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Narrative Review

The Role of Artificial Intelligence in Disaster Management in Iran: A Narrative Review

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Abstract

Introduction: Disaster management refers to preparedness, response, and recovery from disasters, encompassing a broad spectrum of activities, including risk assessment, emergency planning, communication, and resource management. Artificial intelligence (AI) can potentially enhance our disaster management capabilities, ranging from prediction and detection to impact assessment and recovery monitoring. This study aims to provide an overview of the role and application of AI in disaster management in Iran.

Methods: This study adopts a narrative review approach. Full-text articles and reports were retrieved from databases SID and Magiran, ScienceDirect, PubMed, and Google Scholar, using the keywords "Iran," "Disaster Management," and "Artificial Intelligence." Selection criteria focused on relevance to the study objective and the timeframe of 2020-2023. Then, the articles underwent a review process that evaluated their title, abstract, introduction, methodology, results, discussion, and references.

Results: Out of the 314 retrieved studies, seven articles met the inclusion criteria for the study. The most commonly utilized algorithms were artificial neural networks (ANN) and random forests (RF), and the performance of the AI-based algorithms was reported to be satisfactory.

Conclusion: The occurrence of disasters is inevitable, and it may be impossible to prevent events such as earthquakes, floods, and other disasters. However, studies have shown that AI can be utilized for more efficient disaster management, reducing and minimizing damages and enabling more effective responses to such incidents.

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Introduction

Disasters can cause significant damage, destruction, or loss of life and property, usually occurring unexpectedly, and can have wide-ranging consequences on the victims, including physical, emotional, economic, and social disruptions (1).

Based on the available information, Iran is one of the countries vulnerable to natural disasters. According to published statistics from 1975 to 2008, twenty-four significant accidents have occurred globally, three of which occurred in Iran (2). Over the

past few decades, the frequency of disasters and the severity of their impacts have increased dramatically worldwide (3) in such a way that immediate responses to disasters require better and more appropriate performance than in the past. The lack of timely and appropriate response to disasters will significantly increase the current catastrophic risks (4). Effective disaster management and preparedness are vital to minimize their impact on communities (5). Today, timely and effective disaster management must rely on processing large volumes of data collected from various sources based on accurate information (6). Disaster management practices have recently tried integrating disaster management theories and practices with new information technology solutions and digital tools, where artificial intelligence-based programs are the most widespread (7).

Artificial Intelligence (AI) has become a great innovation with new concepts emerging in information and communication technology, computers, and electronics (8). AI lacks a single, universally accepted definition, as researchers characterize it in various ways. Primarily, AI refers to machines or computers designed to replicate cognitive abilities typically linked to the human brain, including learning and problem-solving (9). McCarthy described AI as technology that leverages data with intricate features, employing techniques to accomplish objectives. In simpler terms, AI strives to enhance human cognitive functions within computer systems (10).

Today, the use of AI in disaster management is expanding (11). In many cases, societies directly or indirectly benefit from AI in various ways regarding dealing with and managing disasters. Examples include using AI-based methods to analyze disaster-related information on social media (12), fostering public collaboration and information sharing on disasters through AI tools (13), and enhancing public awareness of different disasters using AI-driven simulations and gaming programs (14).

Historically, emergency responses, such as accidents requiring first aid, were sluggish and often insufficient. Human capabilities could have been improved in processing vast amounts of data on environmental shifts and linking them to swift reactions informed by historical incidents and analogous situations. However, AI now stands as a formidable resource for various organizations. Numerous entities are exploring AI to enhance prompt and efficient emergency responses. Although studies show a need for more research in Iran concerning AI-based disaster management solutions, this study aims to explore the role and implementation of AI in disaster response, focusing on research conducted within Iran.

Methods

This review study was conducted in September 2023 on the available articles in Persian or English regarding the role and application of AI-based technologies in disaster management related to Iran. Information was collected by searching with related keywords in ScienceDirect and PubMed, the Persian language databases SID and Magiran, and the Google Scholar search engine. The time limit was considered from 2020 to 2023. The reference list of all related articles was reviewed to find other possible sources to maximize the comprehensiveness of the search.

