pathways. Historical movements such as the Chipko Movement, Silent Valley, and Narmada Bachao Andolan illustrate the long standing engagement of communities and civil society in environmental protection. Contemporary challenges include integrating adaptation and mitigation strategies into national and local planning, promoting renewable energy, climate-smart agriculture, water management, and urban resilience. Future pathways emphasize low-carbon transitions, community-led adaptation, inclusive governance, climate justice, and behavior change. By linking environmental science, social vulnerability, policy, and governance, this review provides a holistic understanding of the complex interrelationships between climate change and society in India. It also identifies key opportunities for sustainable development, emphasizing equity, resilience, and participatory governance as essential components for a sustainable future.

1. Introduction

India is a diverse country with varied ecosystems. It has mountains, rivers, forests, deserts, and long coastlines. These environments support over 1.4 billion people. The relationship between people and the environment is complex in India. Human activity shapes nature, and nature shapes human life. Climate change is now a critical challenge in India. Rising temperatures, changing rainfall, and frequent disasters affect both rural and urban populations. Climate change adds pressure to already stressed resources. India faces poverty, population growth, and inequality. All these factors increase vulnerability to environmental risks. The link between society and environment in India has deep roots. Agriculture has been the backbone of Indian society for centuries. It depends on monsoon rains. A small shift in climate patterns can disrupt farming. It can harm food security. This shows how environment and society are connected (Dagdeviren *et al*., 2021; Rao *et al*, 2024).

1.1 Global and national context

India is among the world's fastest growing economies, but this rapid growth comes with significant environmental costs. Industrialization, urban expansion, and rising energy consumption have contributed to high pollution levels. The country is now the third largest emitter of greenhouse gases, though its per capita emissions remain lower than those of many developed nations. To tackle climate change, India has signed the Paris Agreement and committed to reducing its emission intensity while expanding renewable energy use. However, the challenge lies in achieving these goals while continuing to lift millions of people out of poverty. Striking a balance between development and sustainability remains a complex and ongoing struggle (Dubash *et al*., 2018; IEA, 2022). A bibliometric analysis serves as a valuable approach to assess scientific productivity, identify leading authors and countries, and explore collaboration networks across institutions (Bazzi *et al*., 2023; Kadda *et al*., 2025). It also reveals the most cited papers and the journals most frequently selected by researchers, providing insights into influential publications and preferred research outlets within the field (Lrhoul *et al*., 2023; Pacheco Aispuro *et al*., 2023; Ansorge, 2024; Hammouti *et al*., 2025). More than 10,200 Scopus-indexed documents have been published under the theme "Environment, Climate Change, and Society." Among these, over 95% consist of research articles, book chapters, conference papers, and books (**Figure 1**). When focusing on India within this context, 494 publications were identified, placing the country in the 8th position globally, after the United States, United Kingdom, China, Australia, Canada, Germany, and France (**Figure 2**).

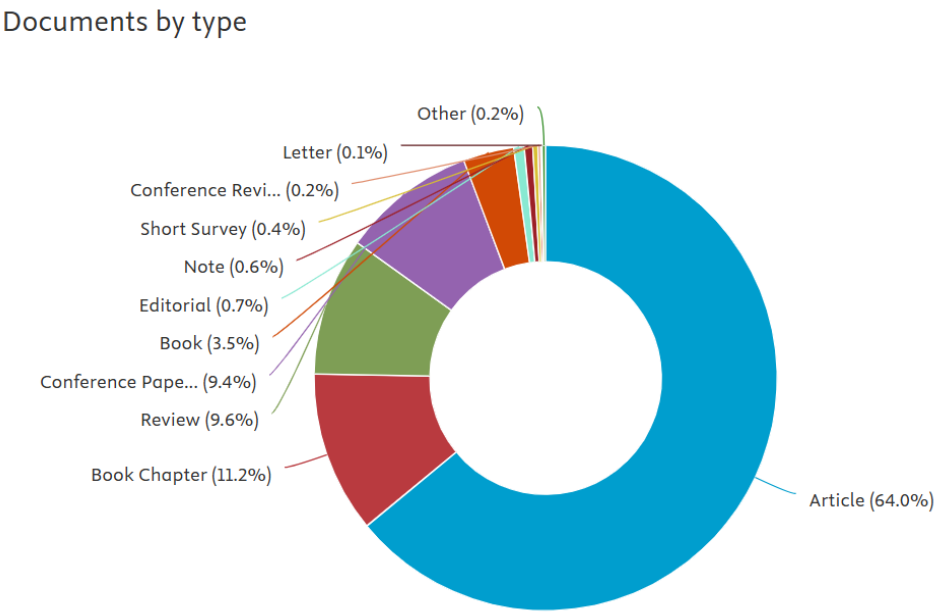

Figure 1. Patterns of research productivity

The relationship between the environment, climate change, and society is deeply interconnected and multifaceted. Climate change has disrupted natural systems and affected billions of people by influencing health, food and water security, infrastructure, and patterns of displacement. At the same time, human activities have significantly contributed to climate change, leaving society with the dual challenge of adapting to its consequences and reducing future greenhouse gas emissions. This relationship is cyclical, societal systems, economies, and lifestyles that once evolved under a stable climate are now being strained by shifting environmental conditions. Since 1995, the United Nations has held annual conferences to coordinate global climate action. This growing international focus has

been paralleled by a sharp rise in scientific research, increasing from about 20 publications in 1995 to more than 800 in recent years (**Figure 3**).

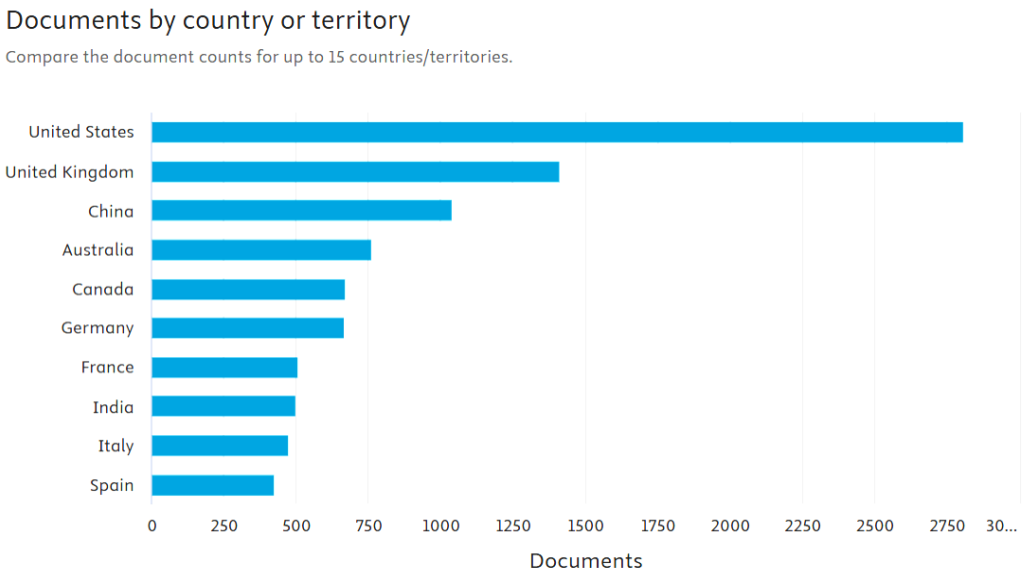

Figure 2. Global leaders in research on these topics

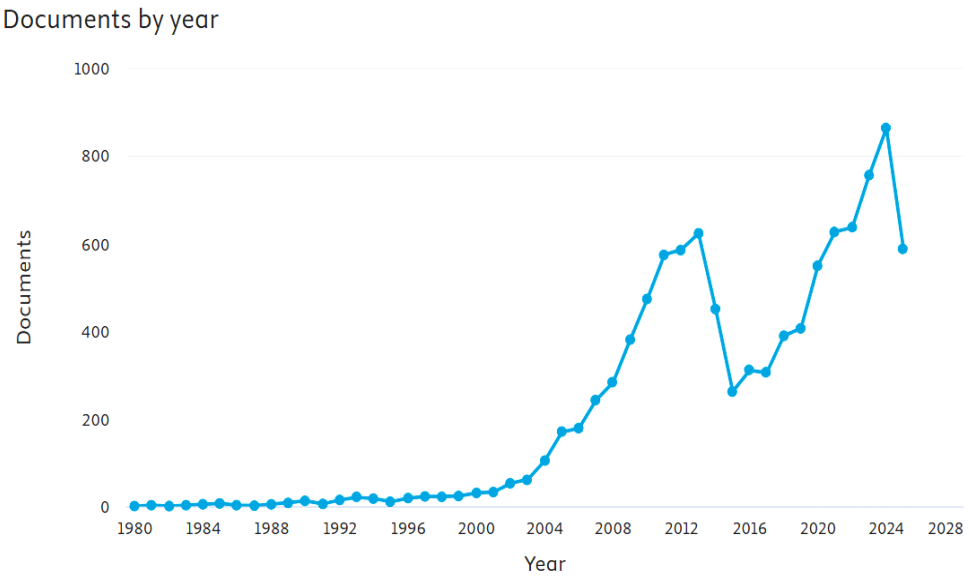

Figure 3. Publication growth over time

1.2 Importance of studying environment and society in India

India is highly vulnerable to climate change. The Global Climate Risk Index ranks India among the most affected countries. Floods, heat waves, droughts, and cyclones are frequent. These disasters disrupt lives and economies. They push vulnerable groups deeper into poverty. Society in India is diverse with differences in caste, class, gender, and region. Climate impacts are not equal. Marginalized groups suffer more. For example, women in rural areas often collect water and fuel wood. Climate change increases their burden. Similarly, small farmers face more risks than large landowners. Studying this intersection helps us understand environmental justice. It shows how social structures affect adaptation and resilience. It also highlights the role of policies and community responses (Agarwal, 2010; Eckstein *et al*., 2021).

1.3 Environmental challenges in India

India faces several pressing environmental challenges. Air pollution remains severe in many cities, with Delhi and other northern regions often ranking among the most polluted in the world. Rural areas struggle with soil degradation, groundwater depletion, and declining crop yields. Although government programs aim to expand forest cover, deforestation pressures persist. Water scarcity is another critical concern, as major rivers like the Ganga and Yamuna suffer from pollution and groundwater is being over-extracted. Climate change intensifies these problems by altering rainfall patterns and reducing water availability in some regions, leading to shortages even in urban areas near rivers. Biodiversity loss adds to the crisis, as deforestation, mining, and infrastructure development threaten native species. India's rich biodiversity, including tigers, elephants, and many endemic plants, is increasingly at risk as climate change disrupts natural habitats and migration routes (Ghosh, 2020).

1.4 Society and vulnerability

Indian society is marked by inequalities. Access to resources, education, and healthcare varies widely. Climate change deepens these gaps. Poor communities often live in fragile areas like floodplains or drought prone zones. They lack resources for recovery. Urban poor live in informal settlements. These areas often lack drainage, clean water, or strong housing. Floods or heat waves hit them hardest. Rural poor depend on natural resources for survival. Crop failure or drought can push them into debt or migration. Social structures also shape responses. Caste and class influence who gets aid or support. Gender roles affect how men and women cope with climate stress. Youth and elderly face unique challenges in adapting to environmental change. Researchers in India and abroad study these links. Environmental sociology looks at how societies interact with nature. Development studies explore how economic growth affects sustainability. Climate science provides data on trends and projections. Together, these fields give a broad view (Jha *et al*., 2018). Recent studies show that India's climate will get hotter and wetter in many regions. Extreme rainfall events are rising. Heat waves are more intense. Sea-level rise threatens coastal cities like Mumbai and Chennai. These changes demand urgent study and response (Shashikanth *et al*., 2018). India stands at a critical point. Environmental change is rapid and widespread. Society is deeply affected. Addressing climate change requires more than technical fixes. It needs social awareness, policy innovation, and community action. Understanding the environment society link is vital. This review will attempt to provide such an understanding.

