A Comprehensive Review on Climate Change: Causes, Impacts, and Mitigation Strategies

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Abstract
Climate change is one of the most important environmental and social problems of the 21st century. It is mostly caused by people using fossil fuels, cutting down trees, building factories, and farming. These actions have raised the temperature of the Earth, changed the weather patterns, and made extreme occurrences like floods, droughts, and heat waves worse. The effects go beyond harming the environment; they also hurt biodiversity, food and water security, human health, and the world's economy. Developing countries are still the most at risk since they don't have enough money or the ability to adapt. To effectively mitigate climate change, we need to cut down on emissions and make natural carbon sinks stronger. This may be done by using renewable energy, making agriculture more sustainable, planting trees, and using new technologies like carbon capture and storage. To get fair, science-based, and long-lasting climate action, countries need to work together through agreements like the Paris Agreement. To make sure that the world stays stable and strong in the long run, we need to take a multi-faceted approach to climate change that includes policy, innovation, and changes in behavior.

Keywords: Climate change, Greenhouse gases, Mitigation, Renewable energy, Paris Agreement, Sustainability.

1. Introduction

The impacts of climate change are widespread and impactful, making it one of the most critical global concerns of our time (Neira et al., 2023). It describes the gradual change in Earth's climate and weather patterns that has been going on since the Industrial Revolution, and is mostly caused by humans (Koch et al., 2024). Greenhouse gas (GHG) emissions have skyrocketed due to human activities such as burning fossil fuels at excessive rates, cutting down forests, and industrialising processes, which have upset the planet's natural energy equilibrium (Filonchyk et al., 2024). The current rate of climate change is mainly caused by human activities rather than natural causes, as confirmed by the Intergovernmental Panel on Climate Change (IPCC), which states that the past few decades have been the warmest in recorded history (Solecki et al., 2024).

This warming will have far-reaching and complex effects. Sea levels have risen, glaciers have melted faster (Rounce, D. R., et al., 2023), and extreme weather events like cyclones, floods, and droughts have become more often due to the increase in global temperatures (Kumar et al., 2023). The alteration of ecosystems is outpacing their ability to adapt, which poses a threat to both biodiversity and food security. Particularly at risk are agricultural and freshwater systems, and heatwaves, vector-borne illnesses, and air pollution pose growing threats to human health (Abbasi, 2025; de Souza & Weaver, 2024). From an

economic perspective, climate change exacerbates inequalities between rich and developing countries, degrades infrastructure, and threatens people's ability to make a living (SenGupta & Atal, 2024).
Reduced emissions, shifts to renewable energy, more sustainable land-use practices, and better climate governance are all essential components of a worldwide strategy to lessen the severity of these impacts (Pivac et al., 2024). One method to curb global warming and encourage a low-carbon future is for countries to cooperate together under agreements like the Paris Agreement (Li et al., 2024).
This review study takes a holistic look at climate change, covering its origins, effects, and potential solutions. It takes a look at the research behind climate change, the effects on society and the environment, and the technical and policy-driven solutions to the problem of making our society more resilient and sustainable in the face of climate change.

2. Causes of Climate Change

The term "climate change" describes the gradual but noticeable transformation of Earth's weather patterns over the past few decades, as a result of human interference. While natural forces have always had a role in Earth's climate, human activities are mostly to blame for the current acceleration of warming (Stein, 2024).

2.1. Pollutants from Greenhouse Gases (GHG)

The buildup of atmospheric greenhouse gases, which act as heat traps and cause an increase in global surface temperatures (Al-Ismail et al., 2023), is the primary factor responsible for climate change. Most notably, there are:
Mostly released into the atmosphere as a byproduct of deforestation and the combustion of fossil fuels such as coal, oil, and natural gas for power generation (Wang & Azam, 2024), transportation (Azhar, U., et al., 2024) and industry (Filonchyk et al., 2024). According to the IPCC, fossil fuels are responsible for about 90% of CO_2 emissions and over 75% of global GHG emissions. Methane (CH_4): Emitted by cows, fields of rice, landfills, and the burning of fossil fuels. Methane has a shorter persistence time than CO_2,

