



Techniques Leveraging from Artificial Intelligence for the Prediction of Climate Change in Pakistan: A Systematic Literature Review

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Received: 13 July 2023; Revised: 10 August 2023; Accepted: 25 August 2023; Published: 31 October 2023

AID: 002-03-000030

Abstract: Forecasting weather is crucial for sustaining life and ecosystems. Throughout history, farmers have predicted weather patterns to optimize crop growth. Weather prediction can be useful for other more crucial factors as well, including flood and drought predictions. In today's era of technological advancement, machine learning, and deep learning have made significant strides across various domains, including weather forecasting. For safeguarding crops and alarming farmers for the protection of their fields, it is necessary to have the ability to provide precise and timely weather predictions. While traditional weather prediction has faced advancements in IoT and machine learning, such as motion detection, speech recognition, and computer vision, it also offers more accurate environmental change predictions. In Pakistan, rising temperatures, erratic weather patterns, and changing precipitation pose significant challenges for the population. Climate change and the emission of harmful industrial gases are accountable for altering rainfall patterns, subsequently impacting economic growth since Pakistan's major economy relies on it. At present, numerous advancements in weather prediction utilize artificial intelligence techniques resulting in notable benchmarks for researchers. This study explores diverse methods of deep learning, machine learning, and advanced IoT devices to enhance weather prediction through a systematic literature review.

Keywords: Weather Forecasting; Machine Learning; Deep Learning; Climate Change; IoT in Agriculture;

1. Introduction

Nowadays every country around the globe is affected by the most pressing issue of Climate change. As an agricultural country highly vulnerable to climate variability, Pakistan faces numerous socio-economic, health, and environmental risks due to climate change. For accurate future climate pattern prediction, these risks need to be effectively adapted and mitigated. This research paper aims to explore the use of artificial intelligence (AI) in climate change prediction specifically tailored to the context of Pakistan.

With its vast geographical diversity, Pakistan experiences various climate patterns, ranging from the arid regions of Balochistan to the monsoonal areas of Punjab and Sindh. Predicting climate change in such a complex system requires robust and sophisticated models that can analyze vast amounts of data. AI, with its capacity to process big data and identify complex patterns, presents a powerful tool for climate change prediction in Pakistan.

The study of climate change in Pakistan dates back several decades. However, traditional climate models have often faced limitations in accurately predicting the region's diverse climatic conditions. AI, on the other hand, offers a new approach that has the potential to overcome these limitations. By analyzing large volumes of climate data, AI algorithms can identify non-linear patterns and relationships that may have been overlooked by traditional models.

The identification of various sources of data by AI is one of its key features. Climate models traditionally rely on meteorological data such as temperature, precipitation, and wind patterns. However, AI can incorporate data from diverse sources such as satellite imagery, oceanic currents, and socio-economic factors, providing a more comprehensive understanding of climate change dynamics. This multi-dimensional approach enables more accurate and robust predictions. Furthermore, AI is capable of learning from historical data to improve its predictive capabilities. Machine learning algorithms can analyze the historical climate data of Pakistan and identify trends, patterns, and relationships that can be used to forecast future climate scenarios. As the algorithm continues to learn and adapt, its predictions become more precise and reliable.

Some challenges need to be addressed for climate change prediction in Pakistan using AI. Quality and data availability is one of the main concerns. Pakistan's climate data infrastructure faces various limitations, including sparse and unreliable data. AI models heavily rely on data, and without robust and high-quality inputs, the accuracy of predictions may be compromised. Therefore, efforts should be made to improve data collection systems and ensure data accuracy and accessibility.

Section 2 discusses the related work of this research. In section 3 the research methodology is discussed which includes research questions formulation, research process, inclusion & exclusion criteria, and article quality assessment. Section 4 presents the findings of the research. Section 5 provides recommendations and discussions. This research article is concluded in section 6.