The original research articles that addressed the use of AI in disaster management in Iran and met the criteria considered by the researchers were selected in the present study. Review articles, articles from qualitative research, abstracts of articles that the researchers could not access the full text of, or articles whose research community was unrelated to Iran or did not address the role and application of AI in disaster management were excluded from the study.

A search yielded 315 articles. Upon examining each study's title, abstract, introduction, methodology, and results and considering the established inclusion and exclusion criteria, only eight articles qualified for inclusion in the research. The full texts of these selected articles were then thoroughly analyzed to extract pertinent research data.

Results

The characteristics of the eight studies reviewed in this research are shown in Table 1. Among these, three studies were related to flood risk assessment,

two on the risk of fire, and three on the evaluation of landslides and earthquakes.

Table 1. Studies related to the role and application of AI in disaster management in Iran

No.	Author	Year of publication	Disaster type	Methods	Results	Conclusion
1	Mohammadifar et al. (15)	2023	Flood	Integrated modeling based on multiplicative short-term memory (mLSTM) deep learning and multi-criteria decision-making models (MCDM) for flood risk assessment	All the criteria used to evaluate the accuracy performance of the model were greater than 90, which shows that the mLSTM model has performed very well.	A flood risk map was created by combining the flood risk and vulnerability maps generated by the mLSTM ensemble model and MCDM.
2	Salehi et al. (16)	2023	Fire	Elements (physiological, vegetation, meteorological, anthropological factors) in forest fires as input to the artificial neural network (ANN) and developing a fuzzy inference system to produce fire zoning maps	The most significant variables were the distance from the current source, i.e., river or stream, type of land formation, altitude, and minimum temperature. The reliability of the fire zoning map was evaluated at 83%, and the RMSE error was assessed at 75%.	Hybrid models effectively deal with the most critical variables obtained when determining the location for establishing fire stations and rural safety services. Moreover, such hybrid models are very efficient for determining fire hazard zones.
3	Sahebi et al. (17)	2022	Fire	Statistical machine learning models, including random forest (RF), support vector machines, naïve Bayes classifier, and ANNs for predicting the duration of emergency evacuation during a hospital fire	Based on the area under the curve (AUC), accuracy, and sensitivity values of 99.5%, 92.4%, and 92.1%, respectively, the RF model performs better than other models for predicting the duration of emergency evacuation from the hospital during a fire.	Evacuation duration prediction can provide managers with detailed information and accurate analysis of these events. Therefore, policymakers and health managers can improve fire preparedness and response by predicting evacuation duration and developing appropriate plans using machine learning models.
4	Ghasemian et al. (18)	2022	Landslide	Using a robust deep learning (DP) model based on a combination of extreme learning machine (ELM), deep belief network (DBN), backpropagation	Out of 25 conditioning factors, only 16 were essential for the modeling method. Among them, distance to the road, road density, lithology, and land use were four	The DP model is a suitable tool for landslide readiness mapping.

Table 1. Studies related to the role and application of AI ... (continued)

