

AI for Climate Vulnerability Assessment

K. Anupriya*, Haripriya I., Jeferina Mary Catchirayar, Lakshmi R.

Abstract

Climate change is one of the biggest problems we face every day. The main problems are high temperatures, rising sea levels, and changes in weather, which will be worse in the upcoming years. To predict and adapt to these impacts, we need to create data-driven solutions. The main tool for predicting climate change is artificial intelligence, which can also be utilized to predict the weather and alert people of impending dangers. Massive information detection from imagery from satellites, various climate models, and other AI may provide useful responses that help in decision-making and frequently help us in becoming ready for climate change. Given the potential outcomes, the use of AI to climate change adaptation presents major moral problems, whereas the model remains to be built. Regarding this, the present study examines the most recent developments and potential routes of AI-enabled climate change adaptation remedies, emphasizing both the potential benefits and ethical concerns that need must be given consideration, using AI to adapt for the future use.

Keywords: Artificial intelligence, AI-powered models, climate change adaptation, early warning systems, climate modeling and projections

INTRODUCTION

Climate change poses one of the most critical global challenges of our time, affecting ecosystems, human health, economies, and infrastructure worldwide. Extreme weather events such as hurricanes, floods, droughts, and heatwaves are the main cause for climate adaptation measures. Understanding and assessing climate vulnerability, the degree to which people, places, and assets are susceptible to climate related risks, has become essential for prioritizing resources and building resilience in the face of a changing climate [1].

Artificial intelligence (AI) has grown up as an effective tool to evaluate climate vulnerability in this context, increasing our understanding of the impacts of climate change and enabling proactive risk management. A huge amount of data from many sources, such as satellite images, meteorological data, demographic data, and socioeconomic indicators, are used in AI-driven climate vulnerability assessment. AI can find complex patterns and relationships in this data.

Machine learning techniques and deep learning models make it easier to assess climate risks at precise temporal and spatial resolutions. Thanks to techniques like neural networks, natural language processing, and geospatial analysis, artificial intelligence (AI) models can recognize people and locations that are at risk, predict future climate conditions, and estimate the possible effects of significant disasters [2].

*Author for Correspondence

K. Anupriya
E-mail: rahul.kundiya@vpmmmpcoe.org

Student, Department of Artificial Intelligence-Machine Learning, Manakula Vinayagar Institute of Technology, Puducherry, India

Received Date: March 05, 2025
Accepted Date: March 29, 2025
Published Date: April 08, 2025

Citation: K. Anupriya, Haripriya I., Jeferina Mary Catchirayar, Lakshmi R. AI for Climate Vulnerability Assessment. International Journal of Radio Frequency Innovations. 2025; 3(1): 19–23p.

Though AI has the potential to be innovative, there are still issues with ensuring data accuracy, interpretability, and mitigating potential biases in vulnerability assessments. It is also necessary to set aside ethical considerations, such as effectively

distributing resources and protecting those in need. The integration of AI in climate vulnerability assessment is examined in this work, along with its methods, probable uses, and future research avenues. Policymakers, urban planners, and communities may make more informed, data-driven decisions to lessen the negative effects of climate change and advance sustainable development by utilizing AI for targeted climate adaptation.

RELATED WORK

The assessment of climate vulnerability has drawn a lot of attention as ecosystems, economies, and human health are becoming increasingly affected by global warming and extreme weather events. To be able to support in climate vulnerability assessment, artificial intelligence (AI) offers complex methodologies and tools, particularly if it gets to analyzing large, complex data in identify patterns, forecast risks, and offer useful data insights. We will go in substantial advancements and related studies for this field here [3].

Climate forecasting and prediction are prominent uses for AI. Due to computation limitations, traditional climate models often are unable to capture localized, fine-grained data; despite this, artificial intelligence (AI), in particular machine learning (ML), can analyze this data more efficiently. For instance, high-dimensional data from satellite imagery, weather stations, and Internet of Things devices may be handled by neural networks and deep neural networks to identify patterns and predict the impact of climate change. As an example, convolutional neural networks (CNNs) have been used to the review of satellite data pictures to detect changes in urban sprawl, water body dynamics, and forest cover, all of which have been strongly related to signs of vulnerability. Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) models are also frequently employed for time-series data analysis, enabling more accurate predictions of future climate conditions in vulnerable regions.

