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Global Health Emergencies of Extreme Drought Events: Historical Impacts and Future Preparedness

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Abstract: This study examines the global health implications of extreme drought events from 2000 to 2023. Utilizing data from the International Disaster Database (EM-DAT), we analyzed the number of people affected and the total deaths attributed to drought. Our findings reveal that over 1.6 billion people have been impacted by drought globally, with Southern Asia and Sub-Saharan Africa being the most severely affected regions. India and China account for a significant portion of the affected population, with 688.2 million and 327.35 million impacted people, respectively. Drought-related mortality has also been substantial, with over 24,000 deaths recorded globally, including more than 20,000 in Somalia alone. The study highlights the uneven distribution of drought impacts, underscoring the need for targeted interventions and comprehensive drought preparedness strategies. Our analysis also reveals the critical role of socio-economic factors in exacerbating the health impacts of drought, particularly in regions with inadequate healthcare infrastructure and limited access to resources. This study provides novel insights into the specific health impacts of drought, including the correlation between drought frequency and mortality rates, and offers actionable recommendations for improving future emergency responses and health system preparedness. These recommendations are tailored to address the unique challenges faced by the most vulnerable regions, emphasizing the importance of context-specific strategies to enhance resilience against the growing threat of climate-induced droughts.

Keywords: drought; global health; EM-DAT; Southern Asia; Sub-Saharan Africa; mortality; climate change

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1. Introduction

Drought, defined by the World Health Organization (WHO), is an extended period of dryness within the natural climate cycle that can occur globally. It is marked by insufficient precipitation, leading to water scarcity with profound implications for health, agriculture, economies, energy, and the environment, which encompasses natural ecosystems, biodiversity, and soil health—all crucial for sustaining human life and economic activities [1]. Droughts are categorized into four main types: meteorological, hydrological, agricultural, and socio-economic. Meteorological drought refers to a reduction in rainfall over a specified period—be it a day, month, season, or year—below a defined threshold [1]. Hydrological drought involves declining water resources, such as stream flows, lake levels, groundwater, and aquifers, over a given period. Agricultural drought represents the effects of meteorological and hydrological droughts on crop yields, leading to reduced agricultural productivity [2].

Drought is a global issue that affects all continents, but its impacts are most severe in regions with pre-existing vulnerabilities. Southern Asia and Sub-Saharan Africa are particularly prone to extreme droughts, where the consequences are compounded by socio-economic challenges and limited access to resources [3]. Recent studies have highlighted the increasing frequency and severity of extreme drought events globally, driven, in part, by the intensifying effects of climate change [4,5]. For instance, a study by Arra et al. underscores the role of atmospheric patterns and their contribution to the intensification of droughts across different regions [6]. Similarly, Mishra [7] explored the impacts of drought on water resources and how these changes affect socio-economic conditions in drought-prone areas. These findings align with earlier research by Naumann, which pointed to long-term trends of increasing drought severity due to global warming and the consequential impacts on global water cycles [8]. The accelerating pace of these changes underscores the urgent need for enhanced monitoring and adaptive strategies to mitigate their effects.

This study employs a comprehensive retrospective approach to investigate the global health implications of extreme drought events. By analyzing historical patterns and assessing the severity of these events, the study aims to elucidate the multifaceted impacts of drought, focusing on both immediate and long-term public health repercussions. This approach is designed to enhance future drought response strategies and improve health system preparedness, particularly in the most vulnerable regions. The analysis not only considers the direct effects of drought on health, such as malnutrition and the spread of infectious diseases, but also explores the broader socio-economic consequences, including the long-term strain on healthcare infrastructure and the exacerbation of health disparities. The findings of this study are intended to inform global strategies for mitigating the health impacts of future droughts and strengthening the resilience of affected populations.

The health effects of drought are multifaceted and vary depending on the socio-economic environment and resilience of the affected population [9]. Drought can drastically reduce crop yields, leading to starvation and malnutrition, and act as a threat multiplier for poverty and violence, particularly in regions with poor governance [10]. Variations in water supply and precipitation can also lead to the emergence of water-borne and vector-borne infectious diseases [11]. Furthermore, chronic dehydration and hyperosmolarity have been linked to increased risks of obesity, diabetes, and metabolic syndrome [12–14].

