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Review Article

Climate Change-Related Natural Disasters: Environmental Effects and Sustainable Monitoring

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Abstract

Disasters are unanticipated, abrupt, dramatic events that cause significant damage. Serious issues arise during post-disaster crisis management as a result of the inadequate planning that preceded the disasters that our nation has suffered in the past. Ensuring sustained monitoring with an understanding that concentrates resource use prior to the disaster and prioritizes risk avoidance is crucial for reducing the environmental harm caused by disasters. International cooperation, rational environmental policies and sustainable monitoring are necessary to increase disaster resilience in the face of a changing climate. Before, during, or after a disaster, the present situation can be monitored using satellite technology or remote sensing (RS) techniques. While the geographic information systems (GIS) offer an appropriate framework for integrating and analyzing the different types of data sources required for disaster monitoring, they may also be utilized to provide baseline data against which future changes can be compared.

Keywords
Natural Disaster
Climate Change
Sustainable
Monitoring
GIS
Remote Sensing

İklim Değişikliğine Bağlı Doğal Afetler: Çevresel Etkileri ve Sürdürülebilir İzleme

Özet

Afetler büyük kayıplarla birlikte ortaya çıkan ani, dramatik, planlanmamış olaylardır. Ülkemizde önceki yıllarda yaşanan afetler öncesi yeterli hazırlığın yapılmamasından dolayı afet sonrası yapılan kriz yönetimi sırasında önemli sorunlarla karşılaşılmaktadır. Afetlerin çevresel zararının azaltılması amacıyla kaynakların kullanımını afet öncesine odaklayan ve risklerin azaltılmasına öncelik veren bir anlayış ile sürdürülebilir izlemenin sağlanması büyük önem taşımaktadır. Uluslararası işbirliği, akılcı çevre politikaları ve sürdürülebilir izleme, değişen iklim karşısında afet dirençliliğini artırmak için gereklidir. Afet öncesinde, sırasında ve sonrasında mevcut durum uydu teknolojisi veya uzaktan algılama (UA) teknikleri kullanılarak takip edilebilmektedir. Coğrafi bilgi sistemleri (CBS), afet izleme için gerekli olan farklı veri kaynaklarının entegrasyonu ve analizi için uygun bir çerçeve sunarken, aynı zamanda gelecekteki değişikliklerin karşılaştırılabileceği temel verileri sağlamak için de kullanılabilir.

Anahtar Kelimeler
Doğal Afetler
İklim Değişikliği
Sürdürülebilir
İzleme
CBS
Uzaktan Algılama

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1. INTRODUCTION

The frequency and severity of natural disasters, such as hurricanes, wildfires, floods, and droughts, have dramatically increased globally in recent years. The Earth's atmosphere is being altered by human activity, leading to climate change, which is responsible for these escalating catastrophic disasters. A substantial body of information derived from scientific investigations on this topic suggests that climate instability and global warming are making natural disasters more severe [1].

The lives of millions of people are negatively affected every year due to increasing natural disasters around the world, especially as a result of climate change. The United Nations has established common goals to determine the ability to prevent or reduce the consequences of natural disasters and to establish guidelines for the application of existing knowledge and technology to disaster mitigation operations, with the aim of promoting global cooperation in combating disaster damage, especially in poor countries [2].

In this article, which reviews the current literature, an evaluation has been made on disaster-oriented sustainable management using certain monitoring tools of climate change, natural disasters and their effects on the environment. In addition to endangering infrastructure and human life, natural disasters—which are made worse by climate change—can seriously and irreversibly affect the ecosystem. Events like hurricanes, floods, and wildfires have a significant impact on the environment, changing ecosystems and changing landscapes. The intricate web of effects that these disasters can cause is thoroughly examined in this paper, which highlights the pressing need for sustainable measures to lessen the effects that disasters can have on the ecosystem.

2. CLIMATE CHANGE AND DISASTERS

There are two possible causes of climate change: human activity and natural phenomena. Climate change has the potential to significantly affect civilization in a number of ways, including changes in growing seasons and water availability, rising sea levels in coastal areas, agricultural areas affected by increased frequency of flooding events, and river deltas affected by both [3-6].

Some of the disasters that fall under the category of natural disasters have limited human participation and are caused by external natural factors. Some examples of these kinds of natural disasters are meteorological and geophysical events [7]. The categories of disasters according to two factors—natural forces and human involvement—are shown in Figure 1.

