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Information technology-based environmental management: A review

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Abstract

This study aimed to describe the role of information and communication technologies (ICT) in the management of natural resources. We conducted a systematic review of 320 articles from academic databases like Scopus, Latindex, Scielo, Dialnet, Redalyc, and Google, scanning the period from 2018 to 2023. We selected forty articles that discussed the application of ICT in predicting and mitigating issues related to climate change, erosion, environmental pollution, drought, and floods. The results indicated that climate change is one of the main drivers of environmental problems such as droughts and floods. Therefore, we concentrated our efforts on developing technologies like artificial intelligence (AI), machine learning (ML), the use of sensors, the Internet, and others. These tools make it possible to manage large amounts of information in real time and make informed decisions to prevent the aforementioned environmental problems. Despite the success of new technologies, it is important to note that they are not within the reach of the entire population due to the existing gap between the most technologically developed countries and those that are lagging. Therefore, we need to make additional efforts to enhance accessibility to technologies, enabling all countries to reap their benefits. In addition, efficient management of natural resources is required to minimize soil and water pollution. This implies the adoption of sustainable practices in the productive sector.

Keywords: Competitiveness, Data, ICT and environmental issues, Innovations in the technological field, Internet decisions, New technologies, Technological gaps.

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1. Introduction

The soil and climate conditions, coupled with optimized agronomic management, have enabled significant growth in core agricultural sectors in Latin America, such as coffee [1], rice [2], oilseeds [3], corn [4], bananas[5], and cocoa [6]. While this growth diversifies the economy, the key factors in the consolidation of agro productive chains are the consolidation of the agro-industrial sector. This is because it adds value, increases product diversity, benefits the involved economic sectors, and leads to greater job generation. However, we must achieve the adaptation of agro-industrial sector technologies for this to be possible. The adaptation of technology, resulting in greater sector growth, will help reduce production costs [7], manufacturing times [8], and losses during this process [9]. The advancement of two technological realms, informatics, and mechatronics [10], lays the groundwork for efficient management of the production process and increased production. They have allowed the development of applications based on fuzzy logic [11], neural networks [12], automated algorithms [13], and prototype design that optimizes production processes.

Successful development of technological innovations has taken place in various sectors through both local and national production-level experiences, which require enhanced efficiency in natural resource management to minimize the impact on soil and water quality due to environmental pollution issues, especially the ones associated with climate change. Hence, it leads to problems such as erosion [14] and increased frequency of droughts and floods [15]. Such issues not only affect agricultural productivity, but also have serious environmental and social consequences.

The need for improved environmental management has led to the development of technological solutions. It involves monitoring processes (wireless sensors, pest risk analysis), production control (humidity and temperature sensors, plant growth sensors), security technologies (cameras, biometric security devices), and prediction technologies weather stations, RPA (Rotary Plate Anemometer). Most of them have been developed by leading companies implementing advanced technologies; instead, geographic conditions and a lack of digital culture in small and medium-sized businesses hinder their adoption, limiting their development in the Latin American context.

Although technological innovation through the development of Information and Communication Technologies (ICTs) has been prioritized solely to support economic development, it is crucial that they are also employed for efficient environmental management. This study promotes a sustainable production model. One of the benefits of smart agriculture and agro-industry is its contribution to reducing CO2 emissions [16] which is the primary agent responsible for global warming due to human activities. The present review addresses these environmental, economic, and social consequences, which directly impact agricultural yields and lead to global warming issues, floods, and droughts.

Efficient environmental management is necessary to mitigate the problems mentioned. ICTs play a significant role in handling a vast amount of data, simulating scenarios, and making decisions. How can technological innovations, such as big data, neural networks, and automated algorithms, be used to predict and prevent natural disasters through effective environmental management?

Therefore, the objective of this review is to describe the main technological applications that allow for monitoring major environmental issues such as climate change, erosion, environmental pollution, drought, and flood risks. These applications facilitate timely decision-making to prevent their occurrence and minimize the damage they cause to the global population.

2. Materials and Methods

2.1. Bibliometric Analysis

The quantitative analysis of the information provided by Scopus is conducted using a bibliometric approach to assess the scientific production related to the importance of ICTs for the environmental management. Furthermore, examples of some research work published in the aforementioned area are qualitatively analyzed from a bibliographic perspective to describe the stance of various authors regarding the proposed topic.

The search is conducted using the tool provided by Scopus and the referenced parameters described in the methodological design.

2.2. Methodological Design

We conducted a three-phase methodological design search for scientific articles on the risks of the chemical combination by anthropogenic activities in the Latin American context:

Phase 1. Data collection. Using the technique of searching with multiple and specific keywords, an exhaustive selection of sources was carried out in Scopus, Redalyc, Scielo, Latindex, Dialnet, and Google Scholar databases.

Phase 2. Selection of Articles. The timeframe of the publication, purpose, outcomes, and new insights related to the scope of the subsequent analysis determined the quality and the relevance of the articles.

Phase 3: Hermeneutic Analysis. An interpretative approach was applied, which made it possible to understand and make sense of texts, discourses, or phenomena.

This analysis pays special attention to multiple interpretations and the influence of context on the understanding of meaning in relation to environmental management based on information technologies to prevent environmental risks, based on a literature review.

Finally, this analysis applied several steps that included the detailed reading of the text, the identification of themes and patterns, the consideration of the context, and the reflection on possible interpretations. This hermeneutical approach is especially useful in interpreting complex or ambiguous texts, and providing a deeper understanding of implicit meanings.

2.3. Information Retrieval

We used a bibliographic review methodology and the technique of documentary exploration to develop this research. It was carried out in two stages: the heuristic stage, during which sources of information were identified, and the hermeneutic phase, which synthesized the information and generated commentary based on theoretical foundations [17].

The method employed in the research allowed for the analysis of various publications by different authors and provided an easier comparison of the subjects. Details of the sources were recorded, enabling the compilation of bibliographic information, and it was also considered their opposite perspectives and research strategies, including hermeneutics' ones. Additionally, the similarities and differences among different authors with similar characteristics and research topics are explained.

2.4. Techniques Applied

We conducted the bibliographic search and localization exhaustively and professionally. After detecting the publications, each section was analyzed, and key topics were identified to categorize the impact, providing a direct and in-depth assessment of each publication. We then extracted the most relevant information and made appropriate comparisons.

2.5. Inclusion Criteria

The selected papers included similar words as in the title of this study. These publications not only met the study's conditions but were also produced within the established timeframe. Terminology was considered during the information search, limiting it to expected results and previous findings related to the significance of ICTs for the environmental management. The analysis encompassed digital journal publications in databases such as Scopus, Google Scholar, Dialnet, Redalyc, Latindex, and Scielo.

The papers were related to innovations used for environmental management and the relevance of ICTs for the environmental management, which refer to the period from 2018 to 2023.

2.6. Exclusion Criteria

Publications that deviated from the content of this study, lacked logical coherence, or lacked a scientific foundation were not considered. Abstracts, conference communications, and thesis were also excluded from the study.