2. Historical Perspective on Environment and Society in India

2.1 Early civilizations and environment

The history of India shows a long link between environment and society. The Indus Valley Civilization flourished along the Indus and Saraswati rivers. People practiced agriculture, animal husbandry, and trade. Their settlements depended on fertile soils and water management (Possehl, 2002). Archaeological evidence shows advanced drainage and urban planning. This reflects how early societies adapted to environmental conditions. Climate shifts may have contributed to the decline of the Indus Valley. Studies suggest changing monsoon patterns and river drying disrupted agriculture (Giosan *et al*., 2012). This shows how environmental change shaped ancient societies. The Vedic period emphasized a cultural relationship with nature. Texts like the Rigveda mention rivers, forests, and mountains as sacred. Cows, trees, and water were central to life and rituals. This spiritual respect shaped social attitudes toward nature (Habib, 2011).

2.2 Medieval period and resource use

In medieval India, agriculture expanded with irrigation systems. Tank irrigation in South India and canal systems in North India supported farming. Kings and local rulers invested in water storage structures. These helped stabilize agriculture during variable monsoons (Shah, 2010). Forests were important for hunting, gathering, and trade. Timber and forest produce were extracted for building and crafts. However, access to resources was shaped by caste and class hierarchies. Upper castes often controlled fertile land, while marginalized groups depended on forests and common lands (Guha, 2000a). Islamic rule brought new agricultural techniques. Crops like rice, wheat, sugarcane, and cotton spread widely. Irrigation expanded under the Delhi Sultanate and the Mughals. The Mughal Empire also documented flora and fauna in detail. Gardens like those in Kashmir reflected a blending of aesthetics and ecological knowledge (Richards, 1993; Guha, 2000b).

2.3 Colonial period and environmental transformation

Colonial rule marked a turning point in India's environment-society relationship. The British exploited forests, land, and water for economic gain. Large-scale deforestation occurred to supply timber for railways and shipbuilding. The Indian Forest Act of 1865 restricted community access to forests. Forests were declared state property (Guha, 1983). Agriculture was reshaped by colonial policies. Cash crops like indigo (neel), tea, and cotton were promoted. This disrupted food security and traditional farming systems. Famines during the 19th century killed millions of people. Researchers argue that colonial land revenue systems worsened vulnerability (Davis, 2001). Irrigation canals expanded under colonial rule, especially in Punjab. While this boosted crop yields, it also created water logging and soil salinity. Colonial focus on revenue, rather than sustainability, led to environmental degradation (Whitcombe, 1972). Colonial rule also introduced modern science and conservation resulting in establishment of Geological Survey of India and Forest Department. However, these were primarily aimed at resource extraction. Communities often resisted forest laws, leading to local protests and conflicts (Gadgil & Guha, 1993).

2.4 Post-independence development and environment

After independence in 1947, India focused on nation building. Large dams and irrigation projects symbolized progress. The Bhakra Nangal and Hirakud dams were called "temples of modern India" by Prime Minister Nehru. These projects boosted agriculture and energy production (Klingensmith, 2007). However, they also displaced millions of people. Tribals and farmers lost land and livelihoods. Resettlement policies were weak. Social movements later criticized this model of development (Baviskar, 1999).

The Green Revolution of the 1960s transformed Indian agriculture. High yielding varieties, fertilizers, and irrigation increased food production and India became food self sufficient. But this came at an environmental cost. Groundwater depletion, soil salinity, and pesticide use rose sharply. The benefits were uneven. Punjab and Haryana prospered, while rain fed regions lagged (Shiva, 1991). Industrialization and urbanization expanded after independence. Cities grew rapidly. Industries contributed to economic growth but also caused air and water pollution. Rivers like the Ganga became heavily polluted due to industrial discharge and sewage (CSE, 1982).

2.5 Rise of environmental movements

From the 1970s, India witnessed strong environmental movements. These movements linked ecology with society and justice. The Chipko movement in Uttarakhand is famous. Villagers, especially women, hugged trees to stop deforestation. They demanded community rights over forests. This movement highlighted both ecological concerns and social justice (Guha, 2014). The Silent Valley movement in Kerala opposed a hydroelectric dam. Environmentalists and local people resisted to protect tropical forests. The project was stopped in 1983. This showed the growing strength of ecological consciousness (Ramakrishnan, 1992). The Narmada Bachao Andolan opposed large dams on the Narmada River. Led by activists like Medha Patkar, it demanded rehabilitation for displaced communities. It questioned the development model based on displacement and ecological damage. Other movements, like anti-mining struggles in tribal areas, also grew. They showed how marginalized groups faced the heaviest costs of development (Baviskar, 1999).

2.6 Policy shifts and environmental governance

India introduced environmental policies in response to these pressures. The National Committee on Environmental Planning and Coordination was set up in 1972. The Wildlife Protection Act was passed in 1972. The Water Act came in 1974, followed by the Air Act in 1981. The Bhopal Gas Tragedy of 1984 was a turning point. The gas leak from Union Carbide killed thousands and harmed many more. It exposed weak industrial safety and environmental regulation. It also showed how poor communities suffered the most (Fortun, 2009). The Environment Protection Act of 1986 gave wide powers to the government. It created a legal framework for environmental protection. Later, the National Green Tribunal (2010) was established for quick resolution of environmental cases. At the same time, global concerns shaped Indian policy. India participated in the 1992 Rio Summit. Climate change became part of national planning. The National Action Plan on Climate Change (NAPCC) was launched in 2008. It created eight missions, including solar energy, water, and sustainable agriculture (Dubash, 2013).

2.7 Linking past and present

The historical relationship between environment and society in India shows continuity and change. Ancient societies respected nature but also faced climate challenges. Medieval rulers expanded irrigation and agriculture, shaping resource use. Colonial rule exploited resources and restricted community rights. Post-independence development emphasized growth, often at social and ecological costs. Environmental movements pushed for justice and sustainability. Policies evolved in response to crises and activism. Today, climate change brings new challenges. Past experiences highlight the importance of balancing environment and society. They show the risks of ignoring sustainability. They also reveal the power of communities in protecting resources.

The history of environment and society in India is not linear. It is shaped by cultural traditions, political power, and economic goals. It shows how human actions transform nature and how nature influences societies. This background is crucial for understanding India's present climate crisis. It explains why inequalities persist and also shows why social movements continue to play a major role.

3. Climate Change in India. Evidence and Trends

Climate change is no longer a distant threat in India and is visible in daily life. Temperatures rising, rainfall patterns shifting and extreme events are becoming frequent. Scientific studies confirm

these trends. They show how climate change is reshaping India's environment and society (Shashikanth *et al*., 2018).

3.1 Temperature rise

India has warmed significantly over the last century. Data from the India Meteorological Department (IMD) show an increase of about 0.7°C between 1901 and 2018 (IMD, 2020). The warming is not uniform. Northern and central regions have seen greater increases than coastal areas. Heat waves are now more frequent. In 2015, a severe heat wave killed more than 2,500 people in Andhra Pradesh and Telangana (Gupta *et al*., 2017). In 2019, many northern cities recorded temperatures above 48°C. Urban areas face higher risks due to the urban heat island effect. Future projections suggest stronger warming. By 2100, average temperatures in India may rise by 2.4-4.4°C under high emission scenarios (MoEFCC, 2020). This will have serious impacts on health, agriculture, and water resources.

3.2 Rainfall variability

The Indian summer monsoon is central to life. It provides nearly 80% of annual rainfall. But monsoon behavior is changing. Studies show a decline in average monsoon rainfall since the 1950s (Goswami *et al*., 2006). Rainfall is now more unpredictable. Some regions experience droughts, while others face floods. Short, intense rain spells are more common. This creates problems for farmers who depend on timely rainfall. Climate models project further variability. Southern India may get wetter, while parts of central and northwestern India may get drier. Monsoon onset and withdrawal dates are also shifting. These trends threaten water security and crop stability (Mall *et al*., 2006a).

3.3 Extreme weather events

Extreme events are rising in frequency and intensity. Floods, cyclones, and droughts are common. Floods affect many Indian states each year. Assam, Bihar, and Uttar Pradesh are frequent victims. In 2018, Kerala faced its worst flood in a century. Over 400 people died, and millions were displaced (Ward *et al*., 2014). Cyclones in the Bay of Bengal and Arabian Sea are increasing. Cyclone Amphan (2020) devastated West Bengal state and cities of Bangladesh. It caused losses of billions of dollars. The Arabian Sea, once calmer, now observes severe cyclones like Tauktae (2021). Warmer seas contribute to this trend. Droughts are also intensifying. Maharashtra, Karnataka, and Telangana often face water shortages. Farmers struggle with crop failures. This triggers migration and debt. Heat waves, floods, cyclones, and droughts together show the rising risks. These events disrupt lives, economies, and infrastructure (Emanuel, 2017).

3.4 Himalayan glaciers

The Himalayas are called the "water towers of Asia." They feed rivers like the Ganga, Brahmaputra, and Indus. But glaciers are retreating. Studies show most Himalayan glaciers are shrinking. The Gangotri glacier has receded by more than 1,500 meters in the last 70 years. Glacial lakes are forming due to melting. These lakes can burst, causing floods downstream. Such glacial lake outburst floods (GLOFs) are a rising risk. Glacier retreat affects water availability. Rivers fed by glaciers support millions of people. Reduced flow in summer months may harm agriculture and drinking water (Bolch *et al*., 2012).

3.5 Sea level rise

India has a coastline of over 7,500 km. Sea level rise is a major concern for coastal areas. Tide gauge data show a rise of about 1.3 mm per year along the Indian coast during the 20th century. Satellite data suggest faster rise in recent decades (Unnikrishnan & Shankar, 2007). Cities like Mumbai, Chennai, and Kolkata are at risk. Coastal erosion is already visible in Kerala and Odisha. Saltwater intrusion threatens groundwater in coastal villages. Rising seas also increase cyclone and storm surge impacts. Future projections warn of a 0.3 to 0.8 meter sea level rise by 2100, depending on emission pathways. This could displace millions of people in low-lying areas like the Sundarbans (IPCC, 2021).

3.6 Regional variations

Climate change does not affect all regions of India equally, as each part of the country experiences distinct trends. In northern India, rising temperatures have led to more frequent heat waves, reduced snowfall, and glacial retreat. The northeastern region, despite traditionally receiving high rainfall, is witnessing a decline in precipitation. Central India faces a higher frequency of extreme rainfall events, while western India is experiencing more droughts and heat stress. Southern India shows an increase in rainfall, but this also brings greater risks of flooding. Coastal zones are particularly vulnerable, with challenges such as cyclones, erosion, and sea-level rise. These variations highlight the importance of regional studies, which play a key role in developing effective local adaptation strategies.

3.7 Projections for the future

Indian climate projections based on models such as CORDEX South Asia, present an alarming picture of the future. By 2100, the annual mean temperature is expected to rise by 2.4 to 4.4°C, while the frequency of heat waves may increase two to three times. Heavy rainfall events are projected to rise by 20 to 30 percent, and drought-prone areas are likely to expand across central India. Coastal regions face even greater risks, as sea-level rise could threaten major cities as well as vulnerable villages. These projections highlight the urgent need for both mitigation and adaptation measures, since the social and economic costs of inaction are likely to be very high (Dhiman *et al.,* 2019; Subramanian *et al.,* 2023).

3.8 Scientific reports and assessments

Several reports provide detailed evidence. The Indian Network for Climate Change Assessment (INCCA) has studied regional impacts. The Ministry of Environment, Forest and Climate Change (MoEFCC) publishes India's National Communication to the UNFCCC. The Intergovernmental Panel on Climate Change (IPCC) reports highlights India's vulnerability. The 2021 report states that South Asia will face strong warming, unpredictable rainfall, and severe extremes (IPCC, 2021).

3.9 Social relevance of climate evidence

The scientific evidence has direct social relevance. Rising temperatures mean higher health risks. Unpredictable monsoons mean uncertain farming. Extreme events mean displacement and migration. Glacier retreat means water stress. Sea-level rise means loss of land and homes. Understanding evidence is important for policy and planning. It shows where adaptation is needed. It highlights vulnerable groups. It warns about the urgency of reducing emissions globally. India is experiencing clear climate change. The evidence is strong. Temperatures are rising. Rainfall is shifting. Extreme events are intensifying. Glaciers are melting. Seas are rising. Regional variations make the problem

complex. The future will be riskier if action is delayed. Science shows the trends and society must prepare. Policies, communities, and individuals all have their roles.

