



AI FOR CLIMATE CHANGE: SMART MODELS TO SAVE THE PLANET

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Abstract: The accelerating threat of climate change demands innovative and data-driven solutions. Artificial Intelligence (AI), powered by machine learning and deep learning, has emerged as a transformative tool to address both climate change mitigation and adaptation.

This research paper explores how AI-enabled “smart models” can analyze massive and complex datasets, enhance predictive capabilities, and optimize resource utilization for sustainable development. Applications range from renewable energy forecasting and precision agriculture to disaster prediction and carbon monitoring. The paper highlights both existing work and future opportunities, while also addressing key challenges such as energy costs, algorithmic bias, and data inequities. By proposing an integrated framework that emphasizes inclusivity, energy efficiency, and explainability, this work contributes toward shaping a sustainable and equitable AI-driven climate future.

Keywords: Artificial Intelligence (AI), Climate Change, Smart Models, Machine Learning, Climate Mitigation, Climate Adaptation, Renewable Energy, Precision Agriculture, Sustainable Development.

I. INTRODUCTION

Climate change has become one of the most pressing global challenges of the 21st century. Rising temperatures, frequent extreme weather events, sea-level rise, biodiversity loss, and disruptions in food and water security threaten ecosystems, human health, and economies worldwide. The Intergovernmental Panel on Climate Change (IPCC) repeatedly warns that urgent and collective action is necessary to limit global warming and secure a sustainable future.

While governments, industries, and communities are taking steps to mitigate greenhouse gas emissions and adapt to changing climate conditions, traditional approaches often fall short in terms of speed, scalability, and accuracy. The climate crisis is not only an environmental problem but also a data-intensive challenge, requiring the processing of vast amounts of information from satellites, sensors, climate models, and socio-economic systems.

Artificial Intelligence (AI) offers a transformative response to this challenge. By applying machine learning (ML), deep learning (DL), and data-driven smart models, AI enables the extraction of meaningful patterns from massive datasets, supports precise forecasting, and optimizes decision-making. For example, AI systems

can forecast renewable energy availability, manage smart power grids, optimize agricultural practices, detect deforestation, and provide early warning systems for natural disasters.

The importance of AI in climate action can be summarized in two dimensions:

1. Mitigation – reducing greenhouse gas emissions and promoting sustainable practices.
2. Adaptation – ensuring resilience against unavoidable impacts by strengthening disaster preparedness, water management, and infrastructure planning.

However, the deployment of AI is not free from challenges. High computational costs, energy consumption of large models, biases in training data, and ethical concerns pose barriers to widespread and equitable adoption. Therefore, responsible innovation and governance frameworks are essential to maximize benefits while minimizing risks.

This research paper explores the applications, methodologies, and implications of AI for climate change, with special emphasis on smart models that enhance both mitigation and adaptation strategies. It also highlights existing work, limitations, and proposed approaches that can shape a sustainable, AI-driven climate future.

II. LITERATURE SURVEY

The intersection of Artificial Intelligence (AI) and climate change has attracted significant attention in recent years, with research expanding across both mitigation and adaptation domains. Several studies emphasize the potential of AI as a key enabler in achieving global climate goals.

AI in Climate Mitigation:

Research highlights that AI can serve as an optimization engine for reducing greenhouse gas emissions. For instance, AI models have been employed to enhance renewable energy forecasting, improve smart grid management, and optimize energy consumption patterns. Google demonstrated that deep learning techniques could improve wind power output predictions, making renewable energy more reliable and cost-efficient. Similarly, AI-driven solutions in industries such as steel, cement, and aviation have shown measurable reductions in energy usage and emissions.

AI in Agriculture and Land Use:

Precision agriculture, supported by AI-based tools, has emerged as a promising field to reduce emissions while enhancing productivity. Machine learning algorithms analyze soil health, crop conditions, and weather patterns to recommend precise irrigation, fertilizer, and pesticide use. Case studies, such as John Deere's AI-enabled systems, demonstrate significant improvements in yields while cutting down resource consumption. Additionally, AI-driven satellite monitoring tools are increasingly used for forest conservation and early detection of illegal logging.

AI in Climate Adaptation:

AI has also been applied to strengthen resilience against climate impacts. Recent literature shows progress in disaster prediction and response, where AI systems improve forecasting of floods, hurricanes, and wildfires. For example, DeepMind's GraphCast model has been shown to outperform conventional weather prediction systems, providing earlier and more accurate forecasts. Similarly, AI-powered platforms such as Google's Flood Hub deliver early flood warnings to vulnerable communities worldwide.