2.7. Quality of the Selected Articles

To determine the methodological quality of the consulted documents, the Critical Review Form for Quantitative Studies process was used to assess manuscripts in the following categories: poor methodological quality ≤ 11; acceptable methodological quality 12-13; good methodological quality 14-15; Very good methodological quality 16-17; and excellent methodological quality ≥ 18.

Furthermore, scientific papers were selected as they report results deriving from qualitative studies, among which, the ones with an Average Count Citation (ACC) index greater than 1.50 were chosen. The ACC index was defined using an instrument called Average Count Citation.2.3 Information Retrieval.

3. Results

The documentary review led to the selection of 40 articles, as illustrated in Figure 1. The articles pertain to the significance of ICTs for the environmental management and cover the years 2018-2023. They are categorized into five distinct categories, outlined in the following graphic:

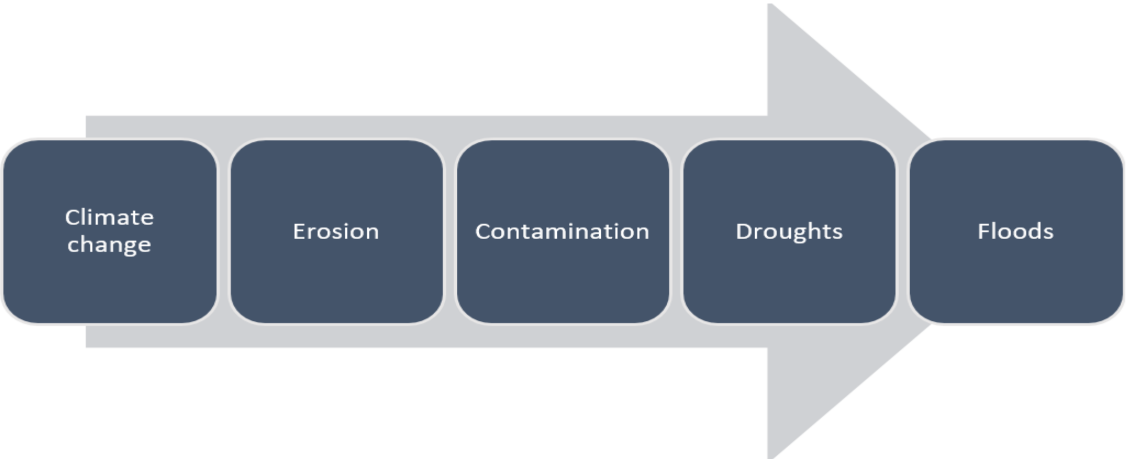

Figure 1.
Categories addressed to analyze the importance of ICT for environmental management during the period 2018-2023.

Based on the bibliometric analysis, it is evident that many scientific articles consider the most employed technological innovations. About six papers focus on the use of AI, followed by research (2 each) that delves into the usage of sensors and big data. Hence, there are two papers each that explore applications of MLand the Internet of Things (IoT), as illustrated in Figure 2.

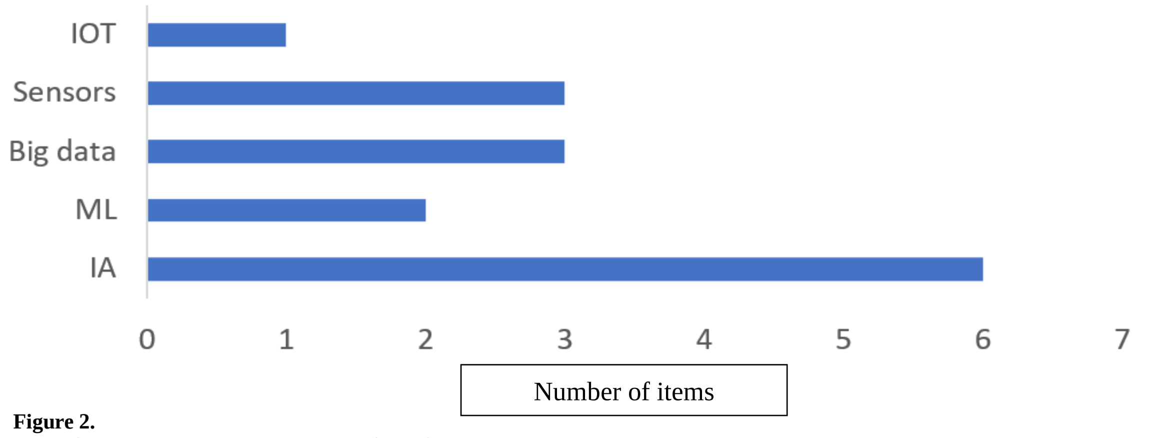

Figure 2.
Scientific articles contemplating the use of ICT for environmental management during the period 2018-2023.

On the other hand, of the issues that ICTs address (Figure 3), 60% of them use information and communication technologies (ICT) to monitor climate change. Then it follows erosion and pollution, each accounting for 20% of the reviewed scientific articles.

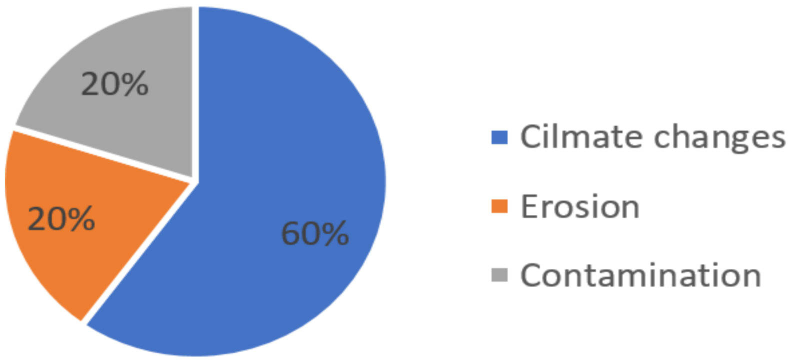

Figure 3.
Use of ICT for monitoring the main environmental issues during the period 2018-2023.

Following the bibliometric analysis, we conducted a hermeneutic analysis of the selected 40 scientific articles. It is noteworthy that the initial 8 papers pertain to the use of ICTs for climate change prevention during the period 2018-2023. Table 1 details them,we describe their key findings.

Table 1.
ICTs applied to environmental management for climate change prevention during the period 2018-2023.

Title	Year	Authors	Database
The role of state broadcasting media and education in addressing climate change in Bangladesh.	2019	Afroz, et al. [18]	Scopus
Big data: From modern fears to enlightened and vigilant embrace of new beginnings.	2020	Dewandre [19]	Scopus
Big data and IoT-based applications in smart environments: A systematic review.	2021	Hajjaji, et al. [20]	Scopus
Monitoring system using XBee and GSM (Global system for mobile communications) technology for climate supervision in banana production.	2020	Miranda-Ramos, et al. [21]	Scopus
Mobile applications as instruments of urban communication for climate change in Loja, Ecuador.	2023	Palacios and Duque-Rengel [22]	Redalyc
The impact assessment of climate change on building energy consumption in Poland.	2021	Bazazzadeh, et al. [23]	Scopus
Development and implementation of an ICT-based disaster prevention and mitigation education program for the young generation.	2021	Uchida, et al. [24]	Scopus
Data analytics for operational risk management.	2020	Araz, et al. [25]	Scopus

Afroz, et al. [18] emphasize that the use of the Internet and social media is beneficial for informing and communicating risk prevention strategies related to extreme hydro-meteorological events. They note that young people prioritize the Internet and social media over risk prevention plans and programs disseminated through official channels. Therefore, it is concluded that various ICTs can favor communication and environmental learning among young individuals.