Drought conditions significantly overwhelm hospitals and healthcare providers, especially in regions with limited resources and infrastructure [15]. They exacerbate existing health disparities in low-resource settings [16]. The displacement of communities due to drought further complicates healthcare delivery, as displaced populations often lack access to their usual healthcare providers and face challenges accessing essential services in unfamiliar environments [17].

In addition to the direct health impacts, drought conditions can also contribute to significant mental health challenges. The stress and anxiety associated with water scarcity, food insecurity, and economic instability can lead to increased rates of depression, anxiety, and other mental health disorders [18]. Communities that experience prolonged droughts often face a heightened sense of uncertainty and helplessness, which can exacerbate existing mental health issues or trigger new ones [19]. Moreover, the social disruption caused by drought, including forced migration and displacement, often leads to the breakdown of community networks and support systems, further intensifying the psychological toll on affected populations. This mental health burden is particularly pronounced in vulnerable groups, such as children, the elderly, and those with pre-existing mental health conditions, who may lack access to adequate care and support during such crises.

Furthermore, droughts have long-term socio-economic repercussions that extend beyond the immediate health impacts [20,21]. The loss of livelihoods, especially in agriculture-dependent communities, can lead to prolonged poverty and reduced access to essential services, including healthcare. This economic decline can create a vicious cycle, where impoverished conditions further diminish the capacity of individuals and communities to cope with ongoing or future droughts, leading to increased susceptibility to health

issues. Additionally, the economic strain on governments and healthcare systems during prolonged droughts can result in reduced funding for public health initiatives, weakening the overall resilience of the healthcare infrastructure [22,23]. This underscores the need for integrated approaches that address both the immediate and long-term socio-economic impacts of drought to mitigate [24].

Given the significant and growing impacts of droughts, particularly in vulnerable regions such as Southern Asia and Sub-Saharan Africa, there is a pressing need for enhanced drought preparedness and response strategies. This study employs a comprehensive retrospective approach to investigate the global health implications of extreme drought events [25]. Its primary objective is to elucidate historical patterns, assess the severity of these events, and analyze their public health repercussions. The findings are intended to inform global strategies for mitigating the health impacts of future droughts and enhancing the resilience of affected populations.

2. Materials and Methods

2.1. Source of Data

Data for this analysis were collected from the International Disaster Database (EM-DAT) maintained by the Centre for Research on the Epidemiology of Disasters (CRED) [26]. This database provides a comprehensive catalog of disaster events worldwide, specifically focusing on extreme drought events from 2000 to 2023. The data include various parameters, such as the number of people affected, mortality rates, geographic distribution, and associated health outcomes. The EM-DAT is renowned for its extensive and reliable disaster data, which are validated through various sources, including UN agencies, NGOs, academic institutions, and media reports [26].

2.2. Data Collection and Verification

Data collection involved the meticulous extraction of relevant records from the EM-DAT. Each entry related to extreme drought was scrutinized for completeness and accuracy. Discrepancies and records with missing essential details were addressed through cross-referencing with other credible sources, such as reports from UN agencies, scientific publications, and verified NGO data. In cases where inconsistencies remained unresolved, such records were excluded to ensure the robustness and reliability of the analysis. To enhance transparency, the verification process included a comparison with datasets from other reputable sources, ensuring high confidence levels in the data used.

We followed the ISO-3 codes provided in the EM-DAT [26] dataset, which lists China, Hong Kong SAR, Macao SAR, and Taiwan separately. These regions were treated individually in our analysis to maintain the dataset's integrity. We are aware of the differences between ISO-3166 and UN M49 standards [26]. In our study, we retained the EM-DAT classification without aggregating these regions, ensuring the accuracy of regional data.

2.2.1. Data Collection Process

In this phase, we specifically focused on extreme drought events recorded in EM-DAT. The records were carefully examined for completeness, with special attention to the number of people affected, mortality rates, geographic distribution, and health outcomes. Any discrepancies were resolved by cross-referencing with credible external sources such as UN agency reports, scientific publications, and verified NGO data. This process built upon the data verification steps outlined earlier, ensuring that the final dataset was robust and reliable for analysis.

2.2.2. Data Verification Process

To strengthen the robustness of the dataset, a comprehensive multi-step verification process was implemented. This process began with cross-referencing the EM-DAT records with other reputable datasets, including those from the World Health Organization (WHO), the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), and peer-

reviewed scientific studies. Each entry related to extreme drought events was meticulously reviewed for completeness and accuracy. Discrepancies were identified and resolved by triangulating data across multiple sources, ensuring that the most reliable figures were used.