4. Impact on Agriculture and Rural Livelihoods

Agriculture is central to Indian society. It provides livelihood to nearly half of the population. It contributes to food security, culture, and rural life. But agriculture is highly climate sensitive. Rainfall, temperature, and soil conditions determine productivity. Climate change is creating new challenges for Indian agriculture. Inconsistent monsoons, extreme heat, floods, and droughts are harming crops. Water scarcity and soil degradation make things worse. Farmers face risks to income and survival. This section reviews how climate change affects agriculture and rural livelihoods in India.

4.1 Dependence on monsoon

The Indian monsoon is vital. About 60% of Indian agriculture is rain-fed. Millions of small farmers depend on timely rainfall. Even a short delay in monsoon onset disrupts sowing (Gadgil & Gadgil, 2006). Climate change is altering monsoon patterns. Rainfall is now more irregular. Some years bring floods, others bring droughts. Short bursts of intense rain damage standing crops. Dry spells reduce yields. This uncertainty increases vulnerability for farmers. In Vidarbha, irregular rainfall contributes to crop failure and farmer distress. In Bihar, floods damage paddy fields frequently. Both extremes reduce farm incomes (Mall *et al*., 2006b).

4.2 Temperature stress on crops

Rising temperatures harm crop growth. Wheat, a major rabi crop, is highly sensitive to heat. A rise of just 1°C during grain filling reduces yields significantly. Studies show wheat yields in India have already declined due to warming (Gupta *et al*., 2017). Rice, the staple food, is also affected. Higher night temperatures reduce rice yields. Extreme heat during flowering reduces productivity. Maize, pulses, and vegetables face similar risks. Livestock also suffers. Heat stress reduces milk production. Animals need more water and feed. This increases costs for farmers (Sreenivasaiah, 2016; Xing *et al*., 2024).

4.3 Water scarcity

Agriculture depends on groundwater and surface water. India is the largest user of groundwater in the world. But climate change worsens water scarcity. Droughts are more frequent. Groundwater tables are falling in Punjab, Haryana, and Uttar Pradesh. Rain fed regions like Bundelkhand face acute water shortages. Irrigation canals dry up during lean seasons. Irrigation demand rises with higher temperatures (Alaoui *et al*., 2013; Kadda *et al*., 2021). Farmers pump more ground water result in deepening depletion of water table. This creates a vicious cycle. Water scarcity affects both crops and livestock (Rodell *et al*., 2009).

4.4 Soil degradation

Soils in India are already under stress. Overuse of fertilizers during the Green Revolution degraded soils. Climate change worsens this. Intense rainfall leads to soil erosion and drought reduces soil moisture. Salinity increases in irrigated areas. Desertification is spreading in Rajasthan and Gujarat.

Studies estimate that about 30% of India's land is undergoing degradation. Poor soils reduce yields and farmer resilience (NAAS, 2010).

4.5 Pests and diseases

Climate change also affects pests and diseases. Warmer temperatures expand pest habitats. For example, the fall armyworm spread quickly in India after 2018. Erratic rainfall also favors pests and fungal attacks. Livestock diseases may also increase. Warmer and wetter conditions spread vector-borne diseases like bluetongue and tick infestations. Farmers face new risks to both crops and animals (Mahato, 2014).

4.6 Impact on farmers' income

Climate shocks reduce farm incomes. A study shows that extreme rainfall and heat waves cut farmer incomes by 15 to 25% in some regions (Mani *et al*., 2018). Smallholders are most affected. They have little savings or insurance. Crop failures push farmers into debt. Distress migration is common in drought-prone areas. Young men migrate to cities for work. Women, children, and elderly stay behind, increasing their burden. Farmer suicides in regions like Vidarbha have been linked to crop failure, debt, and climate stress. Climate change adds to this tragic cycle (Sainath, 2025).

4.7 Regional variations

The impacts of climate change on agriculture in India vary widely across regions, creating distinct challenges for farmers. In northwest India, rising heat has reduced wheat yields and intensified water scarcity. Eastern states struggle with recurring floods that damage rice crops, while cyclones frequently affect coastal areas of Odisha and West Bengal. Central India, where much farming is rain-fed, remains highly vulnerable to drought, and southern states face erratic rainfall and water stress that disrupt the cultivation of millets and pulses. In the Himalayan region, warming temperatures are pushing apple orchards to higher altitudes. These diverse regional impacts highlight the need for tailored adaptation strategies that respond to local conditions.

4.8 Social inequality and agriculture

Climate change does not affect all farmers equally. Marginal farmers and landless laborers are most vulnerable. They lack irrigation, savings, and access to credit. Women farmers face additional burdens. They often do unpaid work like collecting water and fuel wood. Tribal communities depend on forests and shifting cultivation. Climate change reduces forest productivity. This affects food, fodder, and income. Social inequalities deepen when climate stress falls on marginalized groups (Agarwal, 2010).

4.9 Adaptation strategies

Farmers are adapting in different ways. Some change sowing dates. Others shift to drought-resistant crops like millets. Water harvesting and micro-irrigation are spreading in some regions. Crop insurance schemes aim to reduce risks. The Pradhan Mantri Fasal Bima Yojana is one example. However, many farmers report delays in payments and limited coverage. Agroforestry and mixed farming improve resilience. Community seed banks and traditional knowledge also help. Yet, adaptation is uneven. Poor farmers face barriers of cost, knowledge, and institutional support (Birthal and Hazrana, 2019).

4.10 Policy responses

Government policies address climate-agriculture links. The National Mission on Sustainable Agriculture promotes climate-resilient practices. Krishi Vigyan Kendras provide training and support. Watershed development programs improve soil and water conservation. Solar pumps and drip irrigation reduce water stress. Climate-smart villages are being tested in some states. Yet, challenges remain. Policies often focus on technology, but ignore social inequalities. Support for women and small holders are limited. Better credit, insurance, and extension services are needed.

4.11 Future risks

Future climate projections warn of major risks. Studies predict a decline of 10-40% in crop yields by the end of the century if no adaptation is made. Wheat and rice are most vulnerable. Pulses and oilseeds will also decline. Livelihoods of millions of rural people are at stake. Migration from rural to urban areas may increase. Food security for the whole country could be at risk.

Agriculture and rural livelihoods in India are deeply vulnerable to climate change. Rising temperatures, erratic rainfall, floods, and droughts disrupt farming. Water scarcity, soil degradation, and pests add to the stress. Farmers face income loss, debt, and migration. The impacts are uneven. Smallholders, women, and marginalized groups suffer more. Adaptation is happening but is limited. Policies exist but need better implementation. Without urgent action, agriculture may face a severe crisis in the coming decades. Protecting rural livelihoods is not only an economic issue. It is also a matter of social justice (Lal, 2011).

5. Urbanization, Pollution, and Climate Vulnerability

India is urbanizing rapidly. Cities are growing in size and population. Urban areas now host more than 35% of the Indian population. This share is expected to rise above 50% by mid-century. Urban growth brings opportunities. Cities drive economic growth, jobs, and innovation. But it also creates new risks. Pollution, poor infrastructure, and inequality increase vulnerability to climate change (United Nations, 2019).

5.1 Rapid urban growth

India has seen explosive growth of cities. Megacities like Delhi, Mumbai, and Bengaluru have expanded rapidly. Medium and small towns are also growing. Migration from rural to urban areas continues. This growth is not always planned. Informal settlements, slums, and rurban areas expand without infrastructure. Housing, sanitation, and waste services are inadequate. These weaknesses increase vulnerability to climate events. Heat waves, floods, and water shortages hit cities harder when planning is weak (Revi, 2008).

5.2 Urban heat island effect

Urbanization intensifies heat. Concrete and asphalt trap heat during the day and release it at night. This creates the urban heat island effect. Studies show that Delhi and Mumbai are several degrees warmer than nearby rural areas. Climate change adds to this. More frequent and severe heat waves threaten urban residents. Poor households in crowded areas are most at risk. They lack cooling, ventilation, and green cover. Heat stress causes illness, lost productivity, and even death (Islam *et al*., 2024).

5.3 Air pollution

Air pollution is one of India's most severe urban problems. Cities like Delhi, Kanpur, and Lucknow often record hazardous levels of fine particulate matter (PM2.5). Sources include vehicles, industry, construction, and crop residue burning. Winter smog in north India combines these factors with weather conditions. Air pollution has direct health impacts. It causes respiratory disease, heart disease, and premature death. Children and elderly are especially vulnerable. Climate change can worsen pollution. Higher temperatures and stagnant weather increase smog. Dust storms from drought-prone regions also add particles (Guttikunda & Goel, 2013; Saini *et al*., 2019; Saini & Kumar, 2021; Saini, 2022; Saini & Kumar, 2022).

5.4 Water stress in cities

Urban water demand is rising. Cities need water for households, industry, and services. Many rely on groundwater or distant rivers. Climate change disrupts supply. Chennai faced a severe water crisis in 2019 when reservoirs dried up after weak monsoons. Other cities like Bengaluru and Hyderabad also face shortages. Flooding and water logging are another side of the problem. Intense rains overwhelm drains. Cities like Mumbai and Patna face repeated floods. Poor drainage, encroached wetlands, and garbage blocking sewers worsen the risk (Ghosh, 2021).

5.5 Urban flooding

Climate change increases extreme rainfall. Urban areas with poor planning face disaster. Mumbai's 2005 floods killed hundreds. In 2015, Chennai was paralyzed by floods. Both events were worsened by unregulated construction and loss of wetlands. Slum areas near rivers, drains, or low-lying land are most affected. People lose homes, livelihoods, and health. Diseases like dengue and cholera spread after floods (Gupta & Nair, 2011).

5.6 Solid waste and pollution

Urban growth produces massive waste. Solid waste management is weak in many cities. Dumpsites grow near settlements. Methane from landfills adds to greenhouse gases. Plastic waste blocks drains, worsening floods. Poor residents living near dumps face toxic exposure (Sharholy *et al*., 2008). Open burning of waste contributes to air pollution. Pollutants present in the air alter the leaf biochemistry by reducing chlorophyll synthesis, blocking stomata, and lowering photosynthesis. These changes impact normal plant functions (Saini *et al*. 2021; Saini & Kumar, 2024).

5.7 Energy and emissions

Cities are major energy consumers. Electricity demand is rising for households, transport, and industry. Coal-based power and diesel generators dominate. Urban transport emissions are also rising. Vehicle numbers increase daily. Congestion and fuel inefficiency raise emissions further.
Climate change mitigation requires clean energy and better transport. But many cities still lack investment in these areas (Gurjar *et al*., 2010).

5.8 Inequality in urban vulnerability, migration and urban pressure

Urban risks are not shared equally. Rich neighborhoods have air conditioning, private water, and backup power. Poor neighborhoods lack these protections. Slum dwellers face the worst impacts. They live in unsafe housing, often in flood-prone zones. They lack health care, sanitation, and social security. Women, children, and elderly in slums are highly vulnerable. Inequality in cities means climate stress becomes a social justice issue. Rural climate stress pushes migration. Drought, crop failure, and rural poverty drive people to cities. Migrants often end up in informal settlements. They face poor housing, insecure jobs, and climate risks. This cycle links rural and urban vulnerabilities. Climate change in villages adds pressure on already stressed cities (Santha *et al*., 2016).

5.9 Urban governance and policy

Urban governance in India faces many challenges. Overlapping authorities, weak municipal finances, and lack of coordination slow the responses. Programs like Smart Cities Mission and Atal Mission for Rejuvenation and Urban Transformation (AMRUT) aim to improve infrastructure. Climate action plans exist in some cities. But most plans focus on infrastructure, not social inclusion. Local participation is often limited. Marginalized groups rarely have a voice in urban climate policy (Sethi *et al*., 2021).

5.10 Adaptation strategies

Cities are experimenting with adaptation. Green roofs, rainwater harvesting, and urban forestry reduce heat and flooding. Public transport and cycling infrastructure lower emissions. Some cities prepare climate action plans. Surat developed an early warning system for floods. Ahmedabad launched a Heat Action Plan, which reduced mortality during heat waves. Civil society and community groups play an important role. NGOs promote rainwater harvesting in Delhi and Jaipur. Citizen groups campaign for clean air in Bengaluru and Delhi. Urban residents also push for green spaces, cycling lanes, and waste segregation. Social movements bring attention to health and equity issues. Partnerships between communities and local governments can strengthen resilience.