The significance of ICTs in monitoring climate change is highlighted by Dewandre [19] who states that it is currently a top-priority issue on the legislative agenda of all Western countries, especially within the European Union. Environmental deterioration leads to problems such as erosion, drought risks, and floods, which we will discuss later.

The advantages of ICTs, as expressed by Hajjaji, et al. [20] lie in the fact that new technologies enable the processing of large-scale data with complex structures and various types of structured and semi-structured data. These inputs result in more accurate information with few errors, thereby facilitating decision-making.

An example is described by Miranda-Ramos, et al. [21] who evaluated a monitoring system using XBee and GSM technology for climate monitoring in banana production. They found that this system is cost-effective for banana crop owners due to its low cost and the implementation of freely accessible hardware and software. It allows remote monitoring of their plantations' development, providing an easy way to record historical environmental parameters.

Based on the positive results, Palacios and Duque-Rengel [22] affirm the favorable attitude towards using app services to enhance effective urban communication that engages citizens in addressing various city issues, particularly those associated with environmental risks affecting safety and quality of life.

In a similar context, Bazazzadeh, et al. [23] designed a software prototype for assessing the social impact of climate change in coastal settlements in Poland to evaluate the impact of climate change on building energy consumption. Their development offers an easy-to-use web application for the community, facilitating the creation, implementation, and analysis of necessary questionnaires to evaluate the social impact of climate change.

In a similar vein, Uchida, et al. [24] employed a municipal disaster risk management system based on ICTs. This tool aids decision-making in line with strategies established by authorities. It offers intelligent data visualization based on real-time municipal information.

Building on these findings related to climate change monitoring, Araz, et al. [25] assert that using cutting-edge technologies for climate prediction harnesses the best of advances in informatics, computing, software, algorithm programming, high-volume storage systems, statistics, and mathematics. This leads to real-time, precise predictions that facilitate decision-making.

The second group of 8 scientific articles pertains to the use of ICTs in environmental management for erosion risk prevention during the period 2018-2023. They are summarized in Table 2, and their key findings are described below:

Table 2.
Application of ICTs in environmental management for preventing soil Erosion risks during the period 2018-2023.

Title	Year	Authors	Database
Machine learning applications for water-induced soil erosion modeling and mapping.	2021	Sahour, et al. [26]	Scopus
Geographical landslide early warning systems.	2020	Guzzetti, et al. [27]	Scopus
Applicability of an interferometric optical fiber sensor for shallow landslide monitoring–experimental tests.	2021	Ivanov, et al. [28]	Scopus
Knowledge management practices in disaster management: Systematic review. International.	2020	Oktari, et al. [29]	Scopus
Implementation and its effect on public organizations: The case of digital customs and risk management in Korea.	2020	Kim and Kim [30]	Scopus
A critical study on disaster management and role of ICT in minimizing its impact.	2020	Choudhary and Vyas [31]	Scopus
ICT in disaster management context: A descriptive and critical review.	2022	Kaur, et al. [32]	Scopus
Information technologies and disaster management–benefits and issues.	2019	Sakurai and Murayama [33]	Scopus

Sahour, et al. [26] highlight the importance of ICTs due to the challenges of conducting extensive field studies to record soil erosion rates. They propose the use of ML for accurate measurement of annual soil erosion, utilizing ML algorithms to estimate erosion rates for the entire study area.

According to Guzzetti, et al. [27] technological innovations have enabled the design and development of Early Warning Systems (EWS) with mobile application advantages. These systems alert users to prevent landslides in real-time and allow timely decisions to avoid material and human damage.

A landslide is a natural phenomenon that deeply affects the economy and society. Ivanov, et al. [28] demonstrate that a proposed totemic sensor network would be a promising tool for landslide monitoring. It aims to reduce the socio-economic effects caused by natural disasters, particularly in Andean countries where steep slopes and heavy rains favor such processes.

Hence, as well as monitoring, Oktari, et al. [29] assert that communication in risk management is a crucial part of the process involving stakeholders, such as populations at risk. Technologies like ICTs facilitate real-time transmission of events and help communities self-organize to minimize damage.

Among the advantages of new technologies, Kim and Kim [30] emphasize their multifunctionality, ranging from information storage to enabling user interaction. The incorporation of new hardware such as cameras, Global Positioning System (GPS), etc. enhances this diversity. Smartphones, for example, are a widely known example of as exponential increase in applications, serving as practical tools for community use.

Building on the positive outcomes, Choudhary and Vyas [31] affirm that ICTs such as telecommunications satellites, radar, telemetry, and meteorology play a key role as they enable remote detection for early warning. While traditional media (radio, television) and new media (cellular transmission, the Internet, satellite radio) educate and raise public awareness about potential disaster risks.

Given the positive assessment of ICTs, Kaur, et al. [32] underscore the importance of information technology in disaster management. They provide guidance for future ICT-supported disaster management work, acting as tools for monitoring, early warning, real-time information flow, decision-making, and generating precise and reliable information for disaster prevention.

To succeed with digital tools, Sakurai and Murayama [33] express that as advancements in risk reduction and disaster responses through ICTs are observed, local governments require more resources. These governments face difficulties in handling digital tools and information. As a result, collaboration with external institutions and professionals is necessary to develop an environmental management and erosion prevention strategy based on ICTs.

The third group of 8 scientific articles pertains to the use of ICTs in environmental management for pollution risk prevention during the period 2018-2023. These articles are summarized in Table 3, and their key findings are described below:

Table 3.
Application of ICTs in environmental management for the prevention of environmental pollution risks during the period 2018-2023.

Title	Year	Authors	Database
Information and communication technologies (ICTs): A strategy for preventing environmental pollution.	2023	Merino, et al. [34]	Latindex
Understanding the adoption of industry4.0 technologies in improving environmental sustainability. Sustainable	2022	Javaid, et al. [35]	Scopus
Technological challenges of green innovation and sustainable resource management with large scale data.	2019	Song, et al. [36]	Scopus
Smart and portable air-quality monitoring IoT low-cost devices in Ibarra city, Ecuador.	2022	Alvear-Puertas, et al. [37]	Scopus
Design of a WSN (Wireless sensor network) for monitoring airborneCO2 and noise levels in the city of Loja	2020	Mendieta and Garrochamba [38]	Scielo
Application of remote sensors for vegetation cover and water bodies analysis	2020	Veneros, et al. [39]	Scopus
Emerging techniques and materials for water pollutants detection	2020	Soni, et al. [40]	Scopus
A simple and low-cost integrative sensor system for methane and hydrogen measurement.	2020	Fakra, et al. [41]	Scopus

For the prevention of environmental pollution risks, Merino, et al. [34] highlight the significance of biomonitoring exposure to pollutants. This approach provides crucial information for epidemiological research, informed intervention plans, and the formulation of environmental policies, particularly in disadvantaged communities.