2. Related Work

Predicting climate change in Pakistan using different approaches that involve advanced technologies to analyze historical data, simulate future scenarios, and enhance understanding of climate patterns. Several research papers have delved into the application of AI for climate change predictions in Pakistan but a literature review on this particular topic is not available. This literature survey is the first systematic review of climate change prediction and forecasting using AI. Hussain et al. [1] did a comprehensive literature review on the topic of climate change impacts, adaptation, and mitigation of environmental and natural calamities in Pakistan. This study evaluated the effects of climate change in various sectors such as agriculture, livestock, forestry, food, water, and energy security in Pakistan. Although this research does not focus on AI-related techniques. Its overall finding was the societal impacts of irregular weather patterns and other climate change effects in Pakistan. It highlights the need for climate change mitigation and adaptation practices and techniques in Pakistan, considering their economic, social, and environmental aspects. The paper emphasizes the importance of governmental interference and strict accountability of resources for sustainable development and the formulation of state-of-the-art climate policies in Pakistan.

In another article [2], the impact of El-Nino/Southern Oscillation (ENSO) on summer monsoon rainfall in southern parts of Pakistan is studied to deeply understand the characteristics of summer rainfall variation and factors causing severe water shortages in already drought-prone regions. This paper did not utilize any AI-related technique for the prediction. Another review article, T. A. Khan et al. [3] provided details on the engineering-based techniques (such as dam construction) and non-engineering-based techniques (such as Artificial Intelligence-based algorithms), have been used to investigate flash floods. It concluded that swarm intelligence weights optimization for multi-layer perceptron neural network configuration performed the best among all forecasting approaches and is recommended for future enhancement. This study only focused on the problem of flash floods. Other related papers other paper discusses calamities such as crop yield prediction [4], agriculture stock [5], rainfall [12], landslide [13], stream outflow [14], water quality [15] etc.

Overall literature review is not available but individual climate-related problems are addressed. In summary, these research papers collectively contribute to the growing body of knowledge on climate change predictions in Pakistan using artificial intelligence. The studies highlight the diverse applications of AI, ranging from rainfall and heatwave predictions to drought and flood assessments, with a focus on improving the resilience of critical sectors such as agriculture and urban planning.

3. Method

This study has been undertaken as a systematic literature review and its goal is to assess state-of-the-art research in the field of climate change in Pakistan. The systematic literature review method's steps are outlined here.

3.1. Research Questions

This study focuses on the following research questions:

RQ1: What are the existing AI tools, techniques, algorithms and evaluation methods used in the prediction of climate change in Pakistan?

RQ2: What are the hazards caused by climate change in Pakistan?

RQ3: What are the proposed methodologies on the impact of climate change on health in Pakistan?

RQ4: What are the proposed methodologies/ research available on the impact of climate change on agriculture in Pakistan?

3.2. Search Process

IEEE (Institute of Electrical and Electronics Engineers), Science Direct, and ACM (Association for Computing Machinery) digital library are the search engines that are used in this research. These search engines were selected because of the following reasons:

- Well-known professional organizations that publish and provide access to a wide range of scientific paper
- Renowned organizations in the fields of electrical engineering, computer science, and related disciplines.
- These organizations are highly regarded and considered to be of high quality.
- These platforms provide access to papers from researchers and practitioners around the world who may have conducted studies on climate change prediction in Pakistan.
- Advanced search options, allowing you to specify your search criteria.

Table 1: Number of articles against research query in each search engine.

Search Engine	Research Query	Papers
IEEE Xplorer	((("Document Title": "climate change" OR "Document Title": "climate" OR "Document Title": "weather" OR "Document Title": "drought" OR "Document Title": crop OR "Document Title": temperature OR "Document Title": flood) AND ("Document Title": prediction OR "Document Title": forecast OR "Document Title": evaluat*) AND ("Document Title": Pakistan))OR (("Abstract": "climate change" OR "Abstract": "climate" OR Abstract: "weather" OR "Abstract": "drought" OR "Abstract": crop OR "Abstract": temperature OR "Abstract": flood) AND ("Abstract": prediction OR "Abstract": forecast OR "Abstract": evaluat*) AND ("Abstract": Pakistan)))	72

ACM	[[Abstract: "climate change"] OR [Abstract: or "climate" or "weather"]] AND [Abstract: pakistan] AND [E-Publication Date: Past 5 years]	17
Science direct	"climate change" "climate" "pakistan" "Artificial Intelligence"	4

3.2.1. Searching through AI-Powered Research Tools

We used some AI-powered search engines to find the answers to our queries. We used one of the most relevant papers, Hussain et al. [1] as a seed paper for SCISPACE (AI Powered search engine). The search gave us the most relevant papers and their summary which showed that the awareness about this issue of climate change is still low and emphasized the need for a literature survey to Grasp the full magnitude of these peculiar challenges and develop ingenious tactics for fostering sustainable progress in Pakistan. It was also seen that there is a lack of artificial-related approaches to solving the problem as no such papers were found in the search.