AI's role in analyzing climate hazards, exposure, and sensitivity is another key aspect. A variety of studies have developed models that estimate the potential of a forest fire, a flood and droughts in different areas, all of which are crucial components of vulnerability assessment. For example, by integrating topographical, meteorological, and hydrological data, Random Forest (RF) models and Gradient Boosting Machines (GBMs) have been utilized to identify states that have been prone to flood. A more complex understanding of vulnerability is made with AI models that integrate historical climate data with socioeconomic indicators (like income levels and population density) to assess a community's vulnerability to climate hazards and its ability to recover. AI techniques like natural language processing (NLP) which are used to analyze the prediction from the large data and instruct to the government reports, news articles, and social media. NLP algorithms can extract information on public data, policy measures, and community-level impacts related to climate data, which will help researchers understand the climate change. Additionally, clustering algorithms, like K-means and hierarchical clustering, have been used to classify the data with similar climate, which is essential for targeting.

Explainable AI (XAI) has recently emerged as a solution to interpret complex ML models, which is crucial in vulnerability assessment, where transparency and interpretability are vital for stakeholder trust and policy implementation. The two methods which are used are SHAP and LIME which will provide specific features help in various methods, allowing researchers to understand why certain areas are high risk [4].

METHODOLOGY

AI-enhanced Risk Evaluation

The ability of artificial intelligence to quickly analyze large amounts of data is one of its primary benefits. Because of this, it is a very useful tool to identify which regions are most vulnerable to the effects of climate change, such as those that may encounter drought, landslides, or flooding. Governments and communities may create targeted adaptation plans that are suited to the specific risks that each region faces by utilizing AI to analyze data such as weather patterns, satellite imagery, and

climate models. The economy, the environment, and society are all at serious risk from the complex issue of climate change [5]. Developing successful adaptation plans that might reduce the risks and effects of climate change is one of the main issues in addressing it. Governments and communities must have access to precise and pertinent information about the specific hazards that each region faces to create successful adaptation plans. By monitoring an enormous amount of data, including weather patterns, satellite imagery, and climate models, artificial intelligence (AI) can assist governments and communities in addressing this issue and creating focused adaption plans. In this review, we will explore the use of AI in climate change adaptation and how it can help governments and communities develop tailored adaptation plans.

AI-enabled Vulnerability Assessment

AI can be used to develop plans for protecting infrastructure and communities from the effects of climate change by analyzing data from satellite imagery, climate models, and weather patterns. By doing that, stakeholders can take proactive measures to mitigate potential impacts by selecting areas that are most at risk for flooding, erosion, or other hazards related to climate change. Climate models, historical weather patterns, topography, and land-use data serve as some of the few examples of these data sources [6].

For example, stakeholders can predict the potential impact of extreme weather events or sea level rise on coastal communities and infrastructure using AI-powered flood modeling. Stakeholders can take proactive measures to reduce risk, such as building sea walls, infrastructure that is at risk, or implementing zoning regulations by applying AI by analyzing data on topography, land use, and urban development to identify areas that are more vulnerable to erosion and flooding. Like that, systems using AI can observe weather patterns to identify areas that are particularly susceptible to extreme weather occurrences like hurricanes, tornadoes, or droughts over time or with increased intensity. This data can help with emergency preparedness, risk management, and infrastructure expansion. By recognizing and reducing the possible implications of climate-related hazards, AI might one day shield infrastructure and communities from the effects of climate change (Table 1) [7].

AI- powered Models

It is possible to forecast the rise in sea levels using AI models. Large climate datasets and machine learning techniques are used to create models that forecast the effects of sea level rise and assess various adaptation strategies. One project called Coastal AI, for instance, utilizes AI to determine how sea level rise affects the coast. The system uses machine learning algorithms to analyze vast climatic information and forecast the effects of rising sea levels on various architectural kinds, including buildings, bridges, and roadways. By using this data, specific adaptation plans can be created to safeguard communities and infrastructure that are at risk.

Table 1. AI technologies used in disaster prediction.