Future climate projections show rising risks. Heat waves will intensify and flooding events may become more frequent. Air pollution will remain severe if current trends continue. Urban population growth will add more pressure on housing, transport, and resources. Without strong adaptation and emission cuts, Indian cities could face serious crises. Urbanization, pollution, and climate change are deeply connected in India. Cities drive growth but also face high risks. Air pollution, heat stress, floods, and water scarcity already affect millions. Vulnerabilities are unequal. Slum dwellers and marginalized groups suffer most. Policies exist but need stronger focus on equity, planning, and sustainability. The future of India's climate resilience depends heavily on its cities. Urban planning, clean energy, and inclusive governance are keys to reducing risks (Knowlton *et al*., 2014).

6. Public Health and Climate related Challenges

Climate change is not only an environmental issue. It is also a public health challenge. India, with its large and diverse population, faces rising health risks. Climate change worsens old problems and creates new ones. Heat waves, floods, droughts, and air pollution all affect health. Water-borne diseases spread faster with flooding. Vector-borne diseases expand with changing rainfall and temperature. Malnutrition increases with crop failure.

6.1 Heat waves and mortality

Heat waves are becoming more frequent and intense in India. Temperatures in some regions now reach over 48°C. Cities like Ahmedabad, Delhi, and Nagpur face severe heat stress (IMD, 2020). Heat waves increase mortality. The 2015 heat wave killed over 2,500 people across Andhra Pradesh and Telangana (Mazdiyasni *et al*., 2017). Older adults, children, and outdoor workers are most vulnerable. Heat stress causes dehydration, heatstroke, and heart strain. It also reduces labor productivity. Outdoor workers in construction, agriculture, and transport suffer most (Kjellstrom *et al*., 2018).

6.2 Air pollution and respiratory disease

Air pollution is one of the largest health risks in India. It interacts with climate change. Warming worsens smog formation and dust transport. Particulate matter ($PM_{2.5}$) penetrates deep into lungs. It causes asthma, chronic obstructive pulmonary disease (COPD), and heart disease. The Global Burden of Disease study estimates air pollution kills over a million people each year in India. Children face reduced lung function. Pregnant women face higher risks of complications. Poor households using biomass for cooking face double exposure to indoor and outdoor pollution (Balakrishnan *et al*., 2019; Saini & Kumar, 2022).

6.3 Water-borne diseases

Climate change affects water availability and quality. Floods contaminate drinking water with sewage. Droughts force use of unsafe water sources. Diseases like cholera, typhoid, and diarrhea spread more easily. Children are especially vulnerable. Floods in Bihar and Assam are often followed by diarrhea outbreaks. Urban floods also spread disease. Mumbai's floods repeatedly lead to leptospirosis outbreaks. This bacterial disease spreads in water contaminated by animal urine (Graham *et al*., 2013).

6.4 Vector-borne diseases

Changing temperature and rainfall expand habitats for mosquitoes and other vectors. Malaria, dengue, chikungunya, and Japanese encephalitis are spreading to new regions. Dengue, once confined to a few cities, now appears across India. Rising humidity and rainfall create breeding sites. Malaria transmission windows are also changing in highland areas. Public health systems struggle to cope with these shifts. Surveillance and prevention programs must adapt to new risks (Dhiman *et al*., 2010).

6.5 Malnutrition and food insecurity

Climate change threatens food production. Crop losses from droughts, floods, and heat reduce food supply. Prices rise. Poor families cut food intake. Malnutrition is already widespread in India. Over one-third of children under five years of age are stunted (NFHS-5, 2021). Climate stress may worsen this. Protein-rich foods like pulses and milk may become less affordable. Women and children are hit hardest. Malnutrition weakens immunity, increasing vulnerability to disease (Myers *et al*., 2017).

6.6 Mental health and stress

Climate change also affects mental health. Disasters like floods and droughts create trauma. Farmers facing crop loss and debt suffer stress and depression. Farmer suicides are linked to climate stress in

drought-prone regions like Maharashtra and Andhra Pradesh. Displacement after floods or cyclones also increases anxiety and loss of community support. Mental health services are limited in rural India. Climate-related distress often goes untreated (Carleton, 2017).

6.7 Health inequalities

The health impacts of climate change are not equal. Poor households, slum dwellers, and marginalized groups suffer more. They lack safe housing, healthcare, and savings. Women face added burdens. They often care for children and elderly during disasters. They face risks of malnutrition, anemia, and lack of medical access. Tribal communities in forests face loss of food sources. Climate stress deepens health inequalities across caste, class, and gender lines. India's health system is under pressure. Rural areas lack doctors, hospitals, and medicines. Urban hospitals are overcrowded. Climate change increases demand for health services. Heatstroke patients, flood victims, and disease outbreaks all strain the system. Preparedness is limited. Few hospitals are climate resilient. Emergency response systems are often slow. Early warning systems for heat waves and floods are improving, but coverage is uneven (Mahapatra, 2021).

6.8 Adaptation and health policies

Some progress is being made. Ahmedabad launched a Heat Action Plan in 2013. It included early warnings, public awareness, and training for health workers. Deaths from heat waves declined after its implementation. India's National Action Plan on Climate Change (NAPCC) includes a National Mission on Health. Some states have prepared health adaptation plans. Vaccination and disease surveillance programs are expanding. Yet, resources are limited. More investment in public health is needed (Knowlton *et al*., 2014).

6.9 Climate resilient health systems

Building climate-resilient health systems is essential. This includes stronger disease surveillance, early warning systems, and resilient infrastructure. Hospitals need backup power, safe water, and flood protection. Training health workers for climate-related diseases is vital. Public awareness campaigns can reduce risk. Integrating climate science with public health planning can improve preparedness.

Future climate projections warn of serious health threats. Heat-related deaths may rise sharply. Vector-borne diseases may spread to new regions. Water scarcity may reduce hygiene, increasing infections. Food insecurity may worsen malnutrition. Disasters may displace millions, creating health crises. Without adaptation, climate change could undo health progress in India. Climate change is a major health challenge for India. Heat waves, pollution, floods, droughts, and disease outbreaks already affect millions.

Malnutrition, mental health, and inequality deepen the risks. Public health systems are under strain. Adaptation efforts exist but remain small. Building resilient health systems is urgent. Protecting health is central to climate justice. It requires investment, planning, and inclusive policies. Without this, climate change may become a major barrier to human well-being in India (Watts *et al*., 2018).

7. Social Inequalities and Climate Justice in India

Climate change is not just an environmental issue. It is also a social issue that intersects with inequality, poverty, and justice. In India, the burdens of climate change are unevenly distributed. The

poor, marginalized, and vulnerable groups face greater risks than the wealthy and privileged. This unequal exposure and adaptive capacity create serious concerns for climate justice.

7.1 Vulnerability and inequality

India's society is diverse but highly stratified. Class, caste, gender, and region shape people's access to resources. Climate change worsens existing inequalities. Poor households depend more on natural resources and climate-sensitive livelihoods. They have fewer savings, weaker access to insurance and limited voice in decision-making (Dubash, 2013). Farmers in drought prone areas often belong to small and marginal landholding groups. They have limited irrigation facilities and depend heavily on monsoon rainfall. In contrast, wealthy farmers or agribusinesses are better positioned to cope with erratic rains through technology and capital (Sareen & Kale, 2018).

7.2 Gender dimensions

Women in India face distinct climate challenges. They are often responsible for water collection, fuel gathering, and household food security. Climate stress increases their workload and reduces their time for education or income-generating activities (Agarwal, 2010). In drought prone districts of Rajasthan and Maharashtra, women travel longer distances to fetch water as groundwater levels decline. Climate shocks also force male migration, leaving women to manage farms without adequate support (Sugden *et al*., 2014). Women often lack land titles, which makes it harder for them to access credit, relief packages, or adaptation schemes (Arora-Jonsson, 2011).

7.3 Caste and marginalization

Caste-based inequality also shapes climate vulnerability. Dalit and Adivasi communities often live in ecologically fragile regions such as dry lands, forests, or floodplains. They have insecure land tenure and limited access to state resources. Disasters often hit them hardest because they live in poorly constructed housing and lack access to relief distribution (Baviskar, 2020). For instance, during the 2018 Kerala floods, research showed that Dalit households were more likely to be excluded from relief camps or faced discrimination in aid distribution. In tribal regions of Jharkhand and Chhattisgarh, displacement caused by mining and deforestation has added to the climate stress experienced by Adivasi groups (Varughese & Purushothaman, 2021).

7.4 Urban inequalities

Urban India also shows stark inequalities in climate exposure. Slum dwellers and informal workers are more exposed to floods, heat waves, and air pollution. Many live-in low-lying areas near rivers or coastal belts without secure housing. During urban floods in Mumbai and Chennai, poorer residents bore disproportionate losses while wealthier households could recover faster (Revi *et al*., 2014). The urban poor also suffer more during heat waves. They often lack access to cooling, clean water, or reliable electricity. Outdoor workers, such as construction laborers and street vendors, are exposed to extreme heat while lacking healthcare or labor protection (Kjellstrom *et al*., 2018).

7.5 Intergenerational justice

Climate change raises questions about intergenerational equity. Young people and future generations will inherit a hotter and riskier India. Decisions made today will shape the scale of climate damage

tomorrow. School children and youth movements in India have started to raise their voices on climate justice, inspired by global youth activism (Agha & Chowdhury, 2023). Children are also among the most vulnerable. Malnutrition, water scarcity, and disease outbreaks linked to climate change affect children more severely. The United Nations Children's Fund (UNICEF, 2021) ranks India among the most climate-vulnerable countries for children.

7.6 Climate induced displacement and migration

Another justice issue is climate-induced displacement. Climate induced displacement and migrations in India are rising due to floods, droughts, cyclones, and sea-level rise affecting millions each year. Coastal regions like Sundarbans and deltaic areas face severe habitat loss. Rural populations often migrate to cities in search of livelihood and safety. Rising seas in the Sundarbans, recurrent floods in Bihar, and droughts in Bundelkhand force many to migrate. Migration often creates social stresses, disrupts education, and increases risks of exploitation, especially for women and children (Warner & Afifi, 2014). In the Sundarbans, thousands of households have already relocated due to land erosion and salinity intrusion. Many ends up as migrant laborers in cities with low wages and poor living conditions. Such forced migration raises ethical and policy challenges because those least responsible for emissions are often the ones displaced (Chatterjee, 2021).

7.7 Policy and justice debates

Climate justice in India is not only about adaptation. It is also tied to global negotiations. India has long argued for the principle of "common but differentiated responsibilities" (CBDR) in climate agreements (Dubash, 2013). The country stresses that developed nations bear historical responsibility for emissions and should provide finance and technology to developing nations. At the national level, policies often overlook inequalities. Programs such as the National Action Plan on Climate Change (NAPCC) have been criticized for being too top-down and not adequately considering local voices. Social safeguards in climate adaptation and renewable energy projects are often weak. For example, large solar parks or wind farms sometimes displace local communities without fair compensation (Atteridge *et al*., 2012).

7.8 Grassroots movements and justice

Civil society and grassroots movements have played a strong role in pushing for climate justice in India. Farmers' movements, tribal organizations, and women's collectives demand fair access to resources, recognition of rights, and participatory planning. Movements in states like Chhattisgarh and Odisha have resisted coal mining projects that threaten forests and tribal lands. The Chipko and later forest rights movements linked environmental conservation with social justice (Baviskar, 2020). NGOs such as SEWA (Self-Employed Women's Association) work with women in Gujarat to build climate-resilient livelihoods through microfinance and cooperatives (Pattnaik *et al*., 2018).

7.9 Climate justice as human rights

Climate justice is increasingly framed as a human rights issue. Access to clean air, safe water, food security, and shelter are basic rights. Climate change threatens these rights disproportionately for vulnerable groups. The Supreme Court of India has recognized the right to a healthy environment as part of the right to life under Article 21 of the Constitution of India. Legal activism is also rising. Citizens and organizations have filed petitions linking climate inaction to rights violations. While India

has not yet seen large-scale climate litigation like in Europe or the US, early signs point to growing legal debates on justice and responsibility (Beg & Khan, 2022).