Furthermore, we also searched for the keywords, “climate change Pakistan artificial intelligence machine learning IoT deep learning” in the same search engine. It showed that Artificial intelligence (AI) and machine learning (ML) approaches have significantly contributed to the modeling and prediction of hydrological processes, climate change, and earth systems. In the realm of weather forecasting, the integration of AI and ML techniques, coupled with advanced IoT devices, has proven beneficial for more precise and effective weather predictions but It does not specifically mention the use of artificial intelligence, IoT, or climate change in Pakistan.

We also used another AI-powered tool, “researchrabbitapp” to see if there was any relevant paper which has been overlooked. We again used Hussain et al. [1] as our seed paper as this was the most relevant literature survey found. The graph (Figure 1 & Figure 2) shows all the similar papers but most of the work was either not from Pakistan or did not use any AI/ML technique.

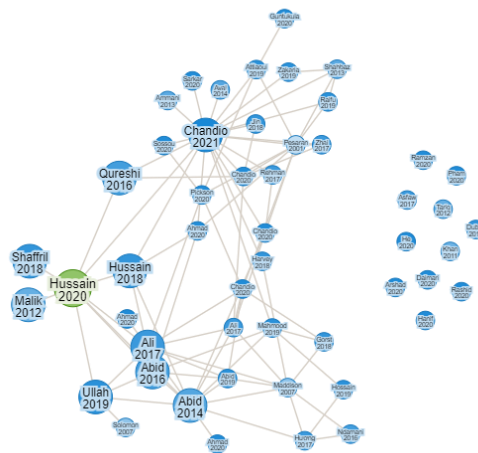


Figure 1: Similar work to the seed paper.

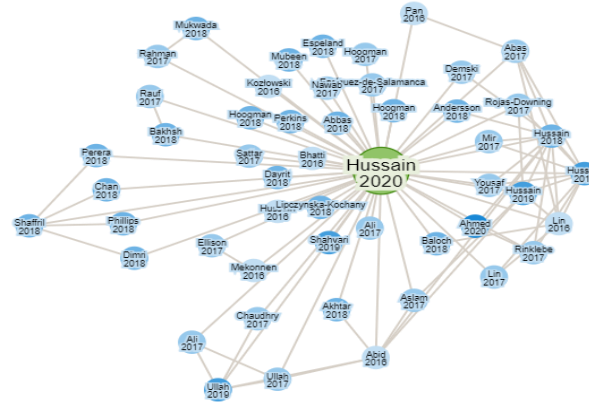


Figure 2: All reference articles of the seed paper

3.3. Inclusion and Exclusion Criteria

The query was designed to get all the results related to the topic therefore the keywords related to artificial intelligence, machine learning, etc were excluded. The research articles in the result of the query were manually checked by reading their titles and abstracts. The articles which were not discussed Artificial intelligence (AI) related techniques were excluded. The exclusion/ inclusion criteria are explained below:

1. This study captures the state-of-the-art work done in the last 5 years therefore the articles from 2018 to 2023 are included in this paper.
2. All articles that do not use AI, ML, DL, etc related techniques are excluded
3. Articles that have no relation with climate change, natural disasters such as floods, or the issues arising due to climate change are excluded
4. Research articles proposing solutions to better farming strategies, wheat price prediction, cotton & chili production, electricity load prediction, risk assessment, wind power generation, solar power production, and tea yield prediction are excluded
5. Papers that propose some forecasting models are included in this review

Papers selected after going through titles and abstracts. In IEEE Xplorer, out of 72, only 11 articles were found relevant to this study. The ACM showed a total of 17 articles from which only 7 were found relevant after reviewing their titles and abstracts. The search engine, science direct showed 4 articles from which 3 were selected.

4. Findings

4.1. Dataset Quality Assessment

In assessing the quality of the work, the first consideration involves whether a dataset is readily accessible. If not, alternative data collection methods are employed to gather the necessary information. These methods can include diverse data sources, such as scientific studies or sensor networks. The government's involvement in data provision underscores its commitment to facilitating research and decision-making processes.