In addition to disseminating information through ICTs, Javaid, et al. [35] assert that there is clear evidence of how the implementation and application of converging technologies like IoT, Deep Learning, ML, real-time sensors, and intelligent data analysis platforms contribute to improving characterization, monitoring, and control of contaminants in water, soil, and air, thereby minimizing environmental impact.

According to Song, et al. [36] analyzing environmental effects with the aid of new technologies offers excellent opportunities to comprehend and address environmental issues. These technologies enable more effective information collection, analysis, monitoring, and control of information and facilitate the development of more sustainable solutions based on reliable results, thereby aiding decision-making.

Despite the reported positive results, Alvear-Puertas, et al. [37] suggest that future work should focus on big data and the development of solid software platforms based on AI and ML models to clean and process the vast amount of generated data. This boosts the effective analysis from different perspectives, leading to more timely decision-making.

Despite the need for more efficient software platforms, the use of current tools has proven useful, as demonstrated by Mendieta and Garrochamba [38]. They designed a wireless system to monitor CO2 and noise levels in the city of Loja. The system is deemed suitable to use in the urban area of Loja and to make decisions when CO2 levels exceed permissible limits.

Similarly, Veneros, et al. [39] determined that obtaining satellite images in small to medium-scale studies can provide high-resolution information for various environmental applications. It involves assessing vegetation abundance, plant population dynamics, ecological conservation, aquatic vegetation, vegetation mapping, water quality, river dynamics, river flow, lake bathymetric maps, and aquatic vegetation variations impacted by anthropogenic interventions.

Among the benefits of technological innovations like biosensors, Soni, et al. [40] point out that they are low-cost systems ideal for field applications and scenarios where processing a large number of samples is necessary. However, researchers concluded that because biosensors do not exhibit a linear response to analyze concentration, their use in primarily qualitative rather than quantitative, primarily for pollutant identification.

The advantage of sensor use is also reported by Fakra, et al. [41] who note that this approach can be employed in applications requiring alarm signals or indicators of clean air. It is also useful to conduct environmental studies by storing results and using AI or ML tools. In cities with high atmospheric pollution due to industrial activity and vehicular traffic, the technologies at issue are valuable.

The fourth group of 8 scientific articles pertains to the use of ICTs in environmental management for drought risk prevention during the period 2018-2023. These articles are summarized in Table 4, and their key findings are described below:

Table 4.
ICTs applied to environmental management for drought prevention during the period 2018-2023.

Title	Year	Authors	Database
Drought risk management toward a comprehensive approach.	2020	Varela-Ledesma and Romero-Suárez [42]	Scielo
Drought monitoring in El Salvador through remote sensing variables using the google earth engine platform	2020	Córdova, et al. [43]	Scopus
Tools for drought monitoring and control: A meta-analysis in context	2023	Pozo and Luna [44]	Dialnet
Comparative evaluation of drought indices for monitoring drought based on remote sensing data. Environmental	2021	Wei, et al. [45]	Scopus
Artificial intelligence application in drought assessment, monitoring, and forecasting: A review. Stochastic environmental	2022	Kikon and Deka [46]	Scopus
Convergence of mechanistic modeling and artificial intelligence in hydrologic science and engineering	2023	Muñoz-Carpena, et al. [47]	Scopus
A regional machine learning method to outperform temperature-based reference evapotranspiration estimations in Southern Spain	2022	Bellido-Jiménez, et al. [48]	Scopus
Geoinformation technologies in support of environmental hazards monitoring under climate change: An extensive review	2021	Tsatsaris, et al. [49]	Scielo

The significance of applying ICTs to environmental management for drought prevention is described by Varela-Ledesma and Romero-Suárez [42] who identified risk components incorporated into an early warning system supported by information technology. It aids the practical translation of national guidelines down to the local scale, assisting local authorities in decision-making.

In this regard, Córdova, et al. [43] achieved continuous monitoring for El Salvador using the Google Earth Engine. The system detects precipitation anomalies and their consequences, enabling more precise delineation of regions affected by specific droughts. These have an impact on both agriculture production and the availability of drinking water for people living in densely populated urban areas or arid and semi-arid regions.

Despite drought's importance, Pozo and Luna [44] note a lack of references to its hydraulic evaluation. Hydraulic drought, a relatively new concept sometimes associated with hydrological and socioeconomic drought, lacks detailed information. Results still primarily focus on meteorological drought, despite evidence that water storage and flow depend on soil conditions.

Given the need to assess meteorologically influenced drought, Wei, et al. [45] evaluated seven climatological variables for spatial-temporal transition identification of potential evapotranspiration, intensity of precipitation through Standardized Precipitation Index (SPI), temporal distribution of water deficits via Modified Normalized Difference Water Index (MNDWI), and temporal distribution of droughts through Vegetative Health Index (VHI) application.

Kikon and Deka [46] suggest the use of AI models for spatial-temporal drought prediction. Successful implementation of the developed model can enable governmental entities to mitigate drought impacts.

In the same vein, Muñoz-Carpena, et al. [47] recommend AI techniques in hydrology, capable of functioning in complex environments with simplified data. This is advantageous for completing information with scarce data, which is common in most meteorological networks in developing countries with limited technological infrastructure.

Tools like ML can even simulate drought scenarios with limited data, as described by Bellido-Jiménez, et al. [48]. They developed a methodology using automated learning, precisely enhancing crop evapotranspiration estimates at a regional level using only temperature data in the analysis process.

Based on the presented findings, Tsatsaris, et al. [49] affirm that decision support information systems, designed with Geographic Information Systems (GIS), allow continuous data updating, impact particularization, behavior prediction, decision alternative suggestion, digital report, and image issuance. Asa consequence, it enables enhanced management planning and contributes to environmental risk management.

Lastly, the final group of 8 scientific articles pertains to the use of ICTs in environmental management for flood prevention during the period 2018-2023. They are summarized in Table 5, and their key findings are described below:

Table 5.
ICTs applied to environmental management for flood prevention during the period 2018-2023.

Title	Year	Authors	Database
Comparison of physical and artificial intelligence models for flood level prediction.	2018	Agudelo-Otálora, et al. [50]	Latindex
Electronic design of early warning system for flood monitoring and detection.	2022	Flores, et al. [51]	Google Scholar
Evaluating urban flood risk using hybrid method of TOPSIS (Technique for order of preference by similarity to ideal solution) and machine learning.	2021	Rafiei-Sardooi, et al. [52]	Scopus
Hazard and vulnerability in urban flood risk mapping: Machine learning techniques and considering the role of urban districts.	2020	Eini, et al. [53]	Scopus
Flash flood risk analysis based on machine learning techniques in the Yunnan province, China.	2019	Ma, et al. [54]	Scopus
Flood risk assessment using hybrid artificial intelligence models integrated with multi-criteria decision analysis in Quang Nam province, Vietnam.	2021	Pham, et al. [55]	Scopus
Use of artificial intelligence to improve resilience and preparedness against adverse flood events.	2019	Saravi, et al. [56]	Scopus
How computer vision can facilitate flood management: A systematic review International.	2021	Iqbal, et al. [57]	Scopus

The increased frequency of floods is one of the most impacted by climate change. Researchers have proposed technological tools to monitor these floods. However, Agudelo-Otálora, et al. [50] point out that when analyzing the behavior of two models used for this purpose, they found that the physical model underestimates high forecasted flow values, while algorithms using neural networks are closer to real values, predicting floods more accurately and rigorously. This allows timely measures to minimize socioeconomic damages, especially in vulnerable areas.