AI Methodologies in Climate Science:

Beyond applications, technical advancements in AI methodologies have also been documented. Physics-Informed Neural Networks (PINNs) integrate physical laws with machine learning, ensuring reliable predictions that align with environmental principles. Natural Language Processing (NLP) models, on the other hand, process vast climate-related texts—including research papers, corporate reports, and policy documents—to track trends and commitments.

Challenges Identified in Literature:

Despite the progress, prior research emphasizes critical challenges. High energy consumption during AI training, risk of algorithmic bias, limited availability of quality climate data in the Global South, and ethical concerns regarding digital inequality are recurring themes. Studies advocate for governance frameworks, responsible innovation, and international collaboration to address these barriers effectively.

III. EXISTING WORK

Several initiatives and research projects worldwide demonstrate how AI is already being integrated into climate change strategies. These works provide valuable insights into both the potential and the limitations of AI-driven smart models.

1) Renewable Energy Optimization:

1. Google DeepMind has successfully applied deep learning to forecast wind energy output with higher precision. This optimization has increased the economic value of wind farms by up to 20%.
2. Smart grids in countries like the UK and Germany are increasingly using AI algorithms to balance supply and demand in real-time. Reinforcement learning techniques help reduce energy waste while integrating variable renewable sources such as solar and wind.

2) Precision Agriculture and Land Use:

1. John Deere's ExactEmerge™ system employs AI to optimize seed planting, fertilizer use, and irrigation. This reduces input costs and minimizes greenhouse gas emissions from agricultural activities.
2. Autonomous AI-powered drones and robots like BoniRob are being deployed for weed detection, soil monitoring, and targeted pesticide spraying, making farming more sustainable.
3. In forestry, AI-driven platforms such as Global Forest Watch leverage satellite imagery and computer vision algorithms to detect illegal deforestation and track forest health in near real time.

3) Climate Adaptation and Disaster Management:

1. Google Flood Hub provides early flood forecasts up to seven days in advance across multiple countries, especially in vulnerable regions of South Asia and Africa. - Pano AI has introduced wildfire detection systems that use high-resolution cameras combined with AI algorithms to detect smoke within minutes of ignition, significantly reducing fire damage.
2. GraphCast by DeepMind has advanced hurricane prediction, providing more accurate forecasts compared to traditional models, offering critical lead time for evacuation and preparation.

4) Carbon Monitoring and Capture:

1. The Climate TRACE initiative uses AI-powered satellite imagery to create a detailed inventory of greenhouse gas emissions at the facility level, improving transparency and accountability in emission reporting.
2. In carbon capture and utilization, AI models are accelerating the discovery of new materials for efficient CO₂ absorption and storage. These tools reduce experimentation time from years to months.

5) Corporate and Policy Integration:

1. Several corporations, including Microsoft's AI for Earth program, are investing in AI-driven environmental sustainability projects, such as water quality monitoring and biodiversity conservation.
2. Governments and organizations are beginning to integrate AI-based decision support systems into climate policy, using predictive models to plan infrastructure development and disaster risk management.

IV. METHODOLOGY

The methodology of this research is designed to analyze and evaluate how Artificial Intelligence (AI) contributes to climate change mitigation and adaptation through the use of smart models. It is structured around four key steps: data collection, model selection, implementation, and evaluation.

1) Data Collection and Sources:

Climate change is a data-rich challenge, with inputs coming from diverse sources. Satellite imagery and remote sensing: Used to monitor land cover, deforestation, urban heat zones, and crop health.

1. Sensor networks and IoT devices: Provide real-time environmental data such as temperature, air quality, and water levels.
2. Climate models and reanalysis datasets: Large datasets such as ERA5 offer historical climate data for model training.
3. Textual and policy data: Research papers, corporate sustainability reports, and international agreements are processed using Natural Language Processing (NLP).

2) Model Selection:

Different AI models are chosen based on the type of problem being addressed:

1. Machine Learning (ML) algorithms: Regression, Random Forests, and Gradient Boosting for forecasting energy demand or crop yields.
2. Deep Learning (DL) models: Convolutional Neural Networks (CNNs) for analyzing satellite imagery, and Recurrent Neural Networks (RNNs) or Transformers for time-series weather prediction.
3. Physics-Informed Neural Networks (PINNs): Integrate physical laws into training to ensure predictions remain scientifically valid.
4. Natural Language Processing (NLP): Extracts insights from large volumes of climate-related documents and reports.