Figure 1. Relative Contribution of Major Climate Change Drivers

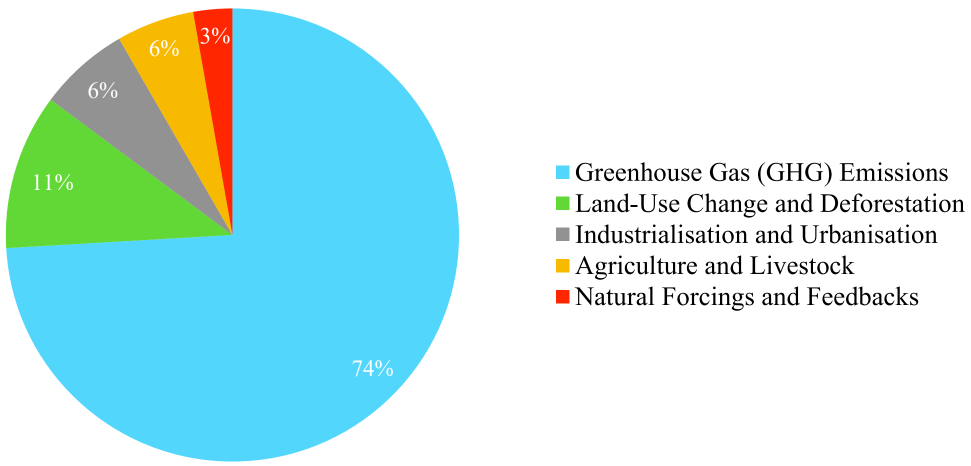

Table 1. Major Drivers of Climate Change, Their Sources, and Relative Contribution.-1

S.No.	Driver	Main Sources	Relative Contribution to Climate Change	Key Notes
1	Greenhouse Gas (GHG) Emissions	Burning of fossil fuels (coal, oil, natural gas), deforestation, industrial processes	~75-80%	Major contributor; includes CO_2, CH_4, N_2O, and fluorinated gases that trap heat in the atmosphere.
2	Land-Use Change and Deforestation	Agricultural expansion, urbanisation, logging	~10-12%	Reduces carbon sinks, increases CO_2, emissions, alters albedo and hydrological cycles.
3	Industrialisation and Urbanisation	Energy production, manufacturing, transport, infrastructure growth	~5-7%	Intensifies energy demand, pollution, and urban heat-island effects.
4	Agriculture and Livestock	Rice cultivation, livestock emissions, fertiliser use, land conversion	~5-6%	Produces CH_4 and N_2O both potent greenhouse gases.
5	Natural Forcings and Feedbacks	Volcanic eruptions, solar cycles, oceanic circulation changes	<3%	Minor contribution; amplifies human-induced warming through feedbacks like ice-albedo and permafrost methane release.

but it is better at capturing heat (Rajendran et al., 2024; Sikiru et al., 2024; Wang et al., 2024; Yu et al., 2023). A long-lived and very powerful greenhouse gas, nitrous oxide (N_2O) is produced by agricultural fertilizers, manure, and some industrial activities (Grace et al., 2023; Zhu et al., 2025). Additional gases and particles: Fluorinated gases and aerosols in the atmosphere can affect weather patterns, with the latter having both cooling and warming impacts (Grace et al., 2023; Wang et al., 2023).

2.2. Deforestation and Land-Use Alterations

The loss of vegetation and its capacity to absorb carbon dioxide (CO_2) is one way in which deforestation and land degradation exacerbate global warming. Forest clearance causes changes to local temperatures, biodiversity, land reflectivity, and water cycles, as well as changes to agricultural use and urban sprawl (Abera et al., 2024)

2.3. Growth in Industry and Cities

Fossil fuel usage has skyrocketed since the Industrial Revolution due to the growth of cities and industries. This has two effects: first, it raises emissions of greenhouse gases; second, it makes the urban heat-island effect worse, which is when city dwellers feel hotter than those in rural areas because of all the concrete and less flora.

2.4. Livestock and Agriculture

Much of the methane and nitrous oxide that is released into the atmosphere comes from farming (Zhang et al., 2024). A large portion of the world's emissions come from livestock, fertiliser usage, rice paddies, and the conversion of land for agricultural (Gerber et al., 2013).