Another successful innovation for flood prediction is described by Flores, et al. [51]. They developed an electronic prototype using the IoT that integrates an early warning system, notifications, and real-time monitoring of flood-prone areas. It allows protective measures for populations affected by this phenomenon, similar to areas prone to typhoons and hurricanes.

In addition to predicting events, models must assist in decision-making. Rafiei-Sardooi, et al. [52] compared three models and found that the random forest model produced the most accurate map. The model identified that urban drainage density and distance play a vital role in modeling urban flood risk. It highlighted densely populated areas as the most vulnerable to flooding.

Thus, Eini, et al. [53] found that ML models provide reliable results in areas where data access is challenging, especially in developing countries with logistical and geographical limitations. This model identified that infrastructure plays a crucial role in quantifying flood vulnerability. Demographic aspects and distance to main drainage channels are the most important factors increasing flood risk.

The ease of identifying vulnerability factors using ML methods, according to Ma, et al. [54] is due to public datasets, obtained from remote sensing images and statistical bulletins. This method is feasible through local historical flood inventory collection. However, it heavily relies on data, lacking evident physical mechanisms. This can lead to issues like uncertainty and poor accuracy when data is insufficient, as it happens in some regions.

Another method for flood prediction and estimation is described by Pham, et al. [55]. The final flood risk map can aid in better flood risk management in the evaluated research area. If the results are positive, we could apply these models to other floods-prone regions.

Random forests are a previously described technique with successful results. Saravi, et al. [56] reaffirm this claim, as analytical results show the technique provides the highest classification accuracy. The classification results can guide better decision-making for flood prevention and preparation, enhancing resilience in vulnerable areas.

Finally, when weighing the findings reported in this review, they contradict those found by Iqbal, et al. [57]. They state that the application of ML methods in the post-disaster scenario is limited, requiring future efforts to combine disaster management knowledge with image processing techniques and ML tools to ensure effective and holistic disaster management in all phases. This technique is only partially effective for flood prediction, as demonstrated by previous results.

4. Discussion

As a result, it is evident that the use of ICTs, including the Internet [58], social media [59] and audiovisual media [60] has played a crucial role as a means of real-time communication. They have been employed to raise awareness and implement alert systems regarding the occurrence of natural disasters that impact the population. However, in recent years, technological innovations have moved beyond mere information dissemination and have become more focused on managing vast amounts of data through tools like big data [61]. These technologies, combined with AI and ML, are creating intelligent systems for decision-making in both disaster prediction and prevention.

The focus on predicting environmental damage has primarily been on identifying the future effects of climate change [62], as the consequences of climate change entail significant social and environmental damages due to changes in precipitation patterns [63], heatwaves [64] and increased frequency of extreme events like hurricanes [65] which can lead to coastal flooding [66]. Therefore, it is essential to determine the causes and future evolution of climate change more accurately, requiring more precise tools given the complexity and variability of climate information.

In addition to climate change, erosion is another environmental issue that requires close monitoring and prediction. Technological tools are key, as erosion is multifactorial in nature[67] and challenging to measure in situ [68]. Predicting erosion is crucial due to the significant damage it and mass movements [69] cause to populations, especially those located in vulnerable areas characterized by high rainfall, unstable terrain, and steep slopes.

Environmental pollution is another problem where sensors [70] AI tools [71] and automated algorithms have been developed to predict the impact of anthropogenic activities such as industry [72], mining [73] and even agriculture [74] on water, soil, and air pollution levels [35]. The health consequences of environmental pollution necessitate urgent measures for mitigation, addressing the progressive deterioration of the environment.

Drought risk determination is one of the most severe issues addressed in this review, requiring more digital tools for accurate prediction [46]. Droughts are associated with decreased agricultural productivity and reduced water availability for the population. Given the economic and social consequences of droughts, precise systems for diagnosing and preventing this problem are essential.

The last environmental issue discussed was floods, which, like droughts, require accurate data management and interpretation. With climate change, the frequency of floods has increased [75] stemming from changes in precipitation patterns [76] or more frequent and intense hurricane occurrences [77]. In either case, floods have significant economic and environmental consequences for affected populations, especially those in vulnerable areas.

5. Conclusions

Technological advancement has enabled the management of vast amounts of data through big data, which, coupled with the use of neural networks and automated algorithms, facilitates the prediction and prevention of natural disasters such as climate change, erosion, pollution, droughts, and floods. This empowers decision-makers to take precise actions to mitigate the impact of these disasters on affected populations.

Climate change is the primary issue that research has focused on when predicting the occurrence of natural events. Diagnosing climate behavior is complex due to its variability. Climate change, in turn, gives rise to other problems explored in this review, such as erosion, drought risks, and floods. These issues are interconnected and associated with global warming, which alters the behavior of climate parameters, particularly temperature and precipitation.

Although the development and application of technological innovations have seen greater success in developed countries, prototypes and applications have played a crucial role in Latin America as well. The region’s high vulnerability to natural disasters such as floods, droughts, and erosion drives the interest in establishing an early warning system. Additionally, many countries in the region rely on environmental factors for economic development, particularly in agriculture and livestock sectors.

References

[1] J.-M. Romero-Rodríguez, M.-S. Ramírez-Montoya, I. Aznar-Díaz, and F.-J. Hinojo-Lucena, "Social appropriation of knowledge as a key factor for local development and open innovation: A systematic review," *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 6, no. 2, p. 44, 2020. https://doi.org/10.3390/joitmc6020044

[2] I. Q. Anugwa, E. A. Onwubuya, J. M. Chah, C. C. Abonyi, and E. K. Nduka, "Farmers’ preferences and willingness to pay for climate-smart agricultural technologies on rice production in Nigeria," *Climate Policy*, vol. 22, no. 1, pp. 112-131, 2022. https://doi.org/10.1080/14693062.2021.1953435

[3] G. Kome, F. Tabi, F. Silatsa, and R. Enang, "Identification of soil management factors for sustainable oil palm (Elaeis guineensis Jacq.) production in coastal plains of Southwest Cameroon," *Journal of Agronomy*, vol. 19, no. 2, pp. 83-93, 2020. https://doi.org/10.3923/ja.2020.83.93

[4] C. Andorf *et al.*, "Technological advances in maize breeding: Past, present and future," *Theoretical and Applied Genetics*, vol. 132, pp. 817-849, 2019. https://doi.org/10.1007/s00122-019-03306-3

[5] G. Vox *et al.*, "A wireless telecommunications network for real-time monitoring of greenhouse microclimate," *Journal of Agricultural Engineering*, vol. 45, no. 2, pp. 70-79, 2014. https://doi.org/10.4081/jae.2014.237