No.	Author	Year of publication	Disaster type	Methods	Results	Conclusion
				(BP), and genetic algorithm (GA) for landslide readiness mapping	critical factors. The results based on the experimental data set showed that the DP model has the highest accuracy (92%) among the compared algorithms.	
5	Seyyedfattahi et al. (19)	2022	Earthquake	A model was created to predict earthquakes using three Lunberg-Marquard backpropagation algorithms, Bayesian, and conjugate gradient methods.	The results showed that all three algorithms provided a good prediction, and the Bayesian algorithm performed best.	According to the results obtained, the investigated area is susceptible to high-magnitude earthquakes, making it necessary to follow the standards in building construction strictly.
6	Avand et al. (20)	2021	Flood	Two game theory algorithms - Borda and Condorcet - and two machine learning models - RF and ANN were used to determine flood probability and prioritize watershed sub-basins.	Twelve independent variables were used to model and prepare flood probability maps from 263 flood locations. The RF model was more accurate than the ANN model.	A tiny part has a high probability of flooding. From a flood risk perspective, quantitative analysis and characterization of watersheds can support decision-making, planning, and investment in mitigation measures.
7	Andaryani et al. (21)	2021	Flood	Using ANN algorithms for classification and supervised machine learning in FSM using three algorithms, MLP, FART, and SOM, with different activation functions for flood preparedness mapping	The inputs of the ANN were spatial data about ten factors affecting the flood. All influencing factors had a positive effect on modeling for FSM generation. The highest success rate was observed for MLP-S (92.1%) and the lowest for FART-T (75.8%).	Integrating machine learning classification with hard and soft monitoring with MLP-S and MLP-L activation functions showed a strong flood forecasting capability for proper flood risk planning and management; MLP-S is a promising method for predicting the probability of spatial expansion of flood events.
8	Nhu et al. (22)	2020	Landslide	Twenty conditioning factors were applied to 111 shallow landslides and tested using the One-R attribute evaluation (ORAE) technique for modeling and validation.	All five machine learning models performed well for shallow landslide susceptibility assessment, but the logistic tree model (AUC = 0.932) had the highest prediction accuracy.	Using the logistic tree model in shallow landslide mapping programs in semi-arid regions was recommended to assist decision-makers, planners, managers, and government agencies in risk reduction.

The results of the studies showed that in the direction of flood management, deep learning multiplicative short-term memory (mLSTM) and multi-criteria decision-making models (MCDM) were used for flood risk mapping in the Minab-Shamil plain based on nine critical features selected by GrootCV. Twelve variables and game theory algorithms (Condorcet, Borda) and two machine learning models, RF and ANN, were used to determine the areas of the Tajen watershed in Iran with the highest probability of flooding. In order to predict the likelihood of spatial expansion of flood events in Ajichai River, ten factors affecting the flood and the combination of ANN algorithms, machine learning, fuzzy adaptive resonance theory (FART), self-organizing map (SOM) with different activation functions, and RF were used. MLSTM, RF, and MLP-S models had higher accuracy and precision.

In predicting the risk of fire to determine the locations for establishing fire stations in the forest areas of the Shimbar National Reserve, four features were used as input to the ANN and the development of a fuzzy inference system to produce fire zoning maps for the study area, validating the map. Fire zoning was evaluated at 83%. In another study, RF algorithms, support vector machines, a simple Bayes classifier, ANN, and a fuzzy inference system were used to predict the duration of emergency evacuation after a hospital fire, and the RF model performed better than other models.

In assessing landslide readiness in Kamiyaran, Kurdistan province, Iran, a robust deep learning (DP) model based on a combination of extreme learning machine (ELM), deep belief network (DBN), genetic algorithm (GA), and One-R feature evaluation technique (ORAE) was used. In order to create a reliable map of shallow landslide readiness in Bijar, the One-R technique (ORAE) was tested for modeling and validation processes, and the results showed that the DP model and the logistic tree model had the highest accuracy among other algorithms. In the risk analysis of earthquake risk in the Azerbaijan region, five features of the earthquake event were extracted from the data related to the 100-year period. The earthquake prediction model was created based on five selected features with three different algorithms with a feedforward neural network, and this model had a high ability to predict earthquakes in the study area.

Discussion

Recent advancements in AI have equipped scientists and researchers with the tools to tap into and scrutinize larger and more diverse datasets than ever before. AI enables the prediction of natural disasters and their potential impacts while recommending proactive strategies for effective disaster management (23,24).

This review corroborates the effectiveness of AI-based approaches in enhancing disaster management for floods, landslides, and fires in Iran. The research indicates a strong emphasis on flood-related studies in the country. Machine learning emerges as a robust tool for forecasting floods, aiding in strategic planning and risk management. It also facilitates the creation of detailed flood risk maps through AI. For instance, a study on Pakistan's Hunza River demonstrated the high accuracy of machine-learning algorithms in flood prediction tasks (25). Similarly, research employing ANNs and data fusion techniques has proven the efficacy of AI, specifically neural networks, in crafting precise flood forecasting systems (26). These insights underscore AI's transformative potential in advancing flood prediction and alert systems, consequently mitigating the adverse effects of natural calamities.