Climate change in India is deeply intertwined with inequality. Poor households, women, Dalits, Adivasis, slum dwellers, and children face greater risks. They have fewer resources to adapt and weaker access to state support. Climate justice in India is about addressing these inequities while ensuring that development pathways remain sustainable and fair. The struggle is both global and local, involving state policies, international negotiations, and grassroots mobilizations.

8. Policy Responses (National and International Frameworks)

India has faced multiple environmental challenges over the last few decades. Rising greenhouse gas emissions, deforestation, air pollution, and climate extremes have put enormous pressure on institutions. Policy responses have therefore evolved at both national and international levels. These responses have aimed to balance economic growth with environmental sustainability. They also reflect India's unique position as a developing country with high vulnerability to climate change but also a rising contributor to global emissions (Dubash *et al*., 2018). This section reviews key frameworks, programs, and negotiations that shape India's climate governance.

8.1 National Action Plan on Climate Change (NAPCC)

The National Action Plan on Climate Change (NAPCC), launched in 2008, is the central policy framework addressing climate change in India. It is built around eight National Missions, including the National Solar Mission, National Mission on Enhanced Energy Efficiency, National Mission on Sustainable Habitat, and National Water Mission (Government of India, 2008). These missions focus on mitigation and adaptation strategies. For example, the Solar Mission has aimed to expand solar energy capacity, while the Energy Efficiency Mission has targeted reductions in industrial energy consumption. The NAPCC represents a shift from ad-hoc environmental programs to a more comprehensive climate policy. However, scholars argue that while the NAPCC created institutional momentum, its implementation has been uneven due to funding gaps and weak coordination (Dubash & Jogesh, 2014).

8.2 State Action Plans on Climate Change (SAPCCs)

In addition to the NAPCC, Indian states were directed to prepare State Action Plans on Climate Change (SAPCCs). These plans attempt to localize climate strategies according to regional vulnerabilities. States like Maharashtra, Odisha, and Madhya Pradesh have included adaptation strategies for agriculture, water resources, and disaster management (Atteridge *et al*., 2012).

However, evaluations suggest that many SAPCCs remain generic and poorly funded. They often replicate national objectives without sufficient attention to local realities. The capacity of state governments to design, monitors, and evaluate projects remains a critical barrier (Petrescu *et al*., 2021).

8.3 Sectoral programs and policies

Several sector-specific initiatives complement the NAPCC and SAPCCs. The Ministry of New and Renewable Energy has promoted large-scale solar parks, wind power, and biomass projects, with India targeting 500 GW of renewable energy capacity by 2030 (IEA, 2021). Energy efficiency is being advanced through the Perform, Achieve, and Trade (PAT) scheme, which encourages energy-intensive industries to reduce consumption and trade energy savings certificates (BEE, 2019). In agriculture and

water management, programs such as the Pradhan Mantri Krishi Sinchai Yojana aim to improve irrigation efficiency, while watershed development initiatives focus on soil and water conservation. The Green India Mission under the NAPCC supports reforestation and afforestation efforts to enhance carbon sinks (MoEFCC, 2018). The National Disaster Management Authority (NDMA) has also integrated climate risk reduction into disaster preparedness programs, especially after severe floods and cyclones. Together, these initiatives reflect India's efforts to embed environmental sustainability into diverse development sectors, though institutional fragmentation and overlapping responsibilities continue to pose challenges (Sharma & Tomar, 2010)

8.4 India in international climate negotiations

India has played a prominent role in global climate diplomacy. As a founding member of the UNFCCC, it has consistently argued for the principle of common but differentiated responsibilities (CBDR). This principle highlights the historical responsibility of industrialized nations while recognizing the development needs of the Global South (Agarwal & Narain, 1991). At the Paris Agreement (2015), India submitted its Nationally Determined Contribution (NDC), pledging to reduce emissions intensity of GDP by 33% to 35% from 2005 levels by 2030, achieve 40% cumulative electric power installed capacity from non-fossil sources, and create a carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through afforestation (UNFCCC, 2015). In recent COP meetings, India has advocated for climate finance and technology transfer as key enablers of its climate commitments. It has also co-launched the International Solar Alliance (ISA) with France in 2015, which aims to promote solar energy in tropical countries.

8.5 Balancing development and climate commitments

India's policy responses reflect a balancing act between growth and sustainability. With more than 270 million people still living below the poverty line, the government emphasizes energy access, food security, and job creation. At the same time, global pressure for emission reduction is increasing. Critics argue that reliance on coal remains a major contradiction in India's climate policy. Although renewable energy is expanding, coal still accounts for more than 50% of India's electricity generation (IEA, 2021). Moreover, big infrastructure projects often displace vulnerable communities, raising concerns of environmental justice (Ray & Saini, 2011).

8.6 Challenges in implementation

Several institutional and structural challenges limit the effectiveness of India's policy frameworks on climate action. Coordination gaps between central and state governments often slow progress, while inadequate domestic and international finance further restricts implementation. At the local level, limited capacity to design and carry out adaptation projects creates additional barriers. Data gaps and weak monitoring systems hinder the ability to evaluate progress, and shifting political priorities sometimes override environmental considerations. These barriers show that although India has set ambitious targets, achieving them will require stronger governance mechanisms and greater accountability.

8.7 Sociological reflections

From a sociological perspective, climate policies are not just technical frameworks. They reshape relationships between state, market, and society. For example, the promotion of solar energy creates

new employment opportunities but may also marginalize traditional livelihoods. Similarly, adaptation projects often target rural communities, raising questions of participation and equity. Civil society actors have criticized top-down policy design, noting that communities are rarely consulted in climate programs. A more inclusive governance model, with participation from farmers, women's groups, and tribal communities, could enhance both legitimacy and effectiveness (Menon, 2024).

Table 1. Key environmental and social dimensions of climate change in India

Theme	Major environmental changes	Social impacts	Adaptation/response strategies	References
Agriculture and food security	Irregular monsoon, droughts, floods, temperature rise	Crop loss, food insecurity, farmer distress, rural migration	Climate-resilient crops, water harvesting, crop insurance	(Das & Ansari, 2021; Pathak, 2023)
Water resources	Glacier retreat, declining groundwater, changing rainfall patterns	Water scarcity, conflict over water use, health risks	Watershed management, community water sharing, efficient irrigation	(Badika *et al*., 2024; Jayaram, 2024)
Health and disease	Heat waves, air pollution, vector-borne diseases	Increased mortality, malnutrition, mental health issues	Public health surveillance, early warning systems, cooling centers	(Majra & Gur, 2009; Kaur & Pandey, 2021)
Urbanization and infrastructure	Heat island effect, poor air quality, flooding	Displacement, loss of livelihood, infrastructure damage	Green infrastructure, sustainable transport, smart cities	(Gupta, 2020; Islam *et al*., 2024)
Gender and social inequality	Unequal access to resources and adaptive technologies	Increased burden on women, social marginalization	Gender-sensitive policy, women's participation in decision-making	(Ravera *et al*, 2016; Anjum & Aziz, 2025)
Indigenous and rural communities	Forest degradation, biodiversity loss	Livelihood loss, cultural displacement	Traditional ecological knowledge, community forestry	(Rist *et al*., 2010; Baul & McDonald, 2015)
Governance and policy	Policy fragmentation, lack of local capacity	Inequitable adaptation benefits, implementation gap	Integrated policy, local governance, climate finance	(Dubash, 2019; Deshpande *et al*., 2025)
Energy and emissions	Rising fossil fuel use, urban energy demand	Energy insecurity, health effects from pollution	Renewable energy, decentralized systems, electric mobility	(IEA, 2021; Lal *et al*., 2025)
Education and awareness	Low climate literacy	Limited public participation in mitigation efforts	Environmental education, awareness campaigns, citizen engagement	(Puri *et al*., 2021; Citaristi, 2022)
Community resilience and future outlook	Intensifying climate extremes	Socioeconomic vulnerability, migration pressure	Community-based adaptation, participatory governance, innovation	(Jha *et al*., 2021; IPCC, 2022)

India's policy responses to climate change show an evolving and multilayered framework. The NAPCC and SAPCCs provide national and state-level strategies, while sectoral programs target renewable energy, forests, agriculture, and disaster management. Internationally, India continues to play a balancing role, seeking recognition of its development needs while committing to ambitious targets. However, the gap between policy ambition and implementation remains wide. Stronger institutions,

financing mechanisms, and community participation are essential for India to address climate challenges effectively.

9. Civil Society, Social Movements, and Community Responses

Civil society has played a vital role in shaping environmental debates in India. Government policies often emerge from political and economic priorities, but social movements, NGOs, and local communities have consistently pushed for ecological protection and social justice. These actors highlight the voices of marginalized groups and bring alternative visions of development. In the context of climate change, civil society initiatives address both mitigation and adaptation, often filling governance gaps. This section reviews the history and contemporary role of civil society, grassroots struggles, and community based responses in India's environmental and climate change landscape.

9.1 Historical roots of environmental movements

The roots of Indian environmental movements go back to the 1970s. The Chipko Movement, which began in Uttarakhand, symbolized community resistance to deforestation. Villagers, especially women, hugged trees to prevent contractors from felling them (Guha, 2014). This movement was not only about saving forests but also about asserting community rights over natural resources. Another milestone was the Silent Valley Movement in Kerala during the late 1970s and early 1980s. Local activists and scientists opposed the construction of a hydroelectric dam that threatened a biodiversity-rich rainforest. The campaign succeeded, and Silent Valley was declared a national park (Gadgil & Guha, 2013). In the 1980s and 1990s, the Narmada Bachao Andolan (NBA) became one of the most prominent social movements. It opposed large dams on the Narmada River, highlighting issues of displacement, environmental degradation, and human rights (Dwivedi, 2020). These movements laid the foundation for contemporary debates on sustainable development, environmental justice, and participatory governance.

9.2 Civil society and environmental governance

Civil society organizations (CSOs) have influenced environmental governance in multiple ways. They mobilize public opinion, file litigations, and monitor government programs. The Centre for Science and Environment (CSE), for example, has been a leading advocacy group publishing critical reports on pollution and climate issues (CSE, 2016). Similarly, the Energy and Resources Institute (TERI) conducts research and policy engagement on climate change. Legal activism has also emerged as a tool. Public interest litigations filed by activists have led to significant judgments from the Supreme Court and National Green Tribunal (NGT). These include rulings on air pollution in Delhi, industrial pollution, and mining regulation (Beg & Khan, 2022). Civil society thus expands the space for accountability beyond formal state mechanisms.

9.3 Grassroots and indigenous struggles

Grassroots movements led by tribal and rural communities continue to resist extractive projects. Anti-mining struggles in Odisha, Jharkhand, and Chhattisgarh reflect tensions between industrial development and indigenous rights. The Dongria Kondh tribe, for instance, successfully resisted bauxite mining in the Niyamgiri hills through a Supreme Court ruling that upheld their right to protect sacred lands. These struggles highlight how environmental and climate challenges intersect with issues

of land rights, displacement, and cultural survival. For many indigenous groups, environmental activism is inseparable from defending livelihoods and traditions (Padel & Mukerjee, 2010).

9.4 Community based adaptation and local innovations

Climate change adaptation often emerges at the community level. Farmers in drought-prone Maharashtra have experimented with watershed management, crop diversification, and collective water sharing (Udmale *et al*., 2014). In coastal areas, fishing communities adapt to rising sea levels and changing fish stocks by shifting livelihoods and forming cooperatives. Civil society organizations facilitate these initiatives by providing training, microfinance, and technical support. NGOs like Development Alternatives and SEWA support women-led adaptation projects in agriculture and energy. These examples show that adaptation is not just about technology but also about social organization and cooperation (O'Brien *et al*., 2004).

9.5 Youth and climate activism

In recent years, youth activism has grown significantly. Inspired by global movements like Fridays for Future, Indian students and young professionals have organized climate strikes and campaigns. Groups such as Fridays for Future India, Extinction Rebellion India, and Let India Breathe mobilize through social media and public demonstrations. These movements highlight the urgency of climate action and demand accountability from governments and corporations. They represent a new wave of activism that combines local concerns, such as air pollution, with global discourses on climate justice (Chaturvedi & Doyle, 2015).