[6] L. A. León-Serrano, A. M. Matailo-Pinta, A. A. Romero-Ramón, and C. A. Portalanza-Chavarría, "Ecuador: Banana, coffee and cocoa production by zones and their economic impact 2013-2016," *Revista Científica UISRAEL*, vol. 7, no. 3, pp. 103-121, 2020. https://doi.org/10.35290/rcui.v7n3.2020.324

[7] A. Barrios-Ulloa, D. Cama-Pinto, J. Mardini-Bovea, J. Díaz-Martínez, and A. Cama-Pinto, "Projections of iot applications in Colombia using 5g wireless networks," *Sensors*, vol. 21, no. 21, p. 7167, 2021. https://doi.org/10.3390/s21217167

[8] Z. Zhai, J. F. Martínez, V. Beltran, and N. L. Martínez, "Decision support systems for agriculture 4.0: Survey and challenges," *Computers and Electronics in Agriculture*, vol. 170, p. 105256, 2020. https://doi.org/10.1016/j.compag.2020.105256

[9] U. Gómez-Prada, M. Orellana-Hernández, and J. Salinas-Ibáñez, "Strategy for the appropriation of a DSS in small bovine producers using simulation and a serious video game," *Information*, vol. 11, no. 12, p. 566, 2020. https://doi.org/10.3390/info11120566

[10] C. Blair, E. Gralla, F. Wetmore, J. Goentzel, and M. Peters, "A systems framework for international development: The data-layered causal loop diagram," *Production and Operations Management,* vol. 30, no. 12, pp. 4374-4395, 2021. https://doi.org/10.1111/poms.13492
[11] F. P. Oganda, M. H. R. Chakim, W. E. Septian, and E. D. Astuti, "User involvement on air quality in incubation rooms in Banten-Indonesia," *ADI Journal on Recent Innovation,* vol. 5, no. 1, pp. 86-92, 2023. https://doi.org/10.34306/ajri.v5i1.989
[12] S. Sharifi, N. Monjezi, and N. Hafezi, "Performance of multilayer perceptron neural network models and radial-based functions in estimation of sugar-cane crop yield," *Journal of Agricultural Science and Sustainable Production,* vol. 30, no. 4, pp. 213-228, 2020. https://doi.org/10.22034/saps.2020.12313
[13] T. Paiva, M. P. Ribeiro, and P. Coutinho, "Capacity-building model to promote innovation and sustainability in the Portuguese agro-industrial sector," *Sustainability,* vol. 14, no. 23, p. 15873, 2022. https://doi.org/10.3390/su142315873
[14] G. Hou *et al.*, "Determining the optimal vegetation coverage for controlling soil erosion in Cynodon dactylon Grassland in North China," *Journal of Cleaner Production,* vol. 244, p. 118771, 2020. https://doi.org/10.1016/j.jclepro.2019.118771
[15] E. W. Sandoval, T. Toulkeridis, A. Aguilar Ponce, S. E. Chiriboga, and E. Salazar, "Risk and vulnerability analysis of flood hazards in the Colón Parrish, western ecuador based on HEC-RAS numerical simulation," presented at the XV Multidisciplinary International Congress on Science and Technology. Cham: Springer International Publishing, 2021.
[16] E. Delgado-Plaza *et al.*, "Thermal evaluation of a hybrid dryer with solar and geothermal energy for agroindustry application," *Applied Sciences,* vol. 9, no. 19, p. 4079, 2019. https://doi.org/10.3390/app9194079
[17] R. A. De By *et al.*, "Principles of geographic information systems," *ITC Educational Textbook Series,* vol. 1, p. 234, 2001.
[18] A. Afroz, S. Khan, I. B. Mahmud, and M. N. Chowdhury, "The role of state broadcasting media and education in addressing climate change in Bangladesh. Confronting climate change in Bangladesh: Policy strategies for adaptation and resilience," pp. 85-101, 2019.
[19] N. Dewandre, "Big Data: From modern fears to enlightened and vigilant embrace of new beginnings," *Big Data & Society,* vol. 7, no. 2, pp. 1-5, 2020. https://doi.org/10.1177/2053951720936708
[20] Y. Hajjaji, W. Boulila, I. R. Farah, I. Romdhani, and A. Hussain, "Big data and IoT-based applications in smart environments: A systematic review," *Computer Science Review,* vol. 39, p. 100318, 2021. https://doi.org/10.1016/j.cosrev.2020.100318
[21] M. M. Miranda-Ramos, A. A. Ortiz, and L. A. Moreno, "Monitoring system using XBee and GSM technology for climate supervision in banana production," *Información Tecnológica,* vol. 31, no. 6, pp. 69-76, 2020.
[22] E. K. C. Palacios and V. K. Duque-Rengel, "Mobile applications as urban communication instruments for climate change in Loja, Ecuador," *Estado & Comunes, Revista De Políticas y Problemas Públicos,* vol. 1, no. 16, pp. 81-100, 2023. https://doi.org/10.37228/estado_comunes.v1.n16.2023.289
[23] H. Bazazzadeh, P. Pilechiha, A. Nadolny, M. Mahdavinejad, and H. S. S. Safaei, "The impact assessment of climate change on building energy consumption in Poland," *Energies,* vol. 14, no. 14, p. 4084, 2021. https://doi.org/10.3390/ en14144084
[24] O. Uchida, S. Tajima, Y. Kajita, K. Utsu, Y. Murakami, and S. Yamada, "Development and implementation of an ICT-based disaster prevention and mitigation education program for the young generation," *Information Systems Frontiers,* vol. 23, pp. 1115-1125, 2021. https://doi.org/10.1007/s10796-020-10082-9
[25] O. M. Araz, T. M. Choi, D. L. Olson, and F. S. Salman, "Data analytics for operational risk management," *Decision Sciences,* vol. 51, no. 6, pp. 1316-1319, 2020. https://doi.org/10.1111/deci.12443
[26] H. Sahour, V. Gholami, M. Vazifedan, and S. Saeedi, "Machine learning applications for water-induced soil erosion modeling and mapping," *Soil and Tillage Research,* vol. 211, p. 105032, 2021. https://doi.org/10.1016/j.still.2021.105032
[27] F. Guzzetti *et al.*, "Geographical landslide early warning systems," *Earth-Science Reviews,* vol. 200, p. 102973, 2020.
[28] V. Ivanov, L. Longoni, M. Ferrario, M. Brunero, D. Arosio, and M. Papini, "Applicability of an interferometric optical fibre sensor for shallow landslide monitoring–experimental tests," *Engineering Geology,* vol. 288, p. 106128, 2021. https://doi.org/10.1016/j.enggeo.2021.106128
[29] R. S. Oktari, K. Munadi, R. Idroes, and H. Sofyan, "Knowledge management practices in disaster management: Systematic review," *International Journal of Disaster Risk Reduction,*vol. 51, p. 101881, 2020. https://doi.org/10.1016/j.ijdrr.2020.101881
[30] S.-B. Kim and D. Kim, "ICT implementation and its effect on public organizations: The case of digital customs and risk management in Korea," *Sustainability,* vol. 12, no. 8, p. 3421, 2020. https://doi.org/10.3390/su12083421
[31] P. Choudhary and R. Vyas, *A critical study on disaster management and role of ICT in minimizing its impact. In: Pant, M., Sharma, T., Basterrech, S., Banerjee, C. (Eds.), Performance Management of Integrated Systems and its Applications in Software Engineering. Asset Analytics*. Singapore: Springer. https://doi.org/10.1007/978-981-13-8253-6_18, 2020, pp. 183-187.
[32] M. Kaur, P. D. Kaur, and S. K. Sood, "ICT in disaster management context: A descriptive and critical review," *Environmental Science and Pollution Research,* vol. 29, no. 57, pp. 86796-86814, 2022. https://doi.org/10.1007/s11356-022-21475-5
[33] M. Sakurai and Y. Murayama, "Information technologies and disaster management–benefits and issues," *Progress in Disaster Science,* vol. 2, p. 100012, 2019. https://doi.org/10.1016/j.pdisas.2019.100012
[34] O. M. Merino, O. A. R. Valencia, C. J. Andrade, and M. M. V. Conforme, "(ICT) a strategy to prevent environmental pollution," *Revista Científica Arbitrada Multidisciplinaria PENTACIENCIAS,* vol. 5, no. 3, pp. 634-642, 2023. https://doi.org/10.59169/pentaciencias.v5i3.589
[35] M. Javaid, A. Haleem, R. P. Singh, R. Suman, and E. S. Gonzalez, "Understanding the adoption of industry 4.0 technologies in improving environmental sustainability," *Sustainable Operations and Computers,* vol. 3, pp. 203-217, 2022. https://doi.org/10.1016/j.susoc.2022.01.008
[36] M. Song, R. Fisher, and Y. Kwoh, "Technological challenges of green innovation and sustainable resource management with large scale data," *Technological Forecasting and Social Change,* vol. 144, pp. 361-368, 2019. https://doi.org/10.1016/j.techfore.2018.07.055
[37] V. E. Alvear-Puertas, Y. A. Burbano-Prado, P. D. Rosero-Montalvo, P. Tözün, F. Marcillo, and W. Hernandez, "Smart and portable air-quality monitoring iot low-cost devices in Ibarra City, Ecuador," *Sensors,* vol. 22, no. 18, p. 7015, 2022. https://doi.org/10.3390/s22187015
[38] O. Á. J. Mendieta and Á. P. Garrochamba, "Design of a WSN for monitoring CO2 in the air and noise levels in the city of Loja," *Maskay,* vol. 10, no. 1, pp. 20-31, 2020. https://doi.org/10.24133/maskay.v10i1.1522