2.5. Forces and Feedbacks from Nature

While natural climate change factors like solar flares, volcanic eruptions, and ocean currents do have an impact, they are insufficient to explain the present rate of warming. Feedbacks caused by humans, such as the reduction of reflectivity due to melting ice or the release of methane from thawing permafrost, enhance the impacts of global warming (Ansor et al., 2023; McCulloch et al., 2024)

3. Impacts of Global Warming

One of the greatest threats of the modern era, climate change affects all parts of Earth's infrastructure. Its impact is far-reaching, interconnected, and becoming worse by the day. Agriculture, water supplies, human health, and the world economy are just a few areas that will feel the effects, which go well beyond environmental shifts.

3.1. Effects on Nature and the Built Environment

Rising world temperatures are among the most obvious effects of climate change. The hottest years on record have occurred in the last several decades (Cheng et al., 2023; Esper et al., 2024), and the average increase in global surface temperatures from the pre-industrial era is over 1°C (Jenkins et al., 2023). Extreme heat waves, longer warm seasons, and shorter cold spells have all been brought about by this increase. Hotter than ever before weather is wreaking havoc on ecosystems, water resources, and people's ability to survive in many parts of the world (Li et al., 2023).

Melting glaciers and polar ice caps are another crucial sign. Sea levels are rising around the world due in large part to the rapid melting of ice caps in the Arctic and Antarctic (Fang et al., 2023; Maure et al., 2023). Some regions, like the Himalayas, rely on glacial meltwater for their freshwater supply, and this is being threatened by melting glaciers (Karakoti et al., 2024). Coastal towns, islands, and deltas are under danger as a result of rising waters, which will cause more floods, erosion, and land loss (Roy et al., 2023). There are existential threats to low-lying nations such as Bangladesh and the Maldives (Cardarelli & Pomper, n.d.).

Worldwide, there has been a noticeable shift in the patterns of precipitation. Prolonged droughts affect some regions, while heavy rains and flooding hit others (Qiu et al., 2023). As a result of this change, water insecurity is worsened, infrastructure is damaged, and agricultural cycles are disrupted. Cyclones, hurricanes, and unseasonal monsoons, among other forms of extreme weather, have also grown in frequency and severity (Islam, F. S., 2025).

The seas are also in a very precarious situation because they take in so much of the extra heat and carbon dioxide gas from the air. Marine ecosystems are being disrupted by ocean warming, which causes coral bleaching and fish species to migrate to colder waters (Yin et al., 2023). Ocean acidification, caused by increased CO_2 absorption, endangers coral reefs, shell-forming creatures, and the millions of people whose livelihoods depend on fisheries (Martins Medeiros & Souza, 2023).

3.2. How It Will Affect Farmers, Water Supplies, and Food Safety

Climate change poses a significant threat to agriculture, which is essential to many countries (Ritchie, 2024). Reduced crop yields and productivity are caused by factors such as changing temperatures, unpredictable rainfall, and increasing pests (Yuan et al., 2024). Research indicates that in susceptible areas, the output of important crops such as wheat, rice, and maize might drop by 7–23%. Soil moisture decreases, plant stress increases, and crop maturation speeds up in warmer weather, all of which contribute to lesser quality produce (Rezaei et al., 2023).

Soil and water resources are greatly impacted by climate change. Extreme rainfall worsens soil erosion, nutrient degradation, and waterlogging, whereas protracted droughts drain reservoirs and groundwater supplies (Ji et al., 2024). As a result of saltwater intrusion caused by rising sea levels, arable land in coastal locations becomes unusable (Tarolli et al., 2023). The freshwater supply for around two billion people is under jeopardy as a result of melting ice in many river systems, especially those that receive their water from the Himalayas. There is significant pressure on fisheries and livestock. The production of dairy products and meat is reduced as a result of heat-related illnesses in animals caused by rising temperatures (Chauhan et al., 2023). The reproduction and migration of fish are influenced by ocean acidification and warming, which in turn affects food availability and the means of subsistence for fishing populations (Gilfoyle & Baird, 2023).

Worries about food insecurity are growing in tandem with falling agricultural productivity. Developing countries are particularly vulnerable to the effects of decreased yields, increasing food prices, and broken supply chains on people's ability to eat and make a living (Kaur, R., & Watson, J. A., 2024). Most impacted are rural populations that rely on agriculture for their livelihood, which causes economic downturn and social unrest (Khatri et al., 2024).