Research on fire risk indicates that hybrid models excel in identifying areas at risk of fire. We can enhance preparedness and response during fires by forecasting evacuation times and designing tailored programs through machine learning models. AI's role in urban settings, specifically for the real-time prediction of tunnel fires, allows for swift and informed decision-making to rescue trapped individuals and firefighters by accurately forecasting the progression of tunnel fires, with studies demonstrating its effectiveness (27).

Moreover, AI—particularly ANNs—proves highly effective for forecasting forest fires in regions like China's Heilongjiang Province by evaluating climate, topography, and vegetation data (28). Additionally,

machine learning techniques have been utilized to predict forest fires using environmental factors such as oxygen levels, humidity, and temperature, employing algorithms like logistic regression, support vector machine, and multiple linear regression (29). These findings highlight AI's versatile application in fire prediction across various settings, from natural landscapes to urban infrastructures.

Findings on landslides showed that the deep learning model is a suitable tool for landslide readiness mapping. Additionally, the decision tree model with logistic regression functions in shallow landslide mapping programs in semi-arid regions has been recommended to help decision-makers, planners, managers, and government agencies reduce risk. In addition, landslide prediction models have been created using AI algorithms such as machine learning, which were trained with rainfall data and landslide occurrence data and have performed well (30). Furthermore, the GBRT algorithm has been used to predict the risk of landslides, indicating the use of AI in preventing disasters related to energy extraction (31). In addition, in a study, AI and machine learning algorithms have been suggested to improve the accuracy of spatial prediction of landslide risks in certain areas (32).

Recent studies since 2020 have yet to address disasters such as hurricanes, volcanic eruptions, tsunamis, tornadoes, and droughts. This gap may be attributed to Iran's frequent severe floods, while other disasters like tsunamis, volcanoes, or tornadoes are not typically part of Iran's climate-related hazards. Additionally, despite Iran being highly susceptible to earthquakes, domestic research remains limited. This may be due to the challenges in predicting earthquakes, their unpredictable nature, and their inherent complexity (33). Nevertheless, extensive research has been conducted globally on these topics (34-36). Imperatively, research managers and policymakers prioritize disaster-related studies and offer adequate incentives to overcome current barriers. Considering Iran's vast territory and diverse climates, region-specific research is essential. Local disasters should be the focus, with regional managers and organizations leading disaster management efforts. Furthermore, applying findings from successful national research to the operational and administrative sectors of disaster management, including organizations like the Crisis Management Organization, is crucial. Research methodologies and disaster management plans should be routinely evaluated, refined, and updated to ensure ongoing effectiveness.

Conclusion

This research focused on the role and application of AI in disaster management in Iran and how to improve disaster management using AI algorithms. It examines the varied applications of AI, seeking effective methods and strategies across different phases of disaster management. In addition, results indicate that AI models significantly manage floods, landslides, fires, and earthquakes. Leveraging robust data analysis and sophisticated algorithms, AI equips managers with powerful tools to forecast disasters and implement rapid, efficient corrective actions. Besides, AI emerges as a crucial ally in strategic decision-making, refining warning and monitoring systems, detecting anomalous patterns, and addressing vulnerabilities within disaster management operations. Moreover, AI's application in disaster response reduces response times and costs, boosts organizational productivity, and enhances user experiences. Recognizing the intricate nature of disaster management, the study advocates for an interdisciplinary approach that incorporates perspectives from often-overlooked fields, such as librarianship and information science, alongside AI and information technology, to foster a more holistic understanding of managing disasters.

Declaration

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Conflicts of Interests

The authors declare no conflict of interest in conducting this research.

Ethical Statement

All ethical principles were followed in

implementing this research, including referring to the first-category sources.

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Authors' contributions

All authors participated in the design, implementation, data collection, analysis, interpretation, and validation of data, writing, editing, revising, and finalizing various sections of the present paper.

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