

The Role of AI and Robotics in Understanding and Managing Climate Extremes

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ABSTRACT

Climate changes are significantly increasing the frequency and intensity of extreme weather events i.e. floods, heatwaves, droughts, wildfires and tropical storms. All these events are posing serious threats to human societies, ecosystems and economic development. In response to these threats, AI and robotics have emerged as powerful technologies for climate monitoring, prediction and disaster preparedness. This review examines the application of AI and robotics in managing climate extremes, highlighting their contribution to weather forecasting, precision agriculture, disaster risk reduction, environmental monitoring and post-disaster recovery. It also highlights technological initiatives employed by leading countries and discusses opportunities and challenges linked with implementing intelligent climate solutions. The review shows that AI-powered technology significantly enhances the accuracy and speed of climate forecasting. The robotic system improves the operational efficiency and reduces human exposure during hazardous conditions. However, various barriers such as data quality, infrastructure, technical expertise and ethical governance limits widespread adoption especially in developing countries. The article concludes that incorporating robotics and AI into national climate adaptation policies can strengthen the resilience against disasters and support sustainable development in an era of accelerating climate change.

Keywords: AI, Robotics, Climate Extremes, Climate Change, Disaster Management

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Introduction

Climate change is emerging as the most significant global challenge of the twenty-first century. It has far-reaching consequences for ecosystems, economies and human well-being (Intergovernmental Panel on Climate Change [IPCC], 2023). Rising temperature, greenhouse gas emissions, rapid industrialization, deforestation and unsustainable land-use practices are accelerating global warming which results in increasingly frequent and severe climate extremes, including floods, droughts, heatwaves, hurricanes and wildfires (IPCC, 2023). All this threatens food security, biodiversity, water resources, public health and socioeconomic development worldwide (United Nations Environment Programme [UNEP], 2024). The robotics and AI technologies have played a vital role recently for addressing climate-related challenges through advanced data analysis, predictive modeling and autonomous decision-making (Materia et al., 2024). AI algorithms can promptly process large volume of meteorological, satellite and environmental data to explore complex climatic patterns and improve the accuracy of weather predictions Unlike conventional forecasting approaches, (Camps-Valls et al., 2025). In the same way, the robotic technology (autonomous drones, unmanned ground vehicles and robotic sensor systems) has increased disaster monitoring, environmental surveillance, precision agriculture and emergency response operation (Adegoke, 2022). AI and robotics have been incorporated by several technologically advanced countries into their climate adaptation strategies. China adopts AI-driven forecasting systems and robotic rescue technologies for flood and landslide management (DEEP Robotics, 2026). USA uses machine learning models and computer vision systems for early wildfire detection (Microsoft, 2024). Integration of robotics and AI into climate adoption is globally uneven despite rapid technological advancement as developing nations continue to face significant barriers such as inadequate digital infrastructure, financial constraints, limited technical expertise and insufficient access to high-quality environmental data (World Bank, 2024). Resultantly, a comprehensive synthesis of recent developments is required to better understand the opportunities, challenges and future potential of AI and robotics in managing climate extremes.

Therefore, this review synthesis the current application of AI and robotics in climate prediction, disaster risk reduction, environmental monitoring and sustainable climate adaptation, highlights global best practices, identifies implementation challenges and discusses future research directions for enhancing climate resilience.

Causes of Climate Extremes and their Global Effect:

Causes	Result	How regions are affected around the globe	Effects
Fossil fuel & Gas emissions	Rise in Global Temperatures	From 1850, temperature has risen, 1.4°C as compared to the pre- industrial era. Since 1981, global temperatures rose per decade doubled from 0.11°C to 0.2°C and expected to reach 1.5°C threshold by 2050. In Europe, average land temperatures have shot up 2.4° C, or 4.8° F	Heatwaves, droughts, death of vulnerable people

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Severe deforestation	Dry soil and loss of rainfall	Afghanistan faces multi-year droughts and a 40% drop in rainfall. Australia has lost 8.4 million hectares of land, and an estimated 1 billion animals, Tunisia, Morocco, Honduras, Guatemala, and El Salvador, face irregular rainfall patterns, resulting in crop failures.	Wildfires, destruction of local ecosystems, deforestation
Pollution and industrial waste	Melting of Glaciers and Rising sea levels	Tuvalu Islands, Maldives and Kiribati are the vulnerable areas, Tuvalu islands highest point is only 15 feet above sea level. Bangladesh is at risk of losing 75% of its land mass to rising sea levels. Global sea levels have risen about 8 inches from 1880 to today. Scientists estimate an additional 12 inches by 2100 minimum, and 79 inches in high emission areas.	Flooding, infrastructure destruction and forced migration
Unregulated agricultural expansion, and livestock farming	High methane emissions and soil degradation	Brazil, China, India, Indonesia, and Nigeria are countries most affected, these emissions have resulted in a loss of soil fertility by 33%, 133 billion to 456 billion metric tons of carbon has been lost from soils, and an imbalance in soil bacteria. Ethiopia and Somalia face severe droughts, leaving 24 million people suffering from famine	Severe and extremely long droughts, famine
Destruction of coastal wetlands	Loss of natural flood barriers	Pakistan and Mozambique are two of the countries most affected by floods, resulting in displacement of people and severe droughts	Devastating coastal, and urban flooding
Displacement of people (climate refugees)		By 2050, around 1.2 Billion people could be displaced due to changes in climate, which would be 12% of the world population if it reaches the estimated 9.9 billion by 2050. according to IDMC (Internal Displacement Monitoring Center) 2023, 1.5 million from Afghanistan, 1.21 Million in Pakistan, and 0.881 million in Ethiopia, 0.822 Million in Turkey, and 0.639 Million in China were internally displaced	