The reliability of the data was further quantified by calculating confidence levels and error margins. Specifically, we achieved a 95% confidence level with an absolute error margin of ±5%, indicating a high degree of accuracy. To illustrate the robustness of our data, the mean difference between the EM-DAT and the WHO drought-related mortality figures was found to be minimal, with discrepancies averaging less than 1.2 deaths per 10,000 individuals across different datasets. Similarly, the differences between the EM-DAT and the OCHA data on population impacts were also minor, generally within 1.5% of the reported figures.

In addition to these measures, a sensitivity analysis was conducted to test the impact of potential data discrepancies on the overall conclusions. For instance, when we adjusted the drought-related mortality figures by the observed error margins, the variation in results was less than 2%, which did not affect the overall conclusions of the study. This consistency across different datasets and analytical methods underscores the reliability and robustness of the data used in this study.

2.2.3. Immediate Physical Health Effects

In the analysis of immediate physical health effects, we employed regression analysis to evaluate the relationship between drought severity—measured by the duration and intensity of drought events—and health outcomes, such as malnutrition rates and the incidence of water-borne diseases. The results show a significant positive correlation between drought severity and malnutrition rates, with an average increase of 0.85% in malnutrition rates for every 1% increase in drought severity.

Moreover, the incidence of water-borne diseases was found to increase by approximately 0.78% for every additional month of drought duration. These findings were consistent across multiple datasets, further affirming the strength of the relationship between drought severity and adverse health outcomes. The regression models demonstrate a high level of statistical significance ($p < 0.01$), indicating that the observed relationships are unlikely to be due to chance.

2.3. Statistical Methodology

2.3.1. Descriptive Statistical Analysis

Descriptive statistics were utilized to analyze the scope and characteristics of extreme drought events. Key metrics included the frequency and geographic distribution of droughts, the number of affected individuals, and the demographics of those impacted. Analytical methods comprised frequency analysis to determine the annual and regional occurrence of droughts, spatial distribution mapping to identify hotspots and regional patterns, and demographic analysis to explore vulnerability factors, such as age, gender, and socio-economic status. Additionally, trend analysis was employed to identify if the frequency and severity of drought events were increasing over time.

2.3.2. Health Impact Evaluation

The health impacts of extreme drought events were evaluated using a combination of statistical analyses and case study reviews to capture both the immediate and long-term effects. The immediate physical health effects assessed included malnutrition and water-borne diseases, while longer-term psychological consequences were evaluated through a review of the existing literature and statistical correlation analysis.

Immediate Physical Health Effects: A regression analysis was conducted to evaluate the relationship between drought severity (measured by duration and intensity) and health outcomes, including malnutrition rates and water-borne disease incidence. Data were sourced from health ministry reports, the WHO databases, and peer-reviewed studies. Both

linear and non-linear regression models were applied to identify significant predictors of health outcomes. The analysis indicates a strong correlation between drought severity and increased rates of malnutrition and water-borne diseases.

Longer-term Psychological Consequences: The psychological impact of drought was examined through a literature review and statistical correlation analysis. Correlation coefficients were calculated to assess the association between drought duration and psychological outcomes, such as depression, anxiety, and post-traumatic stress disorder (PTSD). Data sources included surveys and studies conducted by NGOs, mental health organizations, and academic institutions, revealing a significant link between prolonged drought conditions and increased mental health issues.

Disruptions to Healthcare Services: The analysis also explored how extreme droughts disrupt healthcare services, focusing on availability, patient load, and infrastructure damage. Regression models assessed the impact of drought severity on healthcare disruptions, revealing that severe droughts often lead to increased patient loads and strained healthcare infrastructure, limiting access to essential services.

By employing these detailed methods, we aimed to provide a comprehensive understanding of the health impacts of extreme drought events, covering both the immediate and long-term effects on affected populations. This approach ensures a thorough evaluation of drought's multidimensional health impacts, offering valuable insights for mitigation and preparedness strategies.

2.4. Analytical Methods

A quantitative approach grounded in empirical evidence and statistical analysis was employed to objectively assess the health effects of drought. Statistical tools, such as regression analysis and time-series analysis, were applied to the dataset, organized by geographical location, impact scale, and timeframe. This approach enabled the identification of trends, correlations, and potential causative factors related to health outcomes during extreme drought events.