[39] J. Veneros, L. García, E. Morales, V. Gómez, M. Torres, and F. López-Morales, "Application of remote sensors for the analysis of vegetation cover and bodies of water," *Idesia (Arica),* vol. 38, no. 4, pp. 99-107, 2020. http://dx.doi.org/10.4067/S0718-34292020000400099

[40] R. Soni, M. Soni, and D. P. Shukla, *Emerging techniques and materials for water pollutants detection. In: Pooja, D., Kumar, P., Singh, P., Patil, S. (Eds.), Sensors in Water Pollutants Monitoring: Role of Material. Advanced Functional Materials and Sensors*. Singapore: Springer. https://doi.org/10.1007/978-981-15-0671-0_15, 2020, pp. 277-297.

[41] D. A. H. Fakra, D. A. S. Andriatoavina, N. A. M. N. Razafindralambo, A. K. Amarillis, and J. M. M. Andriamampianina, "A simple and low-cost integrative sensor system for methane and hydrogen measurement," *Sensors International,* vol. 1, p. 100032, 2020. https://doi.org/10.1016/j.sintl.2020.100032

[42] N. Varela-Ledesma and P. L. Romero-Suárez, "Information system for drought risk management in Camagüey, Cuba," *Tecnología y Ciencias Del Agua,* vol. 10, no. 6, pp. 243-260, 2019. https://doi.org/10.24850/j-tyca-2019-06-10

[43] O. Córdova, V. Venturini, and E. Walker, "Monitoring of droughts in El Salvador through remotely detected variables using the Google Earth Engine platforme," *Revista de Teledetección,* no. 55, pp. 93-103, 2020.

[44] E. F. Pozo and L. G. Luna, "Tools for drought monitoring and control: A meta-analysis in context," *Agua y Territorio/Water and Landscape,* no. 22, pp. 229-250, 2023. https://doi.org/10.17561/AT.22.7045

[45] W. Wei, J. Zhang, L. Zhou, B. Xie, J. Zhou, and C. Li, "Comparative evaluation of drought indices for monitoring drought based on remote sensing data," *Environmental Science and Pollution Research,* vol. 28, pp. 20408-20425, 2021.https://doi.org/10.1007/s11356-020-12120-0

[46] A. Kikon and P. C. Deka, "Artificial intelligence application in drought assessment, monitoring and forecasting: A review," *Stochastic Environmental Research and Risk Assessment,* vol. 36, no. 5, pp. 1197-1214, 2022. https://doi.org/10.1007/s00477-021-02129-3

[47] R. Muñoz-Carpena, A. Carmona-Cabrero, Z. Yu, G. Fox, and O. Batelaan, "Convergence of mechanistic modeling and artificial intelligence in hydrologic science and engineering," *PLOS Water,* vol. 2, no. 8, p. e0000059, 2023.https://doi.org/10.1371/journal.pwat.0000059

[48] J. A. Bellido-Jiménez, J. Estévez, and A. P. García-Marín, "A regional machine learning method to outperform tempera-ture-based reference evapotranspiration estimations in Southern Spain," *Agricultural Water Management,* vol. 274, p. 107955, 2022. https://doi.org/10.1016/j.agwat.2022.107955

[49] A. Tsatsaris *et al.*, "Geoin-formation technologies in support of environmental hazards monitoring under climate change: An extensive review," *ISPRS International Journal of Geo-Information,* vol. 10, no. 2, p. 94, 2021. https://doi.org/10.3390/ijgi10020094

[50] L. M. Agudelo-Otálora, W. D. Moscoso-Barrera, L. A. Paipa-Galeano, and C. Mesa-Sciarrotta, "Comparison of physical and artificial intelligence models for flood level prediction," *Tecnología y Ciencias Del Agua,* vol. 9, no. 4, pp. 209-235, 2018. https://doi.org/10.24850/j-tyca-2018-04-09

[51] R. U. R. Flores, R. T. A. Santos, I. A. Valdovinos, and V. R. Licea, "Electronic design of the early warning system for flood monitoring and detection," *Difu100ci@, Revista De Difusión Científica, Ingeniería y Tecnologías,* vol. 16, no. 3, pp. 50-57, 2022.