3) Implementation Process:

The methodology for implementing AI solutions involves:

1. Data preprocessing – Cleaning, normalizing, and labeling data to prepare it for model training.
2. Model training and validation – Dividing datasets into training and testing sets to evaluate performance.
3. Optimization – Using techniques like reinforcement learning and hyperparameter tuning to improve efficiency and accuracy.
4. Deployment in real-world systems – Integrating AI into energy grids, agricultural monitoring platforms, disaster forecasting systems, and carbon accounting frameworks.

4) Evaluation Metrics:

To ensure reliability and practicality, models are evaluated based on:

1. Accuracy – The precision of forecasts and predictions.
2. Scalability – Ability to handle global-scale data and large regions.
3. Efficiency – Energy and time consumption in training and inference.
4. Sustainability impact – Contribution to emissions reduction or resilience building. - Ethical considerations – Fairness, bias reduction, and accessibility across regions, especially the Global South.

V. PROPOSED WORK

While significant progress has been made in applying Artificial Intelligence (AI) to climate change, several gaps remain. The proposed work focuses on enhancing AI's effectiveness, scalability, and fairness by developing an integrated framework of smart models.

1) Development of a Hybrid AI Framework:

A central proposal is to design a hybrid AI framework that combines:

1. Machine Learning and Deep Learning for predictive accuracy.
2. Physics-Informed Neural Networks (PINNs) to ensure predictions remain scientifically consistent.
3. Explainable AI (XAI) tools to make results transparent and interpretable for policymakers and non-experts.

2) Energy-Efficient AI Models:

Since training large AI models consumes high amounts of energy, the proposed work emphasizes the use of:

1. Green AI practices, such as energy-efficient architectures and carbon-aware scheduling.
2. Leveraging renewable-powered data centers for AI computation.
3. Model compression techniques like pruning and quantization to minimize energy consumption.

3) Inclusive and Equitable Climate Data:

A major challenge is the lack of high-quality climate data in developing countries. The proposed system includes:

1. Data-sharing collaborations between developed and developing regions.
2. Use of transfer learning to adapt models trained in data-rich environments for use in data-scarce regions.
3. Integration of local and indigenous knowledge into AI models to improve context relevance.

4) AI-Enabled Decision Support Systems:

The proposed work suggests creating AI-driven platforms that assist governments, industries, and communities in climate decision-making. Examples include:

1. Urban planning tools to design climate-resilient infrastructure.
2. Early warning systems for floods, droughts, and wildfires that integrate real-time sensor data with predictive AI models.
3. Carbon monitoring dashboards that provide transparent emissions reporting at the facility level.

5) Future-Oriented Research Directions:

1. Generative AI for Climate Science: Creating synthetic datasets to fill observational gaps in regions with limited monitoring infrastructure.
2. Quantum AI for Climate Models: Exploring quantum computing to solve large-scale climate simulations more efficiently.
3. Global Collaboration Platforms: Building open-source AI ecosystems for climate research to foster transparency and innovation.

VI. CONCLUSION

The climate crisis represents one of humanity's greatest challenges, demanding urgent, innovative, and scalable solutions. Artificial Intelligence (AI) has emerged as a transformative tool that can strengthen both mitigation and adaptation strategies. By harnessing smart models, AI enables accurate forecasting of renewable energy, efficient resource management in agriculture, early disaster warnings, and transparent carbon accounting. These applications not only accelerate decarbonization but also build resilience against unavoidable climate impacts.

However, the benefits of AI do not come without challenges. High computational energy requirements, potential algorithmic bias, lack of equitable access to climate data, and ethical concerns regarding transparency and misuse must be addressed. Without responsible innovation, AI risks exacerbating existing inequalities rather than alleviating them.

The future of AI for climate action lies in creating integrated, energy-efficient, and inclusive frameworks. Combining data-driven learning with physics-based models, ensuring explainability, and promoting open collaboration can enhance trust and reliability. Furthermore, embedding climate justice principles—equity, accessibility, and sustainability—into AI design will ensure that its benefits reach the most vulnerable communities.

In conclusion, AI is not a silver bullet but a critical ally in the fight against climate change. Its impact will depend on how responsibly and collaboratively it is deployed. With the right governance, global partnerships, and ethical considerations, AI-driven smart models can help secure a sustainable and resilient planet for future generations.

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