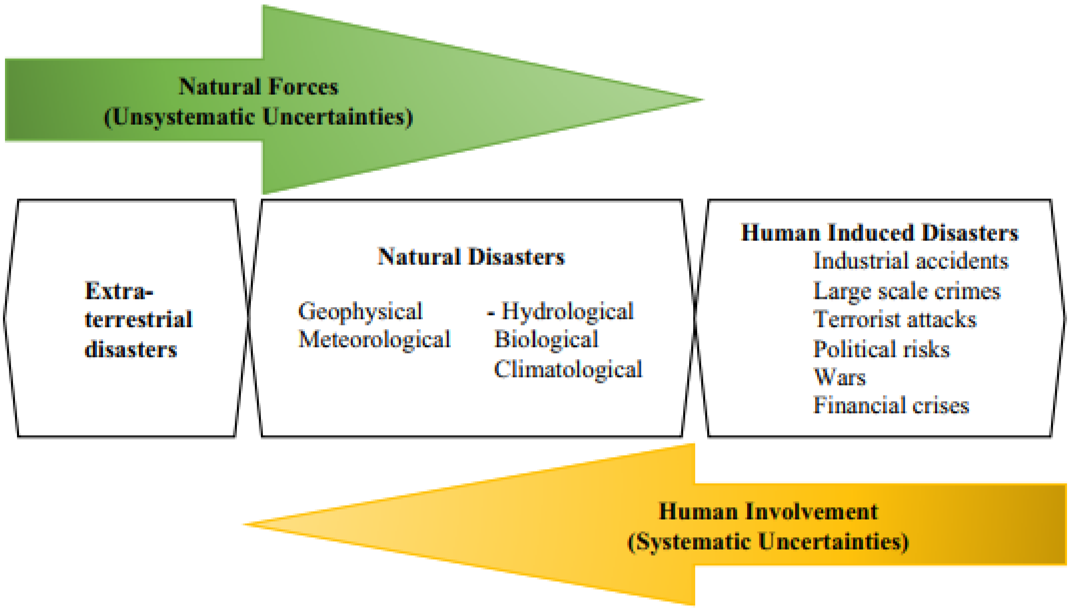

Figure 1. Disaster types and human involvement [7]

Floods are occurring more frequently and with greater intensity due to altered rainfall patterns and glacier melting. Coastal and low-lying locations are particularly vulnerable to flooding, which can have long-term socioeconomic repercussions, force population displacement, and destroy infrastructure. Flood-prone areas are particularly vulnerable to the consequences of climate change due to the combined effects of sea level rise and severe rainfall events [8].

Sea levels are rising as a result of the Arctic and Antarctic ice sheets melting more quickly, according to studies. Living spaces near the seaside now have a greater chance of experiencing flooding in the near future. Extreme sea level events are predicted to occur much more frequently, according to meteorological forecasts. The effects go beyond places close to the coast; they also have an impact on the delicate balance of marine ecosystems and worldwide weather patterns [9].

Hurricane and typhoon effects are further amplified by storm surges due to sea level rise, which is worsened by melting polar ice and expanding saltwater as it warms. Particularly susceptible to these variations are coastal regions, which can result in extensive floods, destruction of infrastructure, and saline infiltration of freshwater sources. One major problem for vulnerable coastal communities is adapting to rising sea levels [10].

2.1. Environmental Impacts of Disasters

2.1.1. Deforestation and Wildfires

Mass deforestation can result from wildfires, which are frequently made worse by extended droughts and rising temperatures. Deforestation also damages delicate ecosystems and reduces biodiversity. Forest fires occur more frequently as a result of warming temperatures and protracted droughts. Unprecedented wildfires, ruined ecosystems, destroyed habitats, and enormous emissions of carbon dioxide into the sky have all affected areas like California and Australia. Comprehensive methods to mitigate and adapt to these changing conditions are urgently needed, as demonstrated by the intricate interplay between wildfires and climate change [1, 11].

2.1.2. Soil Erosion and Landslides

Storms and tropical cyclones can produce heavy rainfall that can cause landslides and severe soil erosion. In addition to causing the loss of productive topsoil, this can also be dangerous for the quality of the water since eroded soil particles can enter bodies of water and create sedimentation [12].

2.1.3. Water Contamination and Marine Ecosystems

Pollutants from urban and industrial regions wash into rivers and oceans, causing floodwater from hurricanes and significant rainfall events to contribute to water pollution. This has an impact on fish populations and coral reefs, posing a serious threat to marine ecosystems [13].