Turning to the quality of the data, several factors come into play. The relevance of the data is crucial, ensuring that it aligns closely with the specific parameters being investigated. Accuracy is another pivotal factor, emphasizing the precision and correctness of the collected information. The assessment of data quality considers these factors collectively, recognizing the significance of robust data sources, relevance, accuracy, and integrity in the overall research framework. It can be seen in Table 2 that half of the studies used proper datasets for their work. Articles used data sources like government datasets including the Pakistan Meteorological Department while others collected data from sensors and IoT devices. Mostly was relevant to the research problem.

Table 2: Summary/ Evaluation of dataset quality and accessibility

Article	Dataset	Data Collection	Relevance	Accuracy	Tool	Transparency
(Hassan et al., 2021)	Yes	Statistical government publications by Pakistan Bureau of Statistic	yes	yes	R Studio	No specific details
(T. A. Khan et al., 2019)	Yes	Pakistan Meteorological Department (PMD)	Yes	Yes	No	No
(Munir, 2013)	No	data sources such as Shuttle Radar Topography Mission (SRTM) DEM, MODIS daily snow product MOD10A1, and spatially distributed NOAA precipitation data	Yes	Yes	No	No
(Bhutto et al., 2009)	No	Rainfall data from 16 stations, Nino 3.4 Index data from 1950 to 2000	Yes	Yes	No	No
(Mubashar et al., 2021)	Yes	Landslide Occurrence Data provided by NASA, TRMM, Shuttle Radar Topography Mission, and Global Land Data Assimilation System	Yes	Yes	No	No
(Kumari et al., 2023)	Yes	Humanitarian Data Exchange (HDX) and 55 years of rainfall data in open research repository	Yes	Yes	No	No
(Rahu et al., 2023)	No	Use of IoT devices to gather data	Yes	Yes	No	No
(Ayub et al., 2022)	Yes	Optical imagery obtained from the Sentinel-2 sensor	Yes	Yes	No	No
(F. Khan et al., 2015)	No	Collection of actual information regarding various barrages, river sizes, reservoirs,	Yes	Yes	No	No
(Ali et al., 2020)	No	Collection through sensors deployed at the riverbanks, sonar Sensor HC-SR04 and other relevant environmental parameters	Yes	Yes	No	No
(Gul et al., 2020)	No	Pakistan Meteorological Department (PMD)	Yes	Yes	No	No

(Saleem et al., 2021)	No	Available data sources and access to daily life observational patterns	Yes	-	No	No
(Jamshed et al., 2022)	Yes	GLOBAL FOREST WATCH platform	Yes	Yes	No	No
(N. Khan et al., 2020)	Yes	Pakistan Meteorological Department's gridded precipitation and temperature datasets (PGF datasets). National Centers for Environmental Prediction / National Center for Atmospheric Research (NCEP/NCAR) reanalysis datasets.	Yes	Yes	No	No

4.2. Methodology

The model selection process involves the careful consideration and choice of the appropriate mathematical or computational model to represent the system under study. The model can be further evaluated based on the use of historical data, its comparison with state-of-the-art models, sensitivity analysis, past Climate Behavior and Future Projections, and the availability of the features used in the process. The reviewed studies, Table 3, mostly use machine learning techniques including SVM and regression models and some of the models use artificial neural networks to solve the climate change problem. It was also observed that most of the studies used historical data to assess the performance of their model. Only one research paper [16], did sensitivity analysis which examines how variations or uncertainties in input parameters affect the model's output. Features refer to the variables or attributes used as input to the model. In the context of climate modeling, features could include various climatic parameters such as temperature, precipitation, atmospheric pressure, etc. The selection of relevant features is crucial for the model's accuracy, and it often involves domain expertise to determine which variables are most influential in representing the dynamics of the system under consideration. Most of the research articles explained the feature set used as input to the proposed model.