3.3. Natural Communities and Their Varieties

Natural ecosystems are being upended by climate change, which is causing habitats to change and endangering biodiversity. Some species are able to adapt and move to higher or cooler areas in time, while others are unable to do so. Many plant and animal species are in danger of extinction as forests change and coral reefs bleach (Hald-Mortensen, 2023). To make matters worse for native plant and animal species, ecological imbalances encourage the spread of alien species and novel pest outbreaks (Guégan et al., 2023; Zhang et al., 2024).

3.4. Society, the economy, and human health

There are both immediate and long-term consequences for human health from climate change and rising temperatures. Heat stroke and heart problems are more common in hot and humid climates, and they are especially dangerous for people who work outside or who are elderly (Wu et al., 2025). Diseases transmitted by mosquitoes, such as dengue, chikungunya, and malaria, are more common in warmer regions (Kumar et al., 2023). Infectious and respiratory illnesses are exacerbated by wildfires, water poisoning, and poor air quality (Monoson et al., 2023). Migration and displacement are also caused by climate change. The influx of millions of people forced to flee their homes due to natural disasters like floods, rising sea levels, and failed crops puts a burden on the resources, infrastructure, and social stability of the places that receive them (Parveen, 2024).

Natural catastrophes caused by climate change have enormous monetary consequences. The yearly cost of repairs to crops, houses, and infrastructure caused by extreme weather occurrences is in the billions (Ferreira, 2024; Newman & Noy, 2023). As a result, poverty and inequality are worsening in developing nations. Critical infrastructure like electricity grids, transportation, and healthcare systems are struggling to keep up with the increasing demands placed on urban systems by heatwaves, floods, and energy use.

4. Mitigation Strategies and Looking Ahead

Efforts to stabilize or reverse climate change, decrease emissions of greenhouse gases (GHGs), and improve natural carbon sinks are together known as mitigation. Innovation in technology, new policies, changes in behavior, and international cooperation are all part of it (Wang et al., 2023). Achieving sustainable growth while keeping global warming below safe bounds is the end aim.

4.1. Make the Switch to Renewable and Carbon-Neutral Power

In order to reduce carbon emissions, the world must transition away from using fossil fuels and towards renewable and low-carbon energy (Singh et al., 2023). The majority of the carbon dioxide that is released into the atmosphere comes from burning fossil fuels such as coal, oil, and natural gas (Murphy, 2024). Substituting renewable energy sources like solar, wind, hydro, geothermal, and bioenergy for them greatly decreases emissions and guarantees energy stability (Chen et al., 2023). In order to achieve a sustainable energy transition, it is crucial to decarbonize industry (Sovacool et al., 2024) and electrify transportation infrastructure, such as public transportation and electric automobiles (Liu et al., 2024). Additionally, in order to back low-carbon development, cleaner industrial methods and energy-efficient technology need to be implemented.

Table 2. Overview of Causes, Impacts, and Mitigation Strategies of Climate Change