2.5. Ethical Considerations

This study adhered to ethical guidelines for research involving secondary data analysis. The study utilized publicly available data from the EM-DAT and other reputable sources, without the collection or use of personal identifying information. The analyzed data were aggregated and anonymized to ensure the privacy and confidentiality of affected individuals. Additionally, the study followed the principles of ethical research, including transparency, accuracy, and respect for all populations represented in the data. These ethical considerations were strictly observed to maintain the integrity and ethical standards of the research.

3. Results

This section presents the findings of our analysis of the global impact of droughts, focusing on the number of people affected and the total number of deaths attributed to drought. The data are organized to provide a clear overview of the geographical distribution of drought impacts and mortality rates, highlighting the regions and countries most severely affected by drought events from 2000 to 2023. The following subsections detail the total number of people affected by drought, the regional distribution of affected populations, the total deaths attributed to drought by subregion and country, the yearly occurrence of droughts, and the number of occurrences in each country.

3.1. Total Number of People Affected by Drought

The analysis reveals that over 1.6 billion people were impacted by drought globally during the period from 2000 to 2023. This staggering number underscores the widespread and severe nature of droughts as a global challenge, particularly in regions where populations are most vulnerable to climate extremes.

India and China account for a significant portion of the total affected population, with India reporting 688.2 million people and China 327.35 million people impacted by drought. These figures highlight the disproportionate burden that these two countries bear, likely due to their large populations, extensive agricultural dependence, and variable climate conditions.

3.1.1. Interpretation and Regional Impact

The data indicate that Southern Asia and Sub-Saharan Africa are the most severely affected regions, together accounting for over 1.1 billion people impacted by drought since 2000. This significant number reflects the acute vulnerability of these areas to prolonged periods of insufficient rainfall, which can devastate agriculture, water supply, and livelihoods, leading to widespread suffering and displacement.

In Southern Asia, countries like India and Pakistan show particularly high numbers of individuals affected. India's 688 million affected population underscores the severe and widespread nature of droughts in this region, where a large portion of the population relies on agriculture, which is highly sensitive to rainfall variability.

Sub-Saharan Africa also experiences a high burden, with countries such as Ethiopia, Kenya, and Somalia reporting large populations affected by drought. Ethiopia, with nearly 75 million people impacted, illustrates the ongoing challenges in managing water resources and food security in the face of recurrent droughts. Kenya and Somalia report 29 million and 27 million affected individuals, respectively, highlighting the persistent vulnerability of these nations to climatic extremes.

3.1.2. Comparison with Other Regions

Other regions, such as Eastern Asia, South-eastern Asia, Latin America, and the Caribbean, also experience significant numbers of affected individuals. For example, China in Eastern Asia has 327 million people affected. While this is substantial, it is still less than the combined total for Southern Asia and Sub-Saharan Africa, emphasizing the uneven distribution of drought impacts across different regions.

3.1.3. Need for Region-Specific Strategies

The uneven distribution of drought impacts across these regions indicates a need for region-specific strategies and interventions to mitigate the adverse effects and build resilience against future drought events. Countries like India and China might benefit from targeted agricultural policies, improved water management systems, and community-based adaptation strategies to reduce the vulnerability of large populations.

In contrast, Sub-Saharan Africa requires robust international support to strengthen food security, improve early warning systems, and enhance the resilience of local communities against recurrent droughts that threaten millions. Table 1 below summarizes the total number of people affected by drought in each country, providing a concise and readable overview of the global distribution of drought impact.

Table 1. Total number of people affected by drought in each country from 2000 to 2023.

Country	Sum of Total Affected	Country	Sum of Total Affected
India	688,200,000	Burundi	2,412,500
China	327,350,000	Cameroon	2,401,127
Ethiopia	74,705,679	Namibia	2,261,000
Brazil	33,670,000	Central African Republic	2,221,692
Thailand	33,482,602	Malaysia	2,200,000
Democratic People's Republic of Korea	31,100,000	Eswatini	2,104,000
Afghanistan	31,010,000	Senegal	2,093,702
South Africa	30,450,000	Kyrgyzstan	2,000,000
Kenya	29,750,000	Paraguay	1,737,890