Table 3: Summary/ Evaluation of the proposed models

Article	Model Selection	Model Evaluation					Features Provided
		Historical	Comparison		Sensitivity	Past/future implications	
(Hassan et al., 2021)	Linear Regression Model	Yes	Root Squared Error (RMSE), Linear Regression and Recurrent Neural Networks (RNNs)	Mean Error and Linear Neural Networks	No	Not specifically but selected factors depict past climate behavior	Yes
(T. A. Khan et al., 2019)	Support Vector Machine (SVM) and K-NN	Yes	Support Vector Machine and classifiers	Vector (SVM) and K-NN	No	No	No

(Munir, 2013)	Snowmelt-Runoff Model (SRM)	Yes	Statistically, Nash-Sutcliffe Efficiency (NSE) R2 and average percentage volume difference Dv	No	Yes	Yes
(Bhutto et al., 2009)	No	Yes	16 stations' data of summer rainfall, sea surface temperature	No	No	No
(Mubashar et al., 2021)	Long Short Term Memory (LSTM) neural network	Yes	Artificial Neural Networks (ANNs)	No	No	Yes
(Kumari et al., 2023)	Regression-related machine learning algorithms	Yes	machine learning models, deep learning models, and statistical models	No	No	Yes
(Rahu et al., 2023)	regression models LSTM,, SVR, MLP, and NARNet	No	Compares the performance of different machine learning models	No	No	Yes
(Ayub et al., 2022)	Random Forest (RF)	Yes	Compared with other approaches in different regions	No	No	Yes
(F. Khan et al., 2015)	No	No	Other countries using wireless sensing techniques for flood prediction and monitoring	No	No	Data from sensor nodes
(Ali et al., 2020)	SP32 development board	No	No	No	No	No
(Gul et al., 2020)	non-parametric statistical tests	Yes	on-parametric statistical tests, including the Mann-Kendall and Sen's slope	No	No	aridity index using precipitation and reference evapotranspiration

(Saleem et al., 2021)	Water Evaluation and Planning system	No	Comparison with supply trends of housing society	Yes	Yes	Yes
(Jamshed et al., 2022)	long short-term memory network (LSTM)	Yes	root mean square error (RMSE)	No	No	Yes
(N. Khan et al., 2020)	Support Vector Machine (SVM) and Artificial Neural Networks (ANNs)	Yes	Support Vector Machine (SVM), Artificial Neural Networks (ANNs), and K-Nearest Neighbors (KNN)	No	No	Yes

4.3. Quality of the selected paper:

The credibility and impact of a research paper are often intricately tied to its publication details. Firstly, the journal name and its publication impact factor provide critical context regarding the paper's standing within the academic landscape, with a higher impact factor indicative of the journal's influence. Additionally, the peer-review process ensures scholarly rigor and authenticity, signifying that the paper has undergone critical evaluation by experts in the field before publication in a reputable journal. Assessing citations and references offers insights into the paper's scholarly influence and integration into academic conversations. Most of the research articles found on the desired problem were published in conferences and only a few journal articles were found. As the selected research articles were from the past 5 years therefore their number of citations was not huge.

Table 4: Summary of Research Articles Quality

Article	Journal/Conference	IF	No. of Citations	Article	Journal/Conference	IF	No. of Citations
(Hassan et al., 2021)	IEEE Consumer Electronics Magazine	-	3	(T. A. Khan et al., 2019)	IEEE 6th International Conference on Engineering Technologies	-	1
(Munir, 2013)	IEEE International Conference on Space Science and Communication	-	5	(Bhutto et al., 2009)	International Conference on Information Science and Engineering	-	5
(Mubashar et al., 2021)	International conference on	-	6	(Kumari et al., 2023)	International Conference on Computing,	-	0

	artificial intelligence				Mathematics and Engineering Technologies		
(Rahu et al., 2023)	IEEE Access,	-	3	(Ayub et al., 2022)	International Conference on Artificial Intelligence	-	4
(F. Khan et al., 2015)	IEEE SENSORS	-	17	(Ali et al., 2020)		-	7
(Gul et al., 2020)	2020 IEEE International Conference on Systems, Man, and Cybernetics	-	11	(Saleem et al., 2021)	Simulation journal	1.7	11
(Jamshed et al., 2022)	Physical Communication Journal	2.2	2	(N. Khan et al., 2020)	Advances in Water Resources	4.7	159

4.4. Transparency

The transparency of the article depicts how easy it is to replicate the work done. It was evaluated based on the availability of the provided dataset publicly and also the description of the code and tools used in the development of the proposed model. As it can be seen from Table 2 almost all research articles have not made their datasets, tools, and code available publicly.