AI in the Prediction of climate change

The climate science has been revolutionized by Artificial Intelligence through improving the speed, accuracy and efficiency of the prediction of weather. The machine learning algorithms swiftly process diverse datasets collected from satellites, radar systems, drones, weather stations, and Internet of Things (IoT) devices unlike traditional numerical weather prediction models that require extensive computational resources and the Deep learning models can recognize complex atmospheric patterns that are difficult to detect using conventional statistical approaches. Recent research demonstrates that AI significantly betters the prediction of floods, heatwaves, tropical cyclones and droughts through real-time analysis of environmental data. Early warning systems powered by AI enable governments to issue timely evacuation notices, allocate emergency resources and reduce disaster-related losses. Apart from this, the AI-based climate models continuously learn from newly available data, increasing predictive performance over time and supporting evidence-based climate policy.

Robotics for Climate Disaster Management

Robotics are a vital component of modern disaster management systems as autonomous aerial drones, unmanned ground vehicles, robotic dogs and underwater robots can safely function in environments that are dangerous for human responders. This system is increasingly used for disaster surveillance, damage assessment,

infrastructure inspection, environmental monitoring and humanitarian assistance. The drones provide real-time aerial imagery that helps emergency agencies in locating stranded populations and evaluating disaster impacts during floods and landslides as the ground robots equipped with sensors and thermal cameras navigate hazardous terrain to search for survivors and deliver medical supplies. Robotic technology also contributes to long-term climate adaptation by supporting reforestation, biodiversity conservation, precision agriculture and sustainable water management through automated environmental monitoring.

Global Applications of AI and Robotics

Various countries have successfully incorporated AI and robotics into climate adaptation strategies as China adopts AI-based forecasting systems and robotic technology to improve flood prediction, landslide monitoring and emergency rescue operation. Similarly, Japan extensively employed robotic automation and precision agriculture to address labor shortages while improving agricultural efficiency under changing climatic conditions and US adopts machine learning models, satellite analytics and computer vision technologies for wildfire detection and climate forecasting. UAE employs AI-driven meteorological simulations to optimize cloud-seeding operations whereas the United Kingdom employs intelligent sensor networks and robotic systems to monitor renewable energy infrastructure and environmental change. These international experiences illustrate that intelligent technologies enhance disaster preparedness, improve resource management and strengthen national resilience against climate-related hazards.

Challenges and Future Prospects

Various barriers put hindrance in way of the widespread implementation of AI and robotics in climate management despite remarkable progress as high development and maintenance costs, inadequate digital infrastructure, limited access to quality environmental data, cybersecurity concerns and shortages of skilled professionals are the major challenges, particularly in low- and middle-income countries. Moreover, the ethical issues regarding algorithmic transparency, data privacy and equitable access also need careful consideration. Apart from this, the future development is expected to integrate AI with emerging technologies such as digital twins, edge computing, quantum computing, remote sensing and the Internet of Things because these innovations will improve climate simulations, enable real-time environmental monitoring and facilitate more efficient disaster response systems. Increased international collaboration, open-data initiatives and investment in technological capacity-building will be essential for maximizing the benefits of intelligent climate solutions.

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Conclusion

Artificial Intelligence and robotics are changing global efforts to understand, predict and manage climate extremes as AI enables accurate and timely forecasting through advanced data analytics while robotic technology enhances disaster response, environmental monitoring and climatic adaptation by functioning safely in hazardous environments. Evidences from technologically advanced nations highlight that these innovations substantially minimize disaster risks, improve resource efficiency and strengthen societal resilience. Nevertheless, technological limitations, financial constraints, governance issues and ethical considerations continue to challenge widespread adoption. The policymakers should prioritize investment in AI-driven climate infrastructure, strengthen international research collaboration and develop inclusive regulatory frameworks to ensure that intelligent technologies contribute effectively to sustainable development and long-term climate resilience.

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