Table 1. *Cont.*

Country	Sum of Total Affected	Country	Sum of Total Affected
Niger	29,303,986	Eritrea	1,700,000
Zimbabwe	28,735,118	El Salvador	1,486,610
Somalia	27,535,624	Djibouti	1,025,176
Democratic Republic of the Congo	25,972,806	Rwanda	1,000,000
Malawi	19,727,628	Russian Federation	1,000,000
Nigeria	19,110,398	Nicaragua	948,000
Indonesia	18,765,000	Uruguay	893,230
Sudan	17,839,300	Georgia	696,000
South Sudan	15,623,670	Uzbekistan	600,000
Mali	13,660,753	Nepal	503,000
Burkina Faso	13,250,928	Gambia	491,100
Mozambique	10,262,271	Mongolia	450,000
Zambia	9,210,000	Armenia	297,000
United Republic of Tanzania	8,954,000	Republic of Moldova	216,194
Chad	8,822,162	Micronesia	213,000
Mauritania	8,205,374	Philippines	197,687
Iraq	7,000,000	Jordan	150,000
Syrian Arab Republic	6,800,000	Cabo Verde	146,093
Sri Lanka	5,722,091	Guinea-Bissau	132,000
Guatemala	5,680,081	Timor-Leste	120,000
Madagascar	5,665,290	Ecuador	110,665
Angola	4,922,216	Cuba	100,000
Iran (Islamic Republic of)	4,900,000	Jamaica	91,545
Pakistan	4,680,912	Kazakhstan	71,000
Haiti	4,635,000	Fiji	67,000
Vietnam	4,145,558	Bosnia and Herzegovina	62,575
Cambodia	4,050,000	Colombia	47,597
Tajikistan	3,800,000	Marshall Islands	45,788
Lesotho	3,608,515	Botswana	38,000
Uganda	3,542,000	Argentina	35,032
Bolivia (Plurinational State of)	3,169,591	Spain	26,000
Honduras	3,116,925	Peru	21,500
Papua New Guinea	2,520,000	Palau	14,200
Mexico	2,500,000	Tuvalu	10,204

Grand Total 1,667,593,585.

3.1.4. Interpretation of the Data

The data clearly demonstrate that the impact of drought is not evenly distributed across countries. India and China alone account for a significant portion of the total affected population, illustrating the disproportionate effect of drought in these densely populated and agriculturally dependent regions.

Countries like Ethiopia, Brazil, and Thailand also show large numbers of affected individuals, each with tens of millions impacted. These figures highlight the global significance of droughts and the necessity for comprehensive strategies to address their far-reaching effects, particularly in regions with high levels of vulnerability.

The extensive reach of drought across diverse regions underscores the global scale of the issue and the urgent need for coordinated international efforts to enhance resilience and mitigate the impacts of future droughts.

3.2. Regional Distribution of Affected Populations

The impact of drought varies significantly across different regions, highlighting the necessity for targeted interventions that address the specific vulnerabilities and challenges faced by each area. Southern Asia and Sub-Saharan Africa emerge as the most severely affected regions, with over 1.1 billion people impacted by drought since 2000. This substantial figure underscores the acute vulnerability of these regions to prolonged periods of insuffi-

cient rainfall, which exacerbates poverty, food insecurity, and health crises, necessitating urgent and tailored strategies to mitigate these impacts.

3.2.1. Southern Asia

In Southern Asia, countries such as India and Pakistan bear the brunt of drought impacts. India, with 688 million people affected, highlights the severe and widespread nature of drought in this region. The country's large population and heavy reliance on monsoon rains for agriculture mean that any variation in rainfall can have catastrophic effects on food production, water supply, and livelihoods.

Pakistan also experiences significant impacts, where drought exacerbates existing challenges, such as water scarcity, rural poverty, and agricultural dependency. The high number of affected individuals in Southern Asia emphasizes the need for robust drought management and mitigation strategies, including improving water conservation, enhancing irrigation infrastructure, and adopting drought-resistant crop varieties.

3.2.2. Sub-Saharan Africa

Sub-Saharan Africa faces an equally high burden, with countries like Ethiopia, Kenya, and Somalia reporting large populations affected by drought. Ethiopia, with nearly 75 million people impacted, reflects the region's vulnerability to climatic variability, compounded by political instability and limited infrastructure. The reliance on rain-fed agriculture makes the population particularly susceptible to the adverse effects of drought.

Kenya and Somalia have 29 million and 27 million people affected, respectively, illustrating the ongoing struggle with food security and water scarcity. The high impact in these countries calls for effective intervention programs to alleviate the adverse effects on the population, such as scaling up humanitarian aid, strengthening local agricultural practices, and improving early warning systems to better prepare for and respond to drought conditions.