AI Technology	Purpose	Data Inputs	Outputs	Example Applications
Machine Learning	Predicting floods	Sensor data (rainfall, river level)	Flood risk maps and alerts	Flood risk prediction and warning systems
Deep Learning	Predicting wildfires	Satellite and weather data	Fire risk maps and alerts	Wildfire prediction and warning systems
Natural Language Processing	Social media monitoring for disaster response	Tweets, posts, and messages related to disasters	Analysis of public sentiment, identification of people in need, and coordination of rescue efforts	Disaster response and emergency management
Computer Vision	Identifying areas at risk of landslides	Satellite and weather data	Landslide risk maps and alerts	Landslide prediction and warning systems

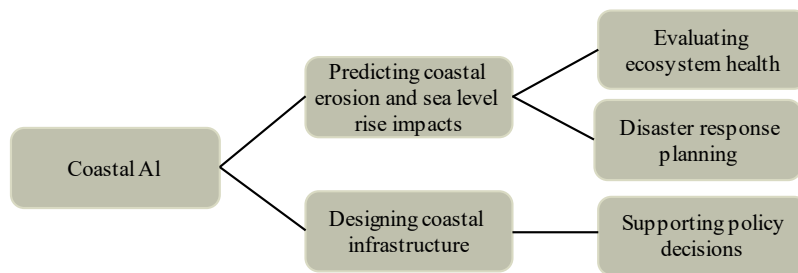


Figure 1. Coastal AI: AI-powered simulation of the impact of sea level rise on coastal infrastructure.

Data collection on various factors that affect coastal infrastructure risk is the first step in the Coastal AI model to sea level rise, such as the height of buildings and roads, the elevation of coastal land, and the proximity to areas at risk of flooding. Large-scale climatic data, including sea level rise and the regions it damages due to climate change, are then merged with this data as shown in Figure 1.

AI-Powered Simulations for Infrastructure and Business Risk Assessment

Intelligent simulations for assessing risks in infrastructure and business: In considering the impacts of climate change, business and infrastructure risk can be accessed using AI powered simulations.

These models will illustrate how supply chains, business operations, and physical infrastructure, such as buildings, roads, and bridges, may be impacted by climate change. AI-powered simulations can help stakeholders in assessing the possible risks of climate change impacts, like flooding, sea level rise, and extreme weather events, by combining data from climate models with data from infrastructure and businesses. For instance, AI-powered models can assist in forecasting the effects of flooding and storm surges on vital infrastructure, like hospitals, power plants, and transportation networks.

The possible economic effects of climate change on companies and industries can also be assessed using AI powered models. AI systems may help organizations in identifying possible risks and opportunities related to the effects of climate change, such as changes in customer demand for products or changes in market conditions, by evaluating supply chain data, market trends, and financial data. All things considered, AI-driven simulations provide an effective tool to assess commercial and infrastructure risks related to the effects of climate change. But there are drawbacks to take into consideration, like the dependability and correctness of data sources and the need for expert result interpretation. Therefore, to make sure that the simulation is used effectively to guide climate change adaptation measures, a detailed review of its limits is required [8, 9].

Advancements in AI for Climate Resilience and Adaptation

To address the complex issues brought out by climate change, AI-powered climate adaptation methods are developing quickly. By combining information from social indicators, weather models, and satellite imagery, future advances will improve climate risk assessment and offer more precise, location-specific insights. By using real-time data from IoT sensors, AI-driven monitoring and early warning systems for extreme weather events, like floods and wildfires, will become more responsive, increasing regional preparation. In agriculture, AI can predict optimal planting schedules, water needs, and potential crop stress, supporting food security. Also, for water resources we can use AI to get the best solution and detect whether there is leakage in the building. In urban areas we will see AI tools designed for heat management, for reducing and maintaining green space and predicting heat. Furthermore, AI can enhance migration forecasting by analyzing demographic and environmental data to predict and prepare for climate-induced population shifts. AI can also predict by analyzing the given data and preparing for the reduction of the climate. Ethical problems have the biggest impact, so that in future we can use AI to predict data for all types of fields. Open AI can also be used for this solution. These advanced techniques position AI as a powerful tool to build sustainable solution for reduction of Climate change (Table 2) [10].