S.No.	Key Aspects	Main Points / Summary	Key Examples or Details
1	**Causes of Climate Change**	**Multiple anthropogenic (human-made) and natural factors contribute to global warming.**	
	a. Greenhouse Gas Emissions	Main driver CO_2, CH_4, N_2O trap heat in the atmosphere.	Fossil fuel burning ~90% of CO_2, emissions; methane from livestock, rice fields, landfills.
	b. Deforestation & Land Use Change	Reduces CO_2, absorption capacity; alters ecosystems and weather patterns.	Forest clearance for agriculture and urbanization.
	c. Industrialization & Urbanization	Increased fossil fuel use and waste heat generation.	Urban heat-island effect in cities.
	d. Agriculture & Livestock	Releases methane and nitrous oxide; affects land quality.	Livestock farming, fertilizers, rice cultivation.
	e. Natural Feedbacks	Natural forces (volcanoes, solar variation) contribute slightly, but human-induced feedbacks dominate.	Melting ice reduces albedo; thawing permafrost releases methane.
2	**Effects of Climate Change**	**Climate change affects ecosystems, agriculture, water, health, and economies globally.**	
	a. Temperature Rise & Weather Extremes	Global temperature increased by >1°C; increased heatwaves and extreme events.	Droughts, floods, cyclones, unseasonal rains.
	b. Melting Ice & Sea Level Rise	Polar and glacial melting cause rising sea levels.	Threat to coastal areas, islands (e.g., Maldives, Bangladesh).
	c. Changes in Rainfall Patterns	Irregular precipitation, droughts, floods, and water scarcity.	Affects agriculture and drinking water availability.
	d. Ocean Impacts	Ocean warming, acidification, and coral bleaching.	Endangers marine species and fisheries.
	e. Agriculture & Food Security	Reduced crop yields, soil degradation, and water shortages.	Wheat, rice, and maize yields may drop 10-50%.
	f. Biodiversity Loss	Habitat shifts and species extinction.	Coral reefs bleaching, invasive species spread.
	g. Human Health & Economy	Heat stress, vector-borne diseases, migration, and economic loss.	Dengue, malaria, infrastructure damage, inequality.
3	**Mitigation & Adaptation Strategies**	**Strategies focus on reducing emissions, promoting sustainability, and increasing resilience.**	
	a. Renewable & Clean Energy	Shift from fossil fuels to solar, wind, hydro, and bioenergy.	Decarbonization, electric mobility, energy transition.
	b. Energy Efficiency	Smart grids, efficient buildings, and behavioral conservation.	Lower demand reduces emissions and costs.
	c. Forest Conservation & Sustainable Land Use	Forests as carbon sinks; promote reforestation and agroforestry.	Protect wetlands and peatlands.
	d. Climate-Smart Agriculture	Reduce CH_4 & N_2O through precision farming and reduced food waste.	Promote plant-based diets and organic farming.
	e. Carbon Capture & Technology	CCUS, green hydrogen, and renewable energy storage innovations.	Emerging but costly technologies.
	f. Waste Management & Circular Economy	Recycling, reuse, and methane recovery from waste.	Biogas production, industrial decarbonization.
	g. Public Awareness & Behavioural Change	Promote eco-friendly lifestyles and climate education.	Reduce meat, use public transport, energy saving.
	h. Policy & Global Cooperation	International climate governance (Paris Agreement).	NDCs, carbon pricing, fossil fuel subsidy removal.
	i. Just & Equitable Transition	Support affected workers and developing countries.	Retraining, green jobs, climate finance.
	j. Monitoring & Climate Finance	Track progress, ensure transparency, fund clean projects.	Green bonds, MRV systems.
4	**Challenges & Future Directions**	**Barriers: limited funding, political resistance, and tech gaps.**	**Need for innovation, collaboration, and equity.**

4.2. Modernizing Energy Savings and Demand-Side Control

Improving energy efficiency is crucial for reducing emissions in all industries. Total energy demand can be reduced by societies through the installation of smart grids, the improvement of building insulation, the upgrade of appliances, and the optimization of industrial activities (abdelaoui et al., 2023; Saleem et al., 2023; Szczotka et al., 2023). Along with technological advancements, behavioural actions like minimizing excessive usage and conserving electricity are essential. In addition to lowering costs and improving energy security, these combined initiatives minimize emissions (Altassan, 2023; Papadakis & Katsaprakakis, 2023).

4.3. Reducing Carbon Emissions with Forestry, Sustainable Land Use

Soils and forests play an essential role as carbon sinks (Liu et al., 2024). Both carbon absorption and biodiversity are improved through mitigation techniques like afforestation and replanting (Zhu et al., 2023). Among the most effective short-term remedies is to avoid deforestation, particularly in tropical regions (Heinrich et al., 2023; Nzabarinda et al., 2025). Soil fertility, erosion control, and carbon sequestration are all enhanced by agroforestry and other forms of sustainable forest management (Pan, J. et al., 2025). Wetlands and peatlands are essential ecosystems that, when protected, increase carbon sequestration and make communities more resistant to natural disasters (Li et al., 2024).

4.4. Agriculture that is Climate Smart and the Transformation of the Food System

Methane from cattle and nitrous oxide from fertilizers are two major sources of air pollution in agriculture (Ogwu et al., 2024). Changing to a more environmentally friendly farming method can lessen this effect. Methods that increase efficiency without sacrificing yield include precision fertilisation, organic farming, crop rotation, and conservation tillage (Arshad et al., 2023). Lowering emissions is another benefit of encouraging plant-based diets and decreasing food waste. Aside from reducing the impact on the environment, sustainable agriculture improves food security and the quality of life for people living in rural areas (Bhatia et al., 2023).