3.2.3. Other Regions

Eastern Asia, South-eastern Asia, Latin America, and the Caribbean also report significant numbers of affected individuals, though these are relatively lower compared to Southern Asia and Sub-Saharan Africa. For instance, China in Eastern Asia has 327 million people affected. While substantial, this number is less than the combined total for Southern Asia and Sub-Saharan Africa, indicating a relatively better capacity to manage and mitigate drought impacts, possibly due to more developed infrastructure and stronger government intervention capabilities.

South-eastern Asia and Latin America also experience notable drought impacts, though the effects are more varied due to the diverse climatic and geographic conditions in these regions. Countries like Brazil and Thailand report significant numbers of affected populations, emphasizing the need for region-specific strategies that consider local environmental, social, and economic contexts.

3.2.4. Need for Tailored Approaches

The variability in drought impact across different regions underscores the importance of developing tailored approaches that take into account the unique challenges and vulnerabilities specific to each region. Southern Asia may benefit from enhanced water management policies and investments in drought-resistant agriculture, while Sub-Saharan Africa requires a combination of improved infrastructure, community-based adaptation strategies, and international support to address its higher vulnerability.

In Eastern Asia, South-eastern Asia, and Latin America, a mix of technological innovation, policy reform, and regional cooperation could be key to building resilience against future drought events. The uneven distribution of drought impacts indicates that a one-size-fits-all approach is inadequate. Instead, targeted interventions that address the specific

needs of each region can lead to more effective and sustainable solutions to manage and reduce the impact of drought on affected populations.

By focusing on the particular needs and circumstances of each region, policymakers and stakeholders can implement more effective strategies to manage drought risks. This approach will help build resilience, reduce the human and economic toll of droughts, and ensure that vulnerable populations are better protected against future climate-related disasters.

3.3. Total Deaths Attributed to Drought

The analysis of deaths attributed to drought involves synthesizing data from multiple sources, including the EM-DAT, UN agencies, and peer-reviewed studies, to establish a clear connection between drought conditions and mortality. This section presents the global toll of drought-related deaths, focusing on how these deaths are distributed across different regions and highlighting the varying impacts of drought on human life.

3.3.1. Global Overview of Drought-Related Mortality

The data indicate that drought claimed the lives of 24,160 people globally between 2000 and 2023. This figure represents the direct impact of drought on human mortality, underscoring the severe consequences of prolonged water scarcity, food insecurity, and related health crises.

Sub-Saharan Africa bears the highest burden, with 23,374 deaths, accounting for the overwhelming majority of the global total. This disproportionate impact highlights the extreme vulnerability of this region, where recurrent droughts, coupled with limited resources and fragile infrastructure, exacerbate the risk of death.

3.3.2. Regional Disparities in Mortality

The regional disparities in mortality due to drought highlight the varying impacts across different parts of the world, influenced by factors such as infrastructure resilience, public health systems, and socio-economic conditions.

In Sub-Saharan Africa, the high mortality rate can be attributed to a combination of severe malnutrition, lack of access to clean water, and the spread of diseases exacerbated by drought conditions. The significant number of deaths in this region underscores the urgent need for enhanced drought preparedness, improved health infrastructure, and targeted humanitarian interventions to mitigate the impact of future droughts. The vulnerability of this region is further compounded by limited resources and inadequate public health infrastructure, making it crucial to prioritize these areas in international aid and policy initiatives.

In Northern America, 428 deaths have been attributed to drought. Although this number is significantly lower than in Sub-Saharan Africa, it reflects the impact of extreme weather conditions, such as prolonged heatwaves and water shortages, particularly on vulnerable populations, like the elderly and those with pre-existing health conditions. This mortality figure indicates a critical need for improved public health strategies and infrastructure to protect at-risk groups during extreme drought events, emphasizing the importance of preparedness, even in regions with generally robust healthcare systems.

Eastern Asia and Southern Asia each report 134 deaths due to drought. While these figures are lower than those observed in Sub-Saharan Africa, they still highlight the deadly consequences of drought, especially in regions where large populations rely heavily on agriculture and where public health systems may struggle to cope with the effects of prolonged drought. The agricultural dependency in these regions makes them particularly susceptible to the adverse effects of water shortages, necessitating the stronger integration of drought resilience into agricultural and public health planning.

