



Original Article

Climate Change and Global Warming: Causes, Consequences, and Sustainable Responses for a Resilient Future

Johirul Islam

Assistant Professor, Department of Assamese, Hamidabad College, Satsia, Dhubri, Assam, India

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Correspondence Address:

Md. Johirul Islam
Assistant Professor,
Department of Assamese,
Hamidabad College, Satsia,
Dhubri, Assam, India
Email-
johirulislam17805@gmail.com

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Abstract

Climate change and global warming constitute the most pressing environmental and existential challenges of the 21st century. Driven predominantly by anthropogenic greenhouse gas emissions resulting from the combustion of fossil fuels, widespread deforestation, industrial processes, and intensive agricultural practices, the Earth's average surface temperature has risen by approximately 1.1°C since the pre-industrial period, with far-reaching and irreversible consequences. These include extreme and unpredictable weather events, accelerated melting of polar ice caps and glaciers, rising sea levels, ocean acidification, widespread loss of biodiversity, disruption of freshwater resources, and an alarming increase in the frequency and intensity of natural disasters.

The industrial revolution marked the beginning of large-scale exploitation of coal, oil, and natural gas, coupled with rapid urbanization and unchecked population growth, dramatically altering the composition of the atmosphere. These human-induced changes have exacerbated the natural greenhouse effect, trapping excessive heat and triggering a cascade of environmental, economic, social, and health-related crises. Developing nations and marginalized communities, despite their minimal historical contribution to global emissions, bear a disproportionately heavy burden of the impacts.

Addressing this multifaceted crisis demands immediate, coordinated, and sustained action through mitigation measures (reducing emissions at source) and adaptation strategies (building resilience to unavoidable changes). Transitioning to renewable energy systems, promoting reforestation and sustainable land-use practices, adopting circular economy principles, enhancing carbon sequestration technologies, and strengthening international cooperation are indispensable steps toward a sustainable and resilient future. This paper critically examines the scientific causes, wide-ranging consequences, and evidence-based solutions to climate change and global warming, underscoring the shared ethical responsibility of governments, industries, civil society, and individuals in safeguarding the planet for present and future generations.

Keywords: Climate Change, Global Warming, Greenhouse Effect, Anthropogenic Emissions, Carbon Dioxide, Methane, Deforestation, Biodiversity Loss, Sea-Level Rise, Renewable Energy, Carbon Sequestration, Mitigation, Adaptation, Climate Justice, Sustainable Development.

Introduction

In recent decades, climate change and global warming have transcended the realm of scientific discourse to become one of the most urgent global emergencies threatening ecological stability, economic prosperity, and human well-being. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (2021–2023) confirms that human activities are unequivocally responsible for the rapid warming observed since the mid-20th century. The global mean surface temperature is now approximately 1.1°C above pre-industrial levels, and without drastic reductions in greenhouse gas emissions, warming is projected to exceed 2°C possibly reaching 3–4°C by the end of the century under high-emission scenarios.

Climate change refers to long-term alterations in temperature, precipitation, wind patterns, and other aspects of the Earth's climate system, whereas global warming specifically denotes the ongoing rise in global average temperature caused primarily by the enhanced greenhouse effect.

While natural climate variability has always existed due to factors such as orbital changes, solar irradiance fluctuations, and volcanic activity, the speed and magnitude of current warming are unprecedented and overwhelmingly attributable to human influence.

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The roots of the present crisis can be traced to the Industrial Revolution, which initiated large-scale burning of fossil fuels, followed by exponential growth in energy demand, deforestation, industrial agriculture, and consumer-driven economies. This paper provides a comprehensive overview of the primary causes of climate change, its multifaceted impacts on natural and human systems, the disproportionate burden on vulnerable populations, and the array of mitigation and adaptation strategies required to forge a sustainable and resilient future.

Causes Of Climate Change and Global Warming

Anthropogenic Greenhouse Gas Emissions

The enhanced greenhouse effect remains the principal driver of contemporary global warming. Major greenhouse gases and their approximate contributions are:

Approximate Contribution to Warming

Greenhouse Gas

Primary Sources

Carbon Dioxide (CO₂) 76% Fossil fuel combustion, cement production, deforestation Methane (CH₄) 16% Agriculture (livestock enteric fermentation), landfills, natural gas leakage Nitrous Oxide (N₂O) 6% Agricultural soil management, fertilizer use, industrial processes Fluorinated Gases 2% Refrigeration, electronics manufacturing Energy-related CO₂ emissions from coal, oil, and natural gas continue to dominate global emissions, followed by land-use change and industrial processes.

Deforestation and Land-Use Change

Forests serve as vital carbon sinks, absorbing approximately 30% of anthropogenic CO₂ emissions annually. Large-scale deforestation—particularly in the Amazon, Congo Basin, and Southeast Asia—for timber, agriculture, and infrastructure has released vast stores of carbon while diminishing the planet's capacity for future sequestration.

Agricultural Practices and Livestock Rearing

Modern industrial agriculture contributes roughly 24% of global greenhouse gas emissions. Methane emissions from ruminant digestion, rice paddies under anaerobic conditions, and manure management, along with nitrous oxide from synthetic fertilizers, significantly amplify warming.

Industrial Processes and Consumerism

Rapid industrialization, overproduction, planned obsolescence, and linear “take-make-dispose” economic models have led to excessive resource extraction, energy use, and waste generation, including non-biodegradable plastics and electronic waste.

Natural Contributing Factors

Although minor in comparison to anthropogenic influences in the current era, natural phenomena such as large volcanic eruptions (releasing aerosols that temporarily cool the planet), El Niño-Southern Oscillation (ENSO) cycles, and variations in solar output continue to modulate short-term climate variability.