9.6 Civil society and policy engagement

Civil society also engages with policymaking processes. NGOs often participate in consultations on climate action plans. Networks such as Climate Action Network South Asia (CANSA) advocate for ambitious targets, climate finance, and community centered adaptation (CANSA, 2019). However, there are tensions. Some activists argue that government consultations are symbolic, with limited influence on final policies. Moreover, the shrinking space for dissent under restrictive regulations has made it harder for organizations to operate independently (Menon, 2024).

9.7 Challenges for civil society responses

Civil society engagement in India faces several challenges that limit its effectiveness. Strict regulations on foreign contributions often create funding constraints, while the criminalization of dissent has led to activists facing legal charges simply for protesting. Many movements also remain fragmented, as struggles are frequently localized and lack broader national coordination. In addition, NGOs are often caught between balancing development and conservation, with some being accused of acting anti-development. Despite these hurdles, civil society continues to play a vital role in environmental and climate governance, making its involvement essential for sustainable change. From a sociological perspective, civil society responses mirror deeper patterns of power, inequality, and participation in India's democracy. Grassroots movements illustrate how marginalized and indigenous communities resist top-down models of development that prioritize industrial growth over local livelihoods and ecological well-being. These groups often excluded from decision making spaces, use protest, public campaigns, and legal action to assert their rights over land, water, and forests. Such actions not only challenge dominant narratives of progress but also expand the meaning of democracy by linking it to environmental justice and collective survival.

In recent years, new forms of activism have emerged, reflecting generational and technological shifts. Youth-led climate movements, digital advocacy, and citizen science initiatives have broadened participation and awareness. To gain national and international visibility, social media has allowed local struggles from deforestation in the Northeast to urban pollution movements. Collaboration between traditional movements and younger, digitally connected activists has strengthened calls for accountability and transparent governance.

Civil society acts as a bridge between global climate discourses and local realities, translating abstract policy goals into community-centered actions. From the Chipko movement to contemporary climate strikes, civil society organizations and movements have defended forests, rivers, and livelihoods while demanding equitable and inclusive climate policies. Though constrained by funding limits, state surveillance, and political repression, their persistence underscores a broader democratic function: holding power to account and ensuring that sustainability remains rooted in justice.

Ultimately, effective climate action in India cannot rely solely on state policies or corporate strategies. It requires the continued mobilization of civil society, the empowerment of local communities, and the creation of participatory spaces where environmental governance is shared and inclusive. Strengthening civil society's autonomy, ensuring freedom of association, and supporting community based climate adaptation are essential steps toward building a resilient and equitable future for India.

10. Future Directions and Sustainable Pathways

India's future will be shaped by how it addresses the dual challenges of development and climate change. Rapid urbanization, growing energy demand, and environmental degradation are pressing issues. At the same time, India has opportunities to build pathways that combine sustainability with equity. This section explores potential directions for sustainable development and outlines strategies that can help India transition toward a low-carbon and resilient society.

10.1 Renewable energy and low carbon transitions

Renewable energy is central to India's climate future. The government has set ambitious targets of 500 GW of renewable capacity by 2030 (IEA, 2021). Solar and wind power have become increasingly competitive compared to coal. Expanding decentralized renewable energy, such as rooftop solar and mini-grids, can provide clean power to rural areas. This also reduces dependence on fossil fuels while creating local jobs (Bhattacharyya, 2018).

Green technologies, including electric mobility and energy storage, will be critical. The transition to electric vehicles is already supported by schemes like the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) program. However, infrastructure and affordability remain barriers. A low-carbon pathway will also require reforming subsidies that currently favor fossil fuels (Dubash *et al*., 2018).

10.2 Sustainable agriculture and food security

Agriculture is highly vulnerable to climate variability. Droughts, floods, and changing rainfall patterns threaten food security. Future pathways must focus on climate smart agriculture, which includes crop diversification, integrated pest management, and efficient irrigation. Promoting millets and other drought-resistant crops can increase resilience (Mall *et al*., 2006a).

Technology can also play a role. Satellite-based weather forecasting, mobile advisory services, and precision farming can help farmers adapt. However, equitable access to these tools is essential to avoid widening social inequalities. Policies should also strengthen farmer cooperatives and ensure minimum support prices for climate-resilient crops (Tankha *et al*., 2020).

10.3 Water security and management

Water scarcity is one of India's greatest challenges. Climate change exacerbates seasonal variability and groundwater depletion. Sustainable water management requires both supply side and demand side interventions. Rainwater harvesting, watershed development, and recycling of wastewater are crucial measures (Shah, 2010; Chetouani *et al.,* 2017). Inter-basin river transfer projects are controversial due to ecological and social risks. A more decentralized approach, empowering local communities to manage water resources, may prove more effective. Traditional systems such as *Tank irrigation* in South India or *Johads* in Rajasthan illustrate the potential of community-based water management (Agarwal & Narain, 1997).

10.4 Urban sustainability and smart cities

Urban areas contribute significantly to emissions while also being vulnerable to heat waves, floods, and pollution. Sustainable urban pathways must prioritize public transport, green buildings, and waste management. The Smart Cities Mission provides an opportunity to integrate sustainability into urban planning, though its current focus has been more on infrastructure than ecological resilience. Expanding green spaces, improving public health infrastructure, and ensuring affordable housing are essential. Urban climate action should also address informal settlements, where poor residents face the greatest exposure to climate risks (Saunders & Baeck, 2015).

10.5 Community led climate adaptation

Future pathways must build on community knowledge and participation. Grassroots organizations and local governments can design adaptation strategies suited to regional contexts. For example, community-based forest management has shown promise in improving both ecological and social outcomes. Empowering women and marginalized groups in decision making is the key. Their participation ensures that adaptation strategies are socially inclusive and address the needs of vulnerable groups. Strengthening Panchayati Raj institutions can help localize adaptation planning (Chhatre & Agrawal, 2009).

10.6 Governance, institutions, and finance

Strong governance is necessary to implement sustainable pathways. Coordination between ministries, states, and local bodies must improve. Integrating climate considerations into all sectors, including transport, health, and education, is essential. Finance remains a major barrier. India requires significant investment for renewable energy, adaptation, and resilience building. International climate finance commitments, such as the Green Climate Fund, are vital. Domestic innovations, such as green bonds and carbon markets, also offer potential. Transparency and accountability in policy implementation will strengthen trust and effectiveness. Strengthening institutions like the National Green Tribunal can ensure environmental justice and enforce regulations (Dubash & Jogesh, 2014; Shukla *et al*., 2015).

10.7 Education, awareness, and behavior change

Education and awareness are critical for sustainable futures. Integrating environmental education into school curricula can build long-term awareness. Media campaigns and civil society initiatives can

promote behavioral changes, such as reducing waste, conserving water, and adopting sustainable diets. Youth engagement is particularly important. India's young population can become drivers of innovation and activism. Platforms for youth participation in policymaking can harness this potential.

10.8 Equity and justice as guiding principles

Sustainability must be guided by principles of equity and justice. Climate change disproportionately affects poor, tribal, and marginalized communities. Future policies must ensure that adaptation and mitigation do not worsen inequalities. Concepts like climate justice emphasize that those who contribute least to emissions often suffer the most (Newell & Mulvaney, 2013). Redistributive policies, targeted subsidies, and social protection schemes can help vulnerable groups transition to new livelihoods. Ensuring fair compensation for displaced communities and participation in decision-making will strengthen social legitimacy.

India's sustainable future depends on pursuing multiple pathways simultaneously. Renewable energy, climate-smart agriculture, water security, and resilient cities must be combined with strong governance, finance, and public participation. Education and awareness will support long-term change, while equity and justice must remain at the center of all strategies. While challenges are immense, India also has unique opportunities to pioneer inclusive and sustainable models of development. By combining traditional knowledge, modern technology, and democratic participation, India can build pathways that safeguard both the environment and society.

11. Conclusion

Environment, climate change, and society in India are deeply interconnected. This review has shown how environmental degradation and climate variability affect agriculture, water, health, livelihoods, and cities. India's large population, dependence on natural resources, and socio-economic inequalities make it especially vulnerable. At the same time, India is also a key global player in climate negotiations and sustainable development initiatives. The review has highlighted sectoral impacts in detail. Agriculture faces rising risks from erratic rainfall, droughts, and floods. Water resources are under pressure from both climate stress and over-extraction. Public health is threatened by heat waves, vector-borne diseases, and air pollution. Forests and biodiversity are under stress due to deforestation, habitat loss, and climate variability. Urban areas face growing challenges of pollution, floods, and extreme weather events. These impacts interact with poverty, gender, caste, and regional disparities, making the social dimensions critical.

11.1 Inequalities and justice dimensions

Climate change does not affect all Indians equally. The poor, women, tribal communities, and informal workers bear the brunt. Climate justice is not only an ethical question but also a practical necessity for building sustainable futures. Just transition policies, inclusive adaptation, and redistributive mechanisms are essential. Social movements and civil society have raised these issues, pressing for both recognition and participation in decision-making.

11.2 Policy and institutional frameworks

India has developed a wide range of policies, from the National Action Plan on Climate Change to state-level missions. It participates actively in international climate negotiations and has set ambitious renewable energy targets. However, gaps remain in implementation, coordination, and integration of climate concerns across sectors. Climate finance and institutional capacity continue to be challenges.

The role of judiciary, through institutions like the National Green Tribunal, has added an important dimension of environmental accountability.

11.3 Pathways for the future

Future directions for India must balance growth and sustainability. Renewable energy expansion, climate-smart agriculture, sustainable water management, resilient cities, and community-based adaptation are promising pathways. Strong governance, adequate finance, and public participation are central to success. Education and youth engagement will shape long-term transformations. Importantly, equity and justice must guide all actions to ensure that the most vulnerable are protected.

India's trajectory matters not only for its citizens but also for the global climate. The choices India makes in energy, agriculture, and urban development will influence global emissions and resilience. At the same time, India's rich traditions of environmental knowledge, social mobilization, and democratic participation offer unique opportunities. This review has aimed to bring together diverse strands of research and policy on environment, climate change, and society in India. The evidence shows that while challenges are immense, there are also multiple opportunities to build a more sustainable and equitable future. Success will depend on integrating science, policy, and society in ways that are inclusive and forward-looking. India's path forward must be one of climate resilience, ecological sustainability, and social justice. Such a pathway is not only possible but necessary for ensuring the well-being of both present and future generations.

Disclosure statement: *Conflict of Interest:* The authors declare that there are no conflicts of interest.
Compliance with Ethical Standards: Not applicable.

References

Agarwal, A., & Narain, S. (1991). Global warming in an unequal world (p. 81)

Agarwal, A., & Narain, S. (1997). Dying wisdom: The decline and revival of traditional water harvesting systems in India. *The ecologist,* 27(3), 112-117.

Agarwal, B. (2010). Gender and green governance: the political economy of women's presence within and beyond community forestry. Oxford University Press.

Agha Z. and Chowdhury S. (2023). Youth climate action from Indian states and regions. Downloaded from https://www.theclimategroup.org/our-work/news/youth-climate-action-indian-states-and-regions

Alaoui S. M., A. Abouatallah A., Salghi R., Amahmid Z., *et al*. (2013), Impact assessment of deficit irrigation on yield and fruit quality in peachorchard, *Der Pharmacia Chemica,* 5 (3), 236-243

Anjum, G., & Aziz, M. (2025). Climate change and gendered vulnerability: A systematic review of women's health. *Women's Health,* 21, 17455057251323645.

Ansorge L. (2024). Bibliometric Studies as a Publication Strategy. *Metrics,* 1(1), 5. https://doi.org/10.3390/metrics1010005

Arora-Jonsson, S. (2011). Virtue and vulnerability. Discourses on women, gender and climate change. *Global Environmental Change,* 21(2), 744–751. https://doi.org/10.1016/j.gloenvcha.2011.01.005

Atteridge, A., Shrivastava, M. K., Pahuja, N., & Upadhyay, H. (2012). Climate policy in India: what shapes international, national and state policy? *Ambio,* 41(Suppl 1), 68-77.

Badika, P., Choudhary, M. K., Nayak, T., Jaiswal, R. K., & Agarwal, A. (2024). Projected water availability in the Tawa River Basin India in changing climate. *Groundwater for Sustainable Development*, 25, 101176.