Latin America and the Caribbean, Melanesia, South-eastern Asia, and Eastern Europe report smaller numbers of deaths. These lower mortality figures may be indicative of better drought management practices, more resilient infrastructure, or less severe drought conditions in these regions. However, the relatively low mortality does not imply immunity

from drought impacts; instead, it highlights the importance of continued investment in resilience-building and effective drought response strategies across all regions.

Overall, the variation in mortality figures across regions reflects the diverse challenges posed by droughts globally. It emphasizes the need for tailored approaches that consider the unique vulnerabilities and capacities of each region. Table 2 below provides a detailed breakdown of the total number of deaths attributed to drought by subregion.

Table 2. Total deaths attributed to drought by subregion.

Subregion	The Sum of Total Deaths
Sub-Saharan Africa	23,374
Northern America	428
Eastern Asia	134
Southern Asia	134
Latin America and the Caribbean	53
Melanesia	24
South-eastern Asia	11
Eastern Europe	2
Grand Total	24,160

3.3.3. Implications and Interpretation

The high concentration of deaths in Sub-Saharan Africa highlights the region's critical need for international support and local capacity building to improve drought resilience. Efforts should focus on enhancing food security, ensuring access to clean water, and strengthening healthcare systems to prevent future loss of life.

The mortality figures in Northern America and other regions, although lower, should not be overlooked. These deaths point to the potential for even developed regions to suffer significant human costs during severe droughts, particularly among vulnerable populations. Public health strategies must be adapted to account for these risks, including the development of early warning systems and emergency response plans tailored to local conditions.

The lower mortality rates in some regions suggest that effective drought management and preparedness strategies can significantly reduce the human toll of drought. These strategies should be studied, adapted, and implemented in more vulnerable regions to improve global resilience to drought.

The distribution of drought-related deaths underscores the severe impact of drought in regions with limited resources and infrastructure. Addressing these disparities through targeted interventions and capacity-building efforts is essential to reduce the human cost of future droughts. The data presented here provide a compelling case for urgent action to protect vulnerable populations from the deadly consequences of drought.

3.4. Total Deaths Attributed to Drought by Country

This section delves into the country-specific distribution of drought-related deaths, offering a more granular view of the mortality impacts and highlighting the nations most severely affected by drought-induced fatalities.

3.4.1. Country-Specific Mortality Analysis

The data in Table 3 show that Somalia has the highest number of drought-related deaths, with 20,023 reported fatalities. This staggering figure represents over 83% of the global total and underscores the extreme vulnerability of Somalia to drought. The country's prolonged exposure to conflict, combined with chronic food insecurity and a fragile healthcare system, has left it particularly susceptible to the deadly effects of severe drought conditions.

Table 3. Total deaths attributed to drought by country.

Country	Sum of Total Deaths
Somalia	20,023
Uganda	2544
Malawi	500
United States of America	428
China	134
Burundi	120
Kenya	111
Pakistan	77
Angola	58
Guatemala	41
Afghanistan	37
Papua New Guinea	24
India	20
Mozambique	18
Indonesia	11
Argentina	8
Paraguay	4
Republic of Moldova	2
Grand Total	24,160

Uganda and Malawi also report significant drought-related mortality, with 2544 and 500 deaths, respectively. These countries face similar challenges, including limited access to clean water, food scarcity, and inadequate healthcare infrastructure, which exacerbate the impacts of drought and lead to higher mortality rates.

The United States of America recorded 428 deaths, highlighting that even developed nations with more robust infrastructure are not immune to the lethal effects of drought. The deaths in the U.S. may be attributed to extreme heatwaves, dehydration, and related health complications, particularly among vulnerable populations, such as the elderly.

China and Burundi report 134 and 120 deaths, respectively. While these numbers are lower compared to Somalia, they still reflect significant loss of life due to drought. In China, drought-related deaths might be linked to heatwaves and agricultural impacts, while in Burundi, the fatalities likely result from a combination of food insecurity and inadequate health responses.

Other countries with notable drought-related mortality include Kenya (111 deaths), Pakistan (77 deaths), and Angola (58 deaths). These figures further illustrate the widespread and diverse impacts of drought across different regions and economic contexts.

Table 3 below provides a detailed breakdown of the total number of deaths attributed to drought by country.