2.1.4. Coral Bleaching and Rising Sea Temperatures

It is possible for corals to progressively lose their natural color due to rising water temperatures, which are made worse by climate change and made worse by instances like heat waves. This process lowers the resilience of coastal ecosystems, damages marine biodiversity, and weakens coral reefs [14].

Hurricanes that are stronger can arise as a result of warming waters. The energy available for these storms can increase as sea surface temperatures rise, creating larger and more deadly hurricanes. The scale of the growing threat is demonstrated by the destruction left behind by storms like Harvey, Irma, and Maria in recent years. Hurricanes are becoming more frequent and intense, which has an impact not just on coastal regions but also on the global economy and human population [15].

2.1.5. Habitat Fragmentation and Wildlife Displacement

Natural disasters disrupt ecosystems, resulting in the fragmentation of habitats and the displacement of wildlife. Animals must either adapt to new surroundings or deal with the difficulties posed by a declining supply of habitat [16].

2.1.6. Air Quality and Respiratory Health

As a result of massive particulate matter and hazardous gas emissions during wildfires, the burning of vegetation lowers air quality. Particularly for vulnerable groups, this presents serious health hazards, including the potential for respiratory issues and other difficulties [17].

2.1.7. Groundwater Depletion and Droughts

Groundwater resources are depleted as a result of droughts, which get worse as a result of climate change. Long-term water scarcity impacts ecosystems that rely on groundwater for nourishment as well as populations. Water supplies, agriculture, and ecosystems are all at risk due to long-term droughts brought on by rising temperatures and shifting precipitation patterns. There are significant implications for food security and human well-being from the acute water scarcity that is being experienced by areas like the American Southwest, the Mediterranean, and portions of Africa. Innovative water management techniques and resilient agricultural practices are necessary given the connection between drought and climate change [18, 19].

2.1.8. Defaunation and Ecological Imbalance

Loss of vegetation and degradation of ecosystems due to natural disasters lead to the decline and extinction of animal populations. This leads to an ecological imbalance that affects pollination, seed dispersal and other important ecological processes [20].

2.1.9. Soil Salinization and Storm Surges

Soil salinization can result from the release of salt water into coastal soils by storm waves linked to tropical cyclones. As a result, the soil is unfit for farming, and the establishment of coastal vegetation is hampered [21].

2.1.10. Persistent Organic Pollutants and Industrial Disasters

Persistent organic pollutants (POPs) can leak from industrial facilities that are destroyed during natural disasters. These facilities are frequently situated in vulnerable coastal areas. These substances pose a long-term risk to human health and ecosystems as they build up in the environment [22].

2.2. Disaster Resilience and Sustainable Monitoring Tools

The United Nations has included promoting socio-economic resilience, reducing social and organizational vulnerability to disasters, and addressing climate change in the Sustainable

Development Goals, acknowledging the seriousness of the threat posed by natural hazards. There is a pressing need to implement comprehensive action plans in response to the increasing frequency and severity of natural disasters brought on by climate change. In order to save habitats and ecosystems from looming dangers, mitigation initiatives to lower greenhouse gas emissions must be complemented with sensible adaptation techniques. To increase resilience in the face of a changing climate, international cooperation, well-informed policymaking, and sustainable behaviors are crucial [7, 23].

Preventive actions are needed to lessen the effects of natural and man-made catastrophes on ecosystems and populations, making disaster resilience a crucial component of sustainable development. Real-time data and educated decision-making are made possible by sustainable monitoring tools, which are essential for improving disaster resilience. Smith et al. (2021) have noted that the integration of comprehensive monitoring systems that span environmental, social, and economic data is necessary for effective catastrophe resilience [24]. By using these methods, authorities can reduce the negative consequences on human and environmental systems by anticipating future disasters, assessing vulnerabilities, and implementing timely remedies.

Using cutting-edge technologies in early warning and monitoring systems is a crucial component of disaster resilience. For example, by giving precise and timely information on changes in climatic conditions, satellite technology and remote sensing greatly reduce the chance of disaster. As stated by Chen et al. (2020), "satellite-based monitoring tools enhance the ability to detect and monitor changes in land cover, vegetation health, and climatic patterns, enabling a more proactive response to potential disasters" [25]. With data-driven decision-making, this technological integration not only improves post-disaster recovery efforts but also helps with disaster preparedness.

Disaster resilience also requires community involvement, and sustainable monitoring systems are critical to promoting community engagement. By giving communities easily available and comprehensible information, real-time monitoring systems empower communities to take an active role in catastrophe risk reduction. Gonzalez et al. (2019), who contend that "empowering communities with monitoring tools fosters a sense of ownership and responsibility, contributing to the overall resilience of the community" [26], underline the importance of this participatory approach. Therefore, sustainable monitoring methods improve the efficacy of catastrophe resilience plans by acting as a link between scientific data and local knowledge.