4.5. The Role of New Technologies in Carbon Capture

There is hope for the direct removal of CO_2 from industrial emissions or the air thanks to new technologies like Carbon Capture, Utilization, and Storage (CCUS) (Hanson et al., 2025). To reach net-zero objectives, these technologies are crucial, but they are expensive and yet in their early phases. Hydrogen fuel, green manufacturing, and innovations in renewable energy storage are also crucial for deep decarbonisation (Akinpelu et al., 2023; Miao et al., 2025). We can speed up progress by increasing research and facilitating worldwide technology transfer.

4.6. Management of Waste and the Circular Economy

Minimizing resource extraction and waste generation can be achieved by shifting from a linear "take-make-dispose" model to a circular economy (Cruz, 2025; Daga et al., 2025). Reducing emissions is the overarching goal of recycling, reusing materials, and energy conversion processes like biogas production and methane recovery (Deng et al., 2025). Another important part of this strategy is using clean technology to decarbonise heavy industries (Tian et al., 2023).

4.7. Altering Behaviour, Raising Public Knowledge

Without a corresponding shift in society, technological solutions will fall short. It is critical to promote sustainable consumerism, eco-friendly lifestyles, and increase climate literacy (Arya, 2023; Pekez et al., 2025). A combination of behavioural changes, such as eating less meat, using less energy, and preferring public or non-motorized transportation, can significantly lower emissions (Lambrecht et al., 2023; Zhang et al., 2025). The promotion of responsibility and awareness is an important function of community programs, the media, and educational institutions (K. Ghazy & M. Fathy, 2023).

4.8. The Role of International Cooperation in Policy and Governance

Every endeavor to mitigate climate change relies on robust policy tools. The Paris Agreement is a historic international framework with the goal of keeping global warming well below 2 degrees Celsius, ideally below 1.5 degrees Celsius (Guzović et al., 2023). Determinations made at the national level to reduce emissions are known as "Nationally Determined Contributions" (NDCs) (Carmona et al., 2024). Carbon pricing, cap-and-trade schemes, and the elimination of subsidies for fossil fuels are examples of economic policies that provide financial incentives for more environmentally friendly decisions (Antimiani et al., 2023; Tat et al., 2023). Transparent reporting, multinational collaboration, and effective governance all work together to make everyone more accountable and make more progress (Kavadis et al., 2024).

4.9. A Fair, Just, and Equitable Transition

Fair and inclusive climate mitigation is essential. People living in areas that rely on fossil fuels may find their way upended by the shift to a low-carbon economic model (Feng et al., 2023). Workers impacted by the change should be guaranteed new job opportunities, retraining programs, and social safety nets (Carcillo & Scarpetta, 2024). To guarantee a fair global response to climate change, it is imperative that wealthier nations help developing ones financially and through the transfer of technology.

4.10. Budgeting, Progress Reporting, and Evaluation

Significant climate funding is necessary for large-scale mitigation efforts. To finance renewable energy projects and the widespread adoption of clean technologies, public-private partnerships, green bonds, and international climate funds can all play a role (Alamgir & Cheng, 2023; Bei & Wang, 2023). To keep tabs on development and keep things open and honest, MRV systems—which stand for monitoring, reporting, and verification—are essential. Using climate-resilient infrastructure or drought-tolerant crops are examples of adaptation measures that can be integrated with mitigation to produce synergy and increase overall climate resilience (Singh et al., 2024).

5. Difficulties and Paths Ahead

There are still obstacles, even with progress. Progress is impeded by economic obstacles, political opposition, a lack of access to technology, and a lack of behavioral change. Lack of funding and institutional ability are further challenges that developing nations encounter. We need more public involvement, creativity, and collaboration to overcome these obstacles. Possible future directions include increasing the use of renewable energy, developing better methods to remove carbon from the air, and making sustainability a part of people's daily lives.

6. Conclusion

Greenhouse gas emissions and unsustainable development, both caused by humans, are the primary causes of climate change, which is a new and unprecedented threat on a global scale. We must act quickly and as a community to mitigate its devastating effects on farming, human health, and the economy. In order to strengthen resilience, it is necessary to employ both adaptation and mitigation techniques. The former might include the use of renewable energy sources, sustainable land use, behavioral changes, and international cooperation. Equity, innovation, and collective global responsibility are essential for achieving climatic stability. Humanity can only preserve Earth's ecological balance and secure a sustainable future for future generations by implementing coordinated, science-based, and fair solutions.

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