Table 2. Overview of various AI systems used for climate analysis and modeling.

AI System	Function
Climate.ai	Uses AI to analyze climate data and generate probabilistic climate change scenarios for future climate modeling and projection
DeepMind	Uses AI to improve climate modeling accuracy by reducing uncertainties in climate simulations and predictions
Google Earth Engine	Uses AI to analyze satellite data to generate high-resolution climate models and projections

CONCLUSION

As AI enables data-driven insights and accurate projects achievable, it is essential for improving assessments for climate. As AI can analyze huge amounts of data from multiple sources, such satellite imagery, historical climate records, and socioeconomic data, it can identify patterns and predict climate risks at finer scales than traditional models. Machine learning algorithms remain able to define critical regions with accuracy, which is critical for providing resources and applying targeted adaptation measures. Moreover, geographic analysis is made simpler through the integration of AI with Geographic Information Systems (GIS) and advanced data visualization closes in, helping stakeholders in recognizing region vulnerabilities and making informed decisions. Defining the processes for making decisions through explainable AI models builds trust as it makes it simpler to implement AI findings into policy. While challenges like data quality and ethical considerations remain, AI-driven climate vulnerability assessments are proving to be transformative, enabling communities to build resilience and adapt proactively to the impact of climate change.

REFERENCES

1. Yoo G, Hwang JH, Choi C. Development and application of a methodology for vulnerability assessment of climate change in coastal cities. *Ocean Coast Manag.* 2011 Jul 1; 54(7): 524–34.
2. Zhang Y, Hu W, Tao Y, Zhang B. How does smart artificial intelligence influence energy system resilience? Evidence from energy vulnerability assessments in G20 countries. *Energy.* 2025 Jan 1; 314: 134290.
3. Ewa WO, Ugwu OO. Security vulnerability assessments for sustainable infrastructure: a scientometric review. *Environ Dev Sustain.* 2025 Feb 7; 1–34.
4. Onyeneke RU, Emenekwe CC, Munonye JO, Nwajiuba CA, Uwazie UI, Amadi MU, Izuogu CU, Njoku CL, Onyeneke LU. Progress in climate–agricultural vulnerability assessment in Nigeria. *Atmosphere.* 2020 Feb 11; 11(2): 190.
5. Huang N, Wang J, Song Y, Pan Y, Han G, Zhang Z, Ma S, Sun G, Liu C, Pan Z. The adaptation mechanism based on an integrated vulnerability assessment of potato production to climate change in Inner Mongolia, China. *Mitig Adapt Strateg Glob Change.* 2022 Mar; 27(3): 24.
6. Singh B, Vig K. Artificial intelligence (AI) and climate action (SDG-13) profound impact on humanity: Impacts, adaptation and vulnerability lensing legal provisions. In: Soni R, Singh G, Singh R, et al., editors. *Futuristic Trends in Artificial Intelligence.* Vol. 3, Book 6. Bengaluru: IIP Series; 2024. p. 177–86. DOI: <https://www.doi.org/10.58532/V3BAAI6P9CH1>.
7. Gong J, Jin T, Cao E, Wang S, Yan L. Is ecological vulnerability assessment based on the VSD model and AHP-Entropy method useful for loessial forest landscape protection and adaptative management? A case study of Ziwuling Mountain Region, China. *Ecol Indic.* 2022 Oct 1; 143: 109379.
8. Li Y, Caceres C, Bazarah AM. A climate change vulnerability assessment design framework: the case of small-scale farmers in western Honduras. *Commun Assoc Inf Syst.* 2023; 53(1): 65–95.
9. Sultana T, Hegde S, Warsi T, Tahama K, Rizvi SS, Mukherjee S, Chemburkar S, Biswas G. Data analytics for drought vulnerability under climate change scenarios. In: *Data Analytics and Artificial Intelligence for Earth Resource Management.* Elsevier; Amsterdam, Netherlands. 2025 Jan 1; 137–156.
10. Srivastava A, Maity R. Assessing the potential of AI–ML in urban climate change adaptation and sustainable development. *Sustainability.* 2023 Nov 30; 15(23): 16461.