Balakrishnan, K., Dey, S., Gupta, T., Dhaliwal, R. S., Brauer, M., Cohen, A. J., ... & Dandona, L. (2019). The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017. *The Lancet Planetary Health,* 3(1), e26-e39.

Baul, T. K., & McDonald, M. (2015). Integration of Indigenous knowledge in addressing climate change. *Indian journal of traditional knowledge,* 1(1), 20-27.
Baviskar, A. (1999). In the belly of the river: tribal conflicts over development in the Narmada Valley (pp. xiv+-286).
Baviskar, A. (2020). Uncivil city: Ecology, equity and the commons in Delhi. New Delhi: Sage.
Bazzi I., Hamdani I., Kadda S., Zaidi K., Merimi C., Loukili E. (2023). Corrosion inhibitors of mild steel in acidic solution: A bibliometric analysis from 1990 to 2023, *Afr. J. Manag. Engg. Technol.* 1(1), 76-89
Beg, M. J., & Khan, M. S. (2022). Environmental Jurisprudence in India. Book Rivers.
Bhattacharyya, S. C. (2018). Mini-grids for the base of the pyramid market: A critical review. *Energies,* 11(4), 813.
Birthal, P. S., & Hazrana, J. (2019). Crop diversification and resilience of agriculture to climatic shocks: Evidence from India. *Agricultural systems,* 173, 345-354.
Bolch, T., Kulkarni, A., Kaab, A., Huggel, C., Paul, F., Cogley, J. G., ... & Stoffel, M. (2012). The state and fate of Himalayan glaciers. *Science,* 336(6079), 310–314. https://doi.org/10.1126/science.1215828
Bureau of Energy Efficiency (BEE). (2019). Perform, Achieve and Trade (PAT) scheme. Annual report 2018–2019. Government of India.
CANSA. (2019). Climate Action Network South Asia. Annual report 2019. Climate Action Network.
Carleton, T. A. (2017). Crop-damaging temperatures increase suicide rates in India. *Proceedings of the National Academy of Sciences,* 114(33), 8746–8751. https://doi.org/10.1073/pnas.1701354114
Centre for Science and Environment (CSE). (1982). The state of India's environment. A citizens' report. New Delhi. Centre for Science and Environment.
Centre for Science and Environment (CSE). (2016). State of India's environment 2016. New Delhi. CSE.
Chatterjee, S. (2021). Decreasing climate change vulnerability through adaptation with special reference to migration: A study in the Indian Sundarbans. Kansas State University.
Chaturvedi, S., & Doyle, T. (2015). Climate terror: A critical geopolitics of climate change. London: Palgrave Macmillan.
Chetouani A., Hammouti B., Salghi R. (2017). Physical-Chemical Study Generated Air pollution and Treated WasteWater, ISBN: 978-3-330-86794-9, *Edit Univ. Europ*. (2017)
Chhatre, A., & Agrawal, A. (2009). Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. *Proceedings of the National Academy of Sciences,* 106(42), 17667–17670. https://doi.org/10.1073/pnas.0905308106
Citaristi, I. (2022). United nations environment programme—UNEP. In The Europa directory of international organizations 2022 (pp. 193-199). Routledge.
Dagdeviren, H., Elangovan, A., & Parimalavalli, R. (2021). Climate change, monsoon failures and inequality of impacts in South India. *Journal of Environmental Management*, 299, 113555.
Das, U., & Ansari, M. A. (2021). The nexus of climate change, sustainable agriculture and farm livelihood. *Climate Research,* 84, 23-40.
Davis, M. (2001). Late Victorian holocausts. El Niño famines and the making of the third world. Verso.
Deshpande, T., Mukherji, R., & Sastry, M. (2025). Policy styles and India's national action plan on climate change (NAPCC). *Policy Studies,* 46(1), 46-63.
Dhiman, R. C., Pahwa, S., Dhillon, G. P. S., & Dash, A. P. (2010). Climate change and threat of vector-borne diseases in India. Are we prepared? *Parasitology Research,* 106(4), 763–773. https://doi.org/10.1007/s00436-010-1767-4
Dhiman, R., VishnuRadhan, R., Eldho, T.I. et al. Flood risk and adaptation in Indian coastal cities: recent scenarios. Appl Water Sci 9, 5 (2019). https://doi.org/10.1007/s13201-018-0881-9
Dubash, N. K. (2013). The politics of climate change in India. Narratives of equity and co-benefits. Wiley Interdisciplinary Reviews. Climate Change, 4(3), 191–201. https://doi.org/10.1002/wcc.210
Dubash, N. K. (Ed.). (2019). India in a warming world: Integrating climate change and development. Oxford University Press.

Dubash, N. K., & Jogesh, A. (2014). From margins to mainstream? State climate change planning in India. *Economic and Political Weekly,* 86-95.

Dubash, N. K., Khosla, R., Kelkar, U., & Lele, S. (2018). India and climate change: Evolving ideas and increasing policy engagement. *Annual Review of Environment and Resources,* 43(1), 395-424.

Dwivedi, R. (2020). Conflict and collective action: The Sardar Sarovar project in India. Routledge India.

Eckstein, D., Künzel, V., & Schäfer, L. (2021). The global climate risk index 2021. Bonn: Germanwatch.

Emanuel, K. (2017). Will global warming make hurricane forecasting more difficult? *Bulletin of the American Meteorological Society,* 98(3), 495-501.

Fortun, K. (2009). Advocacy after Bhopal: Environmentalism, disaster, new global orders. University of Chicago Press.

Gadgil, M., & Guha, R. (1993). This fissured land: an ecological history of India. Univ of california Press.

Gadgil, M., & Guha, R. (2013). Ecology and equity: The use and abuse of nature in contemporary India. Routledge.

Gadgil, S., & Gadgil, S. (2006). The Indian monsoon, GDP, and agriculture. *Economic and Political Weekly,* 41(47), 4887–4895.

Ghosan, L., Clift, P. D., Macklin, M. G., Fuller, D. Q., Constantinescu, S., Durcan, J. A., ... & Gupta, A. K. (2012). Fluvial landscapes of the Harappan civilization. *Proceedings of the National Academy of Sciences*, 109(26), E1688–E1694. https://doi.org/10.1073/pnas.1112743109

Ghosh, P. (2021). Water stress and water crisis in large cities of India. In Sustainable climate action and water management (pp. 131-138). Singapore: Springer Singapore.

Goswami, B. N., Venugopal, V., Sengupta, D., Madhusoodanan, M. S., & Xavier, P. K. (2006). Increasing trend of extreme rain events over India in a warming environment. *Science,* 314(5804), 1442–1445. https://doi.org/10.1126/science.1132027

Graham, S., Desai, R., & McFarlane, C. (2013). Water wars in Mumbai. *Public Culture*, 25(1), 115-141.

Guha, R. (1983). Forestry in British and post-British India: A historical analysis. *Economic and Political weekly*, 1882-1896.

Guha, R. (2000a). Environmentalism. A global history. Oxford University Press.

Guha, R. (2000b). The unquiet woods: ecological change and peasant resistance in the Himalaya. Univ of California Press.

Guha, R. (2014). Environmentalism: A global history. Penguin UK.

Gupta, A. K., & Nair, S. S. (2011). Urban floods in Bangalore and Chennai: risk management challenges and lessons for sustainable urban ecology. *Current Science,* 1638-1645.

Gupta, K. (2020). Challenges in developing urban flood resilience in India. *Philosophical Transactions of the Royal Society A,* 378(2168), 20190211.

Gupta, R., Somanathan, R., & Dey, S. (2017). Global warming and local air pollution have reduced wheat yields in India. *Climatic Change,* 140(3-4), 593–604. https://doi.org/10.1007/s10584-016-1878-8

Gurjar, B. R., Jain, A., Sharma, A., Agarwal, A., Gupta, P., Nagpure, A. S., & Lelieveld, J. (2010). Human health risks in megacities due to air pollution. *Atmospheric Environment*, 44(36), 4606-4613.

Guttikunda, S. K., & Goel, R. (2013). Health impacts of particulate pollution in a megacity—Delhi, India. *Environmental Development,* 6, 8–20. https://doi.org/10.1016/j.envdev.2012.12.002

Habib, I. (2011). Economic history of medieval India, 1200-1500. Pearson Education India.

IEA. (2022). CO_2 emissions in India. International Energy Agency. https://www.iea.org/reports/co2-emissions-in-india

IMD. (2020). State of climate in India 2019. India Meteorological Department, Ministry of Earth Sciences.

India, P. M. C. C. C. (2008). National action plan on climate change. Government of India.

Intergovernmental Panel on Climate Change (IPCC). (2021). Climate change 2021. The physical science basis. Cambridge University Press.

International Energy Agency (IEA). (2021). India Energy Outlook 2021. https://www.iea.org/reports/india-energy-outlook-2021

Islam, S., Karipot, A., Bhawar, R., Sinha, P., Kedia, S., & Khare, M. (2024). Urban heat island effect in India: a review of current status, impact and mitigation strategies. *Discover Cities*, 1(1), 34.

Jayaram, A. A. (2024). Mitigation of Groundwater Depletion in India.

Jha, C. K., Gupta, V., Chattopadhyay, U., & Sreeraman, B. A. (2018). Migration as adaptation strategy to cope with climate change. A study of farmers' migration in rural India. *International Journal of Climate Change Strategies and Management,* 10(1), 121–141. https://doi.org/10.1108/IJCCSM-03-2017-0059

Jha, S. K., Negi, A. K., Alatalo, J. M., & Negi, R. S. (2021). Socio-ecological vulnerability and resilience of mountain communities residing in capital-constrained environments. *Mitigation and Adaptation Strategies for Global Change,* 26(8), 38.

Joshi, P., Chaudhary, E., & Dey, S. (2024). Impacts of Air Pollution on Human Health: Present Status in India and Future Directions. In Air Quality and Human Health (pp. 9-22). Singapore: Springer Nature Singapore.

Kadda S., Belabed A. (2021). Temperature and mechanical extraction effect on chemical compositions of Argania spinosa l seed oil of Eastern region of Morocco, *Moroccan Journal of Chemistry*, 9 (4), 822-831

Kadda S., Merzouki M., Alaloui M.M., Himri C. (2025). DFT and Docking Techniques: Bibliometric analysis, *Arab. J. Chem. Environ. Res.,* 12 (2), 167-178

Kaur, R., & Pandey, P. (2021). Air pollution, climate change, and human health in Indian cities: a brief review. *Frontiers in Sustainable Cities*, 3, 705131.

Kjellstrom, T., Briggs, D., Freyberg, C., Lemke, B., Otto, M., & Hyatt, O. (2018). Heat, human performance, and occupational health. A key issue for the assessment of global climate change impacts. *Annual Review of Public Health,* 39(1), 97–112. https://doi.org/10.1146/annurev-publhealth-040617-014251

Klingensmith, D. (2007). One valley and a thousand. Dams, nationalism, and development. Oxford University Press.

Knowlton, K., Kulkarni, S. P., Azhar, G. S., Mavalankar, D., Jaiswal, A., Connolly, M., ... & Hess, J. J. (2014). Development and implementation of South Asia's first heat–health action plan in Ahmedabad (Gujarat, India). *International Journal of Environmental Research and Public Health,* 11(4), 3473–3492. https://doi.org/10.3390/ijerph110403473

Lal SR, S., Herbert GM, J., Arjunan, P., & Suryan, A. (2025). Advancements in renewable energy transition in India: A review. *Energy sources, part A: recovery, utilization, and environmental effects,* 47(2), 2024921.

Lrhoul H., Turki H., Hammouti B. (2023), Benammar O., Internationalization of the Moroccan Journal of Chemistry: A bibliometric study, *Heliyon,* 9(5), e15857, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2023.e15857

Mahapatra, B., Walia, M., Rao, C. A. R., Raju, B. M. K., & Saggurti, N. (2021). Vulnerability of agriculture to climate change increases the risk of child malnutrition: Evidence from a large-scale observational study in India. *PloS one,* 16(6), e0253637.

Mahato, A. (2014). Climate change and its impact on agriculture. *International journal of scientific and research publications,* 4(4), 1-6.

Majra, J. P., & Gur, A. (2009). Climate change and health: Why should India be concerned?. Indian journal of occupational and environmental medicine, 13(1), 11-16.