5. Discussion

The research done on climate change about AI can be categorized in flood, landslide, crop yield prediction, river flow, and deforestation. Table 5 depicts the total number of papers against each category in the context of Pakistan. A limited number of research articles have addressed climate change-related issues, with a notable gap in addressing the particularly challenging problem of smog. Furthermore, there is a scarcity of research focusing on the application of artificial intelligence technologies in predicting climate-induced challenges such as landslides, deforestation, and river outflows. Efforts to explore and develop solutions in these critical areas remain relatively scarce.

Table 5: Categories of the Research Articles

Categories	Total papers	Categories	Total Papers
Flood	4	Landslide	1
Rainfall/drought	3	Water quality/health	2
Crops/yield prediction	2	Riverflow	1
Deforestation	1	Smog/ Air Quality	0

- RQ1: What are the existing AI tools, techniques, algorithms and evaluation methods used in the prediction of climate change in Pakistan?

AI plays a crucial role in climate change prediction. However, it is seen that the climate change-related problems in Pakistan are still a new field for researchers. In our survey following tools and techniques are mostly used:

1. Machine Learning Algorithms: Algorithms like Linear Regression, Random Forest, Support Vector Machines, and Neural Networks are used for climate modeling.
2. Remote Sensing: AI is employed to analyze satellite data and sensor data extracting valuable information for climate monitoring.
3. Deep Learning: Deep neural networks are used to solve complex problems.
4. Tools: Only one of the research articles mentioned the tool and framework they used in their research. The R studio was used.

Collaborative efforts and interdisciplinary approaches are crucial for comprehensive climate change studies in regions like Pakistan. Researchers can explore datasets and projects by organizations like NASA, and the Pakistan Meteorological Department or utilize platforms like Google Earth Engine. Moreover, the data that has already been collected, needs to be made public so that more innovative research can be performed for regions like Pakistan which are extremely affected by climate change.

- RQ2: What are the hazards caused by climate change?

Climate change has highly affected the countries like Pakistan. Climate change has been associated with various hazards in Pakistan, impacting the environment, economy, and overall well-being of the population. Extreme weather can cause floods, drought, glacier melting, crop failures, reduced river flow, the spread of diseases, deforestation, Air quality, and impact on energy production. The proposed artificial intelligence-related solutions are mostly on flood, rainfall, and drought. There is a need to invest in climate research and innovation to understand the merging climate risk and develop artificial intelligence-based predictive solutions. There is also a need to support the development of technologies and strategies for climate change adaptation and integration. Collaboration with international organizations/neighboring countries on climate change initiatives, data sharing, and joint research projects. The government of Pakistan should also facilitate researchers and scientists working on this particular challenge. Foster collaboration between government agencies, research institutions, and tech companies to share data and expertise. Encourage open-access platforms for sharing AI models and research findings.

- RQ3: What are the proposed methodologies on the impact of climate change on health in Pakistan? In this survey, it was found that only a few researchers are working on the air quality and health issues arising due to climate change. There is a need to monitor air pollutants and analyze trends to link air quality variations with respiratory diseases. Evaluate water quality data, correlate it with climate variables, and study the impact on waterborne diseases, emphasizing preventive strategies.

- RQ4: What are the proposed methodologies/ research available on the impact of climate change on agriculture in Pakistan?

Research articles particularly focusing on agriculture-related problems due to climate change in Pakistan are very few. Only two articles were available which proposed some AI/ML techniques for this problem. They used a supervised machine learning framework that utilizes remote sensing data and machine learning algorithms to estimate wheat area and predict wheat yield and a Random Forest (RF) machine learning algorithm for wheat area estimation and generation of Land Use Land Cover maps. The other paper used Linear Regression Mode to forecast next year's crop consumption, enabling farmers to make informed decisions about their crops.

6. Conclusion

In conclusion, climate change prediction in Pakistan using AI presents a transformative opportunity to enhance our understanding of the region's complex climatic dynamics. By harnessing the power of AI, we can overcome the limitations of traditional climate models and generate more accurate, timely, and comprehensive climate change predictions. However, addressing challenges such as data availability and technical capacity is crucial to unlock the full potential of AI in climate change prediction. This research paper aims to delve deeper into these issues and explore the practical applications of AI for climate change prediction in Pakistan. Through this research, we contribute to the growing body of knowledge on climate

change adaptation and mitigation in the context of Pakistan and also highlight the issue of unavailability of data and research on the latest AI techniques.

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