[52] E. Rafiei-Sardooi, A. Azareh, B. Choubin, A. H. Mosavi, and J. J. Clague, "Evaluating urban flood risk using hybrid method of TOPSIS and machine learning," *International Journal of Disaster Risk Reduction,* vol. 66, p. 102614, 2021. https://doi.org/10.1016/j.ijdrr.2021.102614

[53] M. Eini, H. S. Kaboli, M. Rashidian, and H. Hedayat, "Hazard and vulnerability in urban flood risk mapping: Machine learning techniques and considering the role of urban districts," *International Journal of Disaster Risk Reduction,* vol. 50, p. 101687, 2020. https://doi.org/10.1016/j.ijdrr.2020.101687

[54] M. Ma *et al.*, "Flash flood risk analysis based on machine learning techniques in the Yunnan Province, China," *Remote Sensing,* vol. 11, no. 2, p. 170, 2019. https://doi.org/10.3390/rs11020170

[55] B. T. Pham *et al.*, "Flood risk assessment using hybrid artificial intelligence models integrated with multi-criteria decision analysis in Quang Nam Province, Vietnam," *Journal of Hydrology,* vol. 592, p. 125815, 2021. https://doi.org/10.1016/j.jhydrol.2020.125815

[56] S. Saravi, R. Kalawsky, D. Joannou, R. M. Casado, G. Fu, and F. Meng, "Use of artificial intelligence to improve resilience and preparedness against adverse flood events," *Water,* vol. 11, no. 5, p. 973, 2019. https://doi.org/10.3390/w11050973

[57] U. Iqbal, P. Perez, W. Li, and J. Barthelemy, "How computer vision can facilitate flood management: A systematic review," *International Journal of Disaster Risk Reduction,*vol. 53, p. 102030, 2021.

[58] J. J. Flores-Cueto, R. M. Hernández, and R. G. Argandoña, "Information technologies: Internet access and digital divide in Peru," *Revista Venezolana de Gerencia: RVG,* vol. 25, no. 90, pp. 504-527, 2020.

[59] J. E. Groce, M. A. Farrelly, B. S. Jorgensen, and C. N. Cook, "Using social-network research to improve outcomes in natural resource management," *Conservation Biology,* vol. 33, no. 1, pp. 53-65, 2019. https://doi.org/10.1111/cobi.13127

[60] L. N. V. Leyva, M. E. Morocho Vargas, and E. E. Espinoza Freire, "Educational technology for teaching geography," *Conrado,* vol. 17, no. 82, pp. 465-472, 2021.

[61] M. E. Borja, M. M. Pérez, and R. R. Luna, "Benefits offered by big data management in government institutions in the era of digitalization," *Revista La Propiedad Inmaterial,* vol. 30, p. 93, 2020. https://doi.org/10.18601/16571959.n30.04

[62] Z. Hu *et al.*, "Cloud–edge cooperation for meteorological radar big data: A review of data quality control," *Complex & Intelligent Systems,* vol. 8, no. 5, pp. 3789-3803, 2022. https://doi.org/10.1007/s40747-021-00581-w

[63] M. Agovino, M. Casaccia, M. Ciommi, M. Ferrara, and K. Marchesano, "Agriculture, climate change and sustainability: The case of EU-28," *Ecological Indicators,* vol. 105, pp. 525-543, 2019. https://doi.org/10.1016/j.ecolind.2018.04.064

[64] P. M. Pujar, U. M. Kulkarni, R. M. Kulkarni, and H. H. Kenchannavar, *Internet of Things-based disaster management system. In Nanotechnology-Based Smart Remote Sensing Networks for Disaster Prevention*. Elsevier. https://doi.org/10.1016/B978-0-323-91166-5.00011-2, 2022.

[65] B. Dale, "Alliances for agroecology: From climate change to food system change," *Agroecology and Sustainable Food Systems,* vol. 44, no. 5, pp. 629-652, 2020. https://doi.org/10.1080/21683565.2019.1697787

[66] M. R. Sloggy, J. F. Suter, M. R. Rad, D. T. Manning, and C. Goemans, "Changing climate, changing minds? The effects of natural disasters on public perceptions of climate change," *Climatic Change,* vol. 168, pp. 1-26, 2021. https://doi.org/10.1007/s10584-021-03242-6

[67] T. Plieninger, J. Muñoz-Rojas, L. E. Buck, and S. J. Scherr, "Agroforestry for sustainable landscape management," *Sustainability Science,* vol. 15, pp. 1255-1266, 2020. https://doi.org/10.1007/s11625-020-00836-4

[68] J. Martínez-Valderrama, E. Guirado, and F. T. Maestre, "Can desertification be mapped? Lights and shadows of a challenging task," *Ecosistemas,* vol. 30, no. 3, pp. 2211-2211, 2021.https://doi.org/10.7818/ECOS.2312

[69] A. Mohan, A. K. Singh, B. Kumar, and R. Dwivedi, "Review on remote sensing methods for landslide detection using machine and deep learning," *Transactions on Emerging Telecommunications Technologies,* vol. 32, no. 7, p. e3998, 2021. https://doi.org/10.1002/ett.3998

[70] S. N. Topp, T. M. Pavelsky, D. Jensen, M. Simard, and M. R. Ross, "Research trends in the use of remote sensing for inland water quality science: Moving towards multidisciplinary applications," *Water,* vol. 12, no. 1, p. 169, 2020. https://doi.org/10.31223/osf.io/b9wrq

[71] M. C.-T. Tai, "The impact of artificial intelligence on human society and bioethics," *Tzu-Chi Medical Journal,* vol. 32, no. 4, pp. 339-343, 2020. https://doi.org/10.4103/tcmj.tcmj_71_20

[72] A. Xu, H. Chang, Y. Xu, R. Li, X. Li, and Y. Zhao, "Applying artificial neural networks (ANNs) to solve solid waste-related issues: A critical review," *Waste Management,* vol. 124, pp. 385-402, 2021. https://doi.org/10.1016/j.wasman.2021.02.029

[73] V. V. Tran, D. Park, and Y.-C. Lee, "Indoor air pollution, related human diseases, and recent trends in the control and improvement of indoor air quality," *International Journal of Environmental Research and Public Health,* vol. 17, no. 8, p. 2927, 2020. https://doi.org/10.3390/ijerph17082927

[74] A. M. De Oca and G. Flores, "The AgriQ: A low-cost unmanned aerial system for precision agriculture," *Expert Systems with Applications,* vol. 182, p. 115163, 2021. https://doi.org/10.1016/j.eswa.2021.115163

[75] D. J. Frame *et al.*, "Climate change attribution and the economic costs of extreme weather events: A study on damages from extreme rainfall and drought," *Climatic Change,* vol. 162, pp. 781-797, 2020. https://doi.org/10.1007/s10584-020-02729-y

[76] K. Bellomo, M. Angeloni, S. Corti, and J. von Hardenberg, "Future climate change shaped by inter-model differences in Atlantic meridional overturning circulation response," *Nature Communications,* vol. 12, no. 1, p. 3659, 2021. https://doi.org/10.1002/essoar.10504664.3

[77] R. Marsooli, N. Lin, K. Emanuel, and K. Feng, "Climate change exacerbates hurricane flood hazards along US Atlantic and Gulf Coasts in spatially varying patterns," *Nature Communications,* vol. 10, no. 1, p. 3785, 2019. https://doi.org/10.1038/s41467-019-11755-z