Consequences Of Climate Change

Environmental Impacts

- * Accelerated melting of Greenland and Antarctic ice sheets and mountain glaciers.

- * Thermal expansion and melting ice contributing to global mean sea-level rise of 20 cm since 1900, with projections of 0.6–1.1 m by 2100 under high-emission pathways.

- * Ocean acidification (30% increase in acidity since the Industrial Revolution) threatening marine ecosystems and coral reefs.

- * Disruption of hydrological cycles leading to desertification and reduced freshwater availability

- * Loss of biodiversity: the IPBES (2019) estimates one million species face extinction, many within decades; the IPCC projects that the proportion of species at very high risk of extinction could reach 9% (up to 14%) at 1.5°C warming, rising to 18% at 2°C and 29% at 3°C

Economic Impacts

- * Declining agricultural productivity and rising food prices.

- * Increased frequency and severity of extreme weather events causing trillions of dollars in damages

- * Disruption of global supply chains, insurance markets, and tourism-dependent economies

- * The Global Commission on the Economy and Climate estimates that bold climate action could generate US\$26 trillion in economic benefits by 2030

Social and Health Impacts

- * Heightened incidence of heat-related illnesses and deaths.

- * Expansion of vector-borne diseases (malaria, dengue, Zika) into new regions.

- * Worsening air quality and respiratory conditions

- * Mental health consequences for climate-displaced populations and farmers facing crop failure

Climate-Induced Migration and Conflict

By 2050, the World Bank projects up to 216 million people could be forced to migrate within their own countries due to climate impacts. Competition for dwindling water and arable land may exacerbate social tensions and geopolitical conflicts.

Disproportionate Impact on Developing Nations and Climate Justice

Low-income and lower-middle-income countries, despite contributing less than 10% of historical emissions, suffer the earliest and most severe consequences due to geographical vulnerability, reliance on climate-sensitive sectors, and limited adaptive capacity. For instance, agricultural productivity in Africa has declined by 34% since 1961 due to climate change, more than in any other region, and up to 116 million people in Africa could be exposed to sea-level rise by 2030. The principle of “common but differentiated responsibilities” enshrined in the UNFCCC underscores the moral and legal obligation of industrialized nations to provide financial assistance, technology transfer, and capacity-building support to the Global South.

Mitigation Strategies

Mitigation Strategies

Transition to Renewable Energy

Aggressive deployment of solar, wind, hydropower, geothermal, and emerging green hydrogen technologies, coupled with energy efficiency improvements and electrification of transport and heating. Modelled

pathways to net-zero emissions emphasize transitioning from fossil fuels to renewables, which are now often cheaper than fossil fuels in many regions.

Sustainable Land-Use and Forestry

Large-scale reforestation, afforestation, and restoration of degraded lands; protection of primary forests and peatlands.

Low-Carbon Agriculture

Promotion of regenerative practices, precision farming, alternative proteins, and methane-reducing livestock feed additives.

Carbon Capture, Utilization, and Storage (CCUS)

Deployment of both nature-based solutions and engineered technologies to remove CO₂ from the atmosphere, though the IPCC stresses that deep emissions reductions remain primary.

International Frameworks and Agreements

Agreement	Year	Key Objective
UNFCCC	1992	Stabilize GHG concentrations at safe levels
Kyoto Protocol	1997	Legally binding emission reduction targets for developed nations
Paris Agreement	2015	Limit warming to well below 2°C, pursuing efforts for 1.5°C
Glasgow Climate Pact (COP26)	2021	Phase-down of coal, phase-out of inefficient fossil fuel subsidies
Loss and Damage Fund	2022	Financial support for nations most impacted by climate disasters

Role Of Education, Technology, And Public Participation

- *Effective climate action requires:
- *Integration of climate literacy into curricula at all educational levels
- *Leveraging artificial intelligence, remote sensing, and big data for monitoring and prediction
- *Empowering youth, indigenous communities, and grassroots movements
- *Individual behavioral changes: reducing energy and water consumption, adopting plant-rich diets, minimizing waste, and **supporting green policies**

Conclusion

Climate change and global warming represent an unprecedented challenge that tests humanity's capacity for cooperation, innovation, and ethical stewardship. The scientific evidence is unequivocal, the impacts are already severe, and the window for effective action is rapidly closing. Achieving the goals of the Paris Agreement and securing a livable planet demands immediate decarbonization of economies, restoration of natural ecosystems, and equitable support for the most vulnerable populations.

The transition to a sustainable, resilient, and just future is not merely a technical or economic necessity—it is a profound moral imperative. Every sector of society must contribute: governments through bold policy and finance, corporations through responsible innovation, scientists through continued research, and citizens through conscious daily choices. The legacy we leave for future generations hinges on the urgency and sincerity with which we act today. Protecting the Earth is the ultimate expression of intergenerational solidarity and human responsibility.

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Circular Economy and Sustainable Consumption

Reducing, reusing, repairing, and recycling materials; shifting toward service-based and sharing economies.

Adaptation Strategies

- *Development and deployment of drought- and flood-resistant crop varieties.
- *Construction of resilient infrastructure (sea walls, elevated buildings, sponge cities).
- *Integrated water resource management and desalination where necessary.
- *Early-warning systems and community-based disaster risk reduction.
- *Climate-proofing health systems and social safety nets.

research paper titled "Climate Change and Global Warming: Causes, Consequences, and Sustainable Responses for a Resilient Future."

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The authors declare that there are no conflicts of interest regarding the publication of this paper.

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