Research and innovation must be prioritized if sustainable monitoring instruments are to continue to advance. Sustained research and multidisciplinary cooperation are essential for improving these instruments' capacities and guaranteeing their applicability in a world that is changing all the time. According to Wang and Li (2022), "sustainable monitoring tools should be adaptive and responsive to emerging challenges, requiring ongoing research efforts to improve their precision, scope, and applicability" [27]. Stakeholders may increase catastrophe resilience measures and ultimately construct more resilient and sustainable communities by allocating resources towards research and development.

2.3. Environmental Impact Assessment with a Disaster Focus

A variety of methods, such as the application of geoinformatics techniques, have been used to evaluate the possible effects of climate change on coastal wetlands. In order to evaluate the possible effects of climate change, geographic information and remote sensing (RS) techniques are applied. A geographic information system (GIS) is a computer system that consists of hardware, software, and data that enables the user to combine various types of information as long as the data share a similar geographic location [28].

Recent advances in computer-assisted technology have greatly aided in the development of models used in hazard analysis and flood calculation. GIS is utilized to undertake risk or vulnerability analysis, hazard assessment, and flood phenomena visualization in 1D, 2D, or 3D. The model results can be verified by remote sensing by comparing the area inundated by flooding. Because they may be obtained at any time and in any weather, remote sensing images are utilized as basis maps for flooded areas [29].

Rainfall data has historically served as the basis for a number of operational indicators used in drought monitoring and assessment. These indexes are frequently not comfortably understood by decision makers and are not readily available. A typical method for obtaining the required data is to apply climatic drought indicators, like the Palmer Drought Monitoring Index, which has been extensively utilized by the U.S. Department of Agriculture. Standardized Precipitation measure (SPI), created by McKee et al. (1993), is another well-liked climatic drought measure that can provide information about emerging dry months for use in regional and worldwide contexts [30-32].

In order to acquire current environmental data at both the local and synoptic levels for climate change studies, RS is a necessary instrument. To find CO_2 sources and sinks on land and in the ocean, scientists are now employing satellite equipment. However, when it comes to integrating dispersed field-based observations with remotely sensed data, geographic information systems (GIS) play a critical role in environmental monitoring and modeling [33, 34].

3. CONCLUSION

Understanding the wide-ranging consequences of natural disasters on the ecosystem is essential to living resiliently and sustainably. As the frequency and intensity of disasters grow due to climate change, proactive measures to mitigate their effects on the environment are critical for protecting the environment and ensuring the well-being of future generations.

The study results are summarized as follows:

- The ramifications of soil erosion extend beyond the recent calamity, impacting water resources and agricultural output for an extended period.

- The cumulative impact of drought on land and aquatic ecosystems highlights the interdependence of environmental systems and underscores the necessity of employing sustainable ways to detect the degree of drought emergency situations.

- It is evident how crucial it might be for sensitive areas to have strong disaster preparedness and security measures in place after natural disasters. This amount of stress on wildlife populations has the potential to cause an ecological balance to be disrupted and a reduction in species variety.

- Fires can have an impact on air quality over a region in addition to the immediate affected areas. The aftermath of wildfires extends beyond the immediate affected areas, impacting air quality on a regional scale.

- One of the most significant environmental issues that arise following natural disasters is the financial impact on coastal communities that heavily rely on agriculture. Natural catastrophes have both direct and indirect expenses, which result in post-disaster secondary costs. Secondary expenses have an impact on public revenues, employment, consumption, national income, production, and the procurement of raw materials for rehabilitation in addition to economic growth.

- In the short term, natural disasters have a negative impact on employment, economy, and inflation. The costs of publicly supported disasters, as well as initiatives for mitigation and prevention, place a heavy load on the budget's meager resources.

- Today, GIS and Remote Sensing (RS) are widely used in disaster management and planning studies and data analysis. Making the best choices requires carefully considering urban growth/expansion and density considerations using geographic information systems (GIS).

Countries change or postpone their development programs due to disasters. The integration and processing of data from various sources, including RS, GIS, and monitoring of environmental consequences related to disasters, is an ongoing and effective process in disaster management research in our country. Geographic Information System and Remote Sensing are utilized not only for mapping disasters but also for several tasks and procedures that need to be completed both before and after the disasters. These tools are rapidly becoming indispensable tools for mitigating the risk of future disasters and averting damages.

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