Mall, R. K., Gupta, A., Singh, R., Singh, R. S., & Rathore, L. S. (2006a). Water resources and climate change: An Indian perspective. *Current science, 1610*-1626.

Mall, R. K., Singh, R., Gupta, A., Srinivasan, G., & Rathore, L. S. (2006b). Impact of climate change on Indian agriculture. A review. *Climatic Change,* 78(2–4), 445–478. https://doi.org/10.1007/s10584-005-9042-x

Mani, M., Bandyopadhyay, S., Chonabayashi, S., & Markandya, A. (2018). South Asia's hotspots: The impact of temperature and precipitation changes on living standards. World Bank Publications.

Mazdiyasni, O., AghaKouchak, A., Davis, S. J., Madadgar, S., Mehran, A., Ragno, E., ... & Sadegh, M. (2017). Increasing probability of mortality during Indian heat waves. Science Advances, 3(6), e1700066. https://doi.org/10.1126/sciadv.1700066

Menon, M. (2024). Mobilisation of social movements and the local state in Independent India. Contemporary South Asia, 32(4), 563-579.

Ministry of Environment, Forest and Climate Change (MoEFCC). (2018). Green India Mission. Annual Report 2017–18. Government of India.

Ministry of Environment, Forest and Climate Change (MoEFCC). (2020). India's third biennial update report to the UNFCCC. Government of India.

Myers, S. S., Smith, M. R., Guth, S., Golden, C. D., Vaitla, B., Mueller, N. D., ... & Huybers, P. (2017). Climate change and global food systems. Potential impacts on food security and undernutrition. Annual Review of Public Health, 38(1), 259–277. https://doi.org/10.1146/annurev-publhealth-031816-044356

National Academy of Agricultural Sciences (NAAS). (2010). Degraded and wastelands of India. Status and spatial distribution. New Delhi. NAAS.

National Family Health Survey (NFHS-5). (2021). Fact sheets. Key indicators 2019–21. Ministry of Health and Family Welfare, Government of India.

Newell, P., & Mulvaney, D. (2013). The political economy of the 'just transition'. The Geographical Journal, 179(2), 132–140. https://doi.org/10.1111/geoj.12008

O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., … West, J. (2004). Mapping vulnerability to multiple stressors. Climate change and globalization in India. Global Environmental Change, 14(4), 303–313. https://doi.org/10.1016/j.gloenvcha.2004.01.001

Pacheco Aispuro G., Rojas Jácome I.B., Martínez Zamora C.A., Gil-Ortiz Mejía C., Mader C., Castillo Rangel C., Monroy Sosa A., Flores-Vázquez M., Arroyo Zavala O.J., Ramos-Zúñiga R., *et al*. (2023). Bibliometric Analysis: Six Decades of Scientific Production from a Nationwide Institution: Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado (ISSSTE) from Mexico. Healthcare, 11(12), 1725. https://doi.org/10.3390/healthcare11121725

Padel, F., Das, S., & Mukerjee, M. (2010). Out of this earth: East India Adivasis and the aluminium cartel. New Delhi.

Pathak, H. (2023). Impact, adaptation, and mitigation of climate change in Indian agriculture. Environmental Monitoring and Assessment, 195(1), 52.

Pattnaik, I., Lahiri-Dutt, K., Lockie, S., & Pritchard, B. (2018). The feminisation of agriculture or the feminisation of agrarian distress? Tracking the trajectory of women in agriculture in India. Journal of the Asia Pacific Economy, 23(1), 138–155. https://doi.org/10.1080/13547860.2017.1394569

Petrescu, D., Petcou, C., Safri, M., & Gibson, K. (2021). Calculating the value of the commons: Generating resilient urban futures. Environmental Policy and Governance, 31(3), 159-174. https://doi.org/10.1002/eet.1890

Possehl, G. L. (2002). The Indus civilization. A contemporary perspective. Rowman Altamira.

Puri, K., Vel, A. S., Manoharan, N., James, R. A., & Joshi, R. (2021). Environment education in India: Challenges and opportunities. The holistic approach to environment, 11(4), 122-127.

Ramakrishnan, P. S. (1992). Shifting agriculture and sustainable development: an interdisciplinary study from north-eastern India.

Ravera, F., Iniesta-Arandia, I., Martín-López, B., Pascual, U., & Bose, P. (2016). Gender perspectives in resilience, vulnerability and adaptation to global environmental change. Ambio, 45(Suppl 3), 235-247.

Ray, S., & Saini, S. (2011). Development and displacement: The case of an opencast coal mining project in Orissa. Sociological Bulletin, 60(1), 45-64.

Revi, A. (2008). Climate change risk. An adaptation and mitigation agenda for Indian cities. Environment and Urbanization, 20(1), 207–229. https://doi.org/10.1177/0956247808089157

Revi, A., Satterthwaite, D. E., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R. B. R., Pelling, M., ... & Solecki, W. (2014). Urban areas. Contribution of Working Group II to the Fifth Assessment Report of the

Intergovernmental Panel on Climate Change, Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.
Richards, J. F. (1993). The Mughal Empire (Vol. 5). Cambridge University Press.
Rist, L., Shaanker, R. U., Milner-Gulland, E. J., & Ghazoul, J. (2010). The use of traditional ecological knowledge in forest management: an example from India. Ecology and Society, 15(1).
Rodell, M., Velicogna, I., & Famiglietti, J. S. (2009). Satellite-based estimates of groundwater depletion in India. Nature, 460(7258), 999–1002. https://doi.org/10.1038/nature08238
Roy, A., Kumar, S., & Rahaman, M. (2024). Exploring climate change impacts on rural livelihoods and adaptation strategies: Reflections from marginalized communities in India. Environmental Development, 49, 100937.
Sainath, P. (2025). Everybody loves a good drought: Stories from India's poorest districts. Verso Books.
Saini, D. K. (2022). Major Ambient Air Pollutants and Their Impact on Plants and Human Health in Gajraula City. Ph.D. thesis. Department of Plant Sciences, Mahatma Jyotiba Phule Rohilkhand University, Bareilly, India. https://doi.org/10.13140/RG.2.2.25404.14727
Saini, D. K., & Kumar, M. (2021). Respiratory health effects of ambient air pollutants on road-side vendors in industrial city Gajraula, Uttar Pradesh, India. Plant Archives, 21 (2), 697-703.
Saini, D. K., & Kumar, M. (2022). Seasonal changes in respiratory health status of road-side vendors in industrial city Gajraula. Pollution Research, 41(3), 1106-1111. https://doi.org/10.53550/PR.2022.v41i03.048
Saini, D. K., & Kumar, M. (2024). Seasonal variation in biochemical parameters of few medicinal plants in industrial area of Gajraula of district Amroha (UP), India. *Flora and Fauna,* 30 (1), 44-50.
Saini, D. K., Garg, S. K., & Kumar, M. (2019). Major air pollutants and their effects on plant and human health: a review. *Plant Archives,* 19 (2), 3273-3278.
Saini, D. K., Gupta, A., & Kumar, M. (2021). Estimating the response of some plant species to ambient air pollution in industrial city gajraula for potential green belt development. *Plant Archives,* 21(2), 565-575.
Santha, S. D., Jaswal, S., Sasidevan, D., Khan, A., Datta, K., & Kuruvilla, A. (2016). Climate variability, livelihoods and social inequities: The vulnerability of migrant workers in Indian cities. *International Area Studies Review*, 19(1), 76-89. https://doi.org/10.1177/2233865915626832
Sareen, S., & Kale, S. S. (2018). Solar 'power': Socio-political dynamics of infrastructural development in two Western Indian states. *Energy Research & Social Science,* 41, 270-278. https://doi.org/10.1016/j.erss.2018.03.023
Saunders, T., & Baeck, P. (2015). Rethinking smart cities from the ground up. London: Nesta.
Sethi, M., Sharma, R., Mohapatra, S., & Mittal, S. (2021). How to tackle complexity in urban climate resilience? Negotiating climate science, adaptation and multi-level governance in India. *PLoS One,* 16(7), e0253904.
Shah, T. (2010). Taming the anarchy. Groundwater governance in South Asia. Routledge
Sharholy, M., Ahmad, K., Mahmood, G., & Trivedi, R. C. (2008). Municipal solid waste management in Indian cities – A review. *Waste Management*, 28(2), 459–467. https://doi.org/10.1016/j.wasman.2007.02.008
Sharma, D., & Tomar, S. (2010). Mainstreaming climate change adaptation in Indian cities. Environment and Urbanization, 22(2), 451-465.
Shashikanth, K., Ghosh, S., & Karmakar, S. (2018). Future projections of Indian summer monsoon rainfall extremes over India with statistical downscaling and its consistency with observed characteristics. *Climate Dynamics*, 51(1), 1-15.
Shiva, V. (1991). The violence of the Green Revolution. Third World agriculture, ecology, and politics. Zed Books.
Shukla, P., Dhar, S., Pathak, M., Mahadevia, D., & Garg, A. (2015). Pathways to deep decarbonization in India.

Sreenivasaiah, K. (2016). Climate change and its impact on milk production in India. In Climate Change Challenge (3C) and Social-Economic-Ecological Interface-Building: Exploring Potential Adaptation Strategies for Bio-resource Conservation and Livelihood Development (pp. 531-547). Cham: Springer International Publishing.

Subramanian A, Nagarajan AM, Vinod S, Chakraborty S, Sivagami K, Theodore T, Sathyanarayanan SS, Tamizhdurai P, Mangesh VL. (2023) Long-term impacts of climate change on coastal and transitional eco-systems in India: an overview of its current status, future projections, solutions, and policies. *RSC Adv.* 13(18), 12204-12228. https://doi.org/10.1039/d2ra07448f

Sugden, F., Maskey, N., Clement, F., Ramesh, V., Philip, A., & Rai, A. (2014). Agrarian stress and climate change in the Eastern Gangetic Plains. Gendered vulnerability in Bihar, India. *Global Environmental Change,* 29, 258–269. https://doi.org/10.1016/j.gloenvcha.2014.10.008

Tankha, S., Fernandes, D., & Narayanan, N. C. (2020). Overcoming barriers to climate smart agriculture in India. *International Journal of Climate Change Strategies and Management,* 12(1), 108-127.

Udmale, P., Ichikawa, Y., Kiem, A. S., & Panda, S. N. (2014). Drought impacts and adaptation strategies for agriculture and rural livelihood in the Maharashtra state of India. *Open Agric J* 8: 41–47.

UNICEF. (2021). The climate crisis is a child rights crisis. Introducing the Children's Climate Risk Index. United Nations Children's Fund. Retrieved from https://www.unicef.org

United Nations Framework Convention on Climate Change (UNFCCC). (2015). India's Intended Nationally Determined Contribution (INDC). UNFCCC Secretariat.

United Nations. (2019). World urbanization prospects. The 2018 revision. New York. UN.

Unnikrishnan, A. S., & Shankar, D. (2007). Are sea-level-rise trends along the coasts of the north Indian Ocean consistent with global estimates? *Global and Planetary Change*, 57(3-4), 301–307. https://doi.org/10.1016/j.gloplacha.2006.11.029

Varughese, A., & Purushothaman, C. (2021). Climate change and public health in India: the 2018 Kerala floods. World Medical & Health Policy, 13(1), 16-35.

Ward, P. J., Jongman, B., Kummu, M., Dettinger, M. D., Sperna Weiland, F. C., & Winsemius, H. C. (2014). Strong influence of El Niño Southern Oscillation on flood risk around the world. *Proceedings of the National Academy of Sciences,* 111(44), 15659-15664.

Warner, K., & Afifi, T. (2014). Where the rain falls. Evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. *Climate and Development,* 6(1), 1–17. https://doi.org/10.1080/17565529.2013.835707

Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Belesova, K.,... & Costello, A. (2018). The 2018 report of the Lancet Countdown on health and climate change. Shaping the health of nations for centuries to come. *The Lancet,* 392(10163), 2479–2514. https://doi.org/10.1016/S0140-6736(18)32594-7

Whitcombe, E. (1972). The United Provinces Under British Rule, 1860–1900. University of California Press.

Xing, Y.H., Lu, H., Zhu, X. et al. (2024). How Rice Responds to Temperature Changes and Defeats Heat Stress. *Rice* 17, 73, https://doi.org/10.1186/s12284-024-00748-2