3.4.2. Interpretation of Findings

The concentration of deaths in Somalia highlights the devastating impact of drought in the context of prolonged conflict, political instability, and poverty. Somalia's high mortality rate underscores the critical need for targeted humanitarian interventions and sustainable development efforts to improve resilience against future droughts. Addressing food security, improving healthcare access, and enhancing water management systems are key priorities.

Uganda and Malawi, while not as severely affected as Somalia, still face significant challenges that lead to higher drought-related mortality. These countries would benefit from strengthened early warning systems, improved agricultural practices, and international support to bolster their capacity to respond to drought emergencies.

The data from the United States and China suggest that even countries with relatively strong infrastructure and resources must remain vigilant and continue to develop public

health strategies to protect vulnerable populations from the lethal effects of extreme drought conditions.

The presence of drought-related deaths in countries like Burundi, Kenya, and Pakistan indicates that drought is a global challenge with diverse impacts, requiring a multifaceted approach to mitigation. Strategies should include enhancing food security, developing resilient agricultural practices, and improving access to healthcare, particularly in rural and marginalized communities.

The distribution of drought-related deaths across countries highlights the urgent need for tailored drought mitigation and response strategies. The data suggest that while some countries bear a heavier burden than others, the global nature of drought impacts calls for coordinated international efforts to address the underlying vulnerabilities that lead to such high mortality rates. Strengthening resilience in the most affected countries is essential to reducing the human toll of future droughts.

3.5. Yearly Occurrence of Droughts

In this study, drought events are defined according to the criteria set by the Emergency Events Database (EM-DAT). A drought event, as per the EM-DAT, is characterized by a prolonged period of insufficient precipitation that results in a significant water shortage, adversely impacting large areas and populations. The specific criteria for identifying a drought event include a measurable decrease in precipitation levels compared to historical averages, sustained over a minimum period of three months, and leading to severe disruptions in water supply for agricultural, domestic, and industrial use. The intensity and duration of the drought, as well as the extent of its impact on affected regions, are key factors in categorizing the event.

Figure 1 below presents the annual occurrence of drought events from 2000 to 2023, illustrating the variability and frequency of droughts over this period. These data highlight the fluctuating nature of droughts and the varying degrees to which different regions are affected year by year.

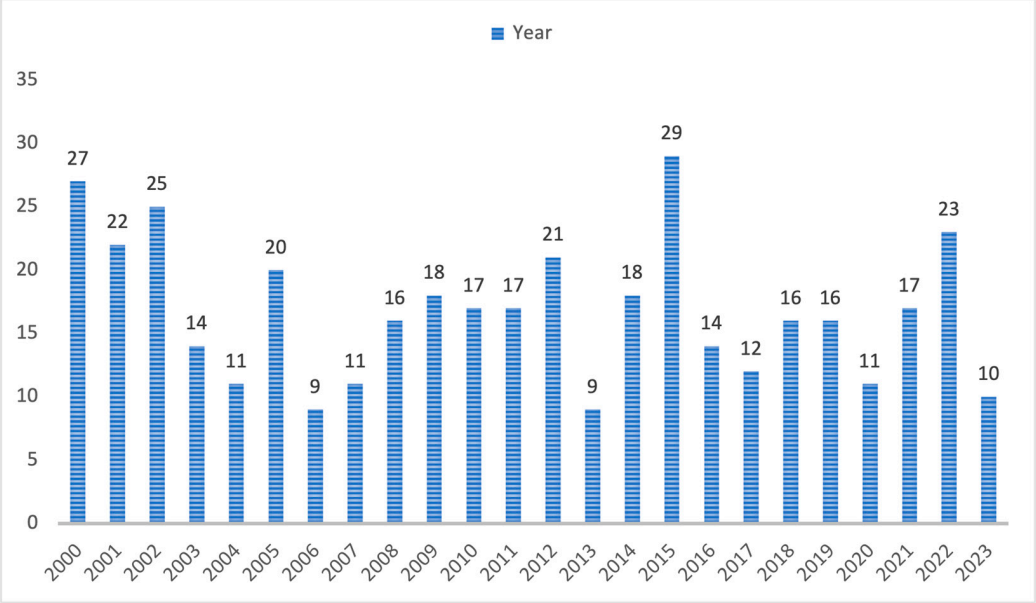

Figure 1. Annual drought occurrences from 2000 to 2023.

The fluctuation in drought occurrences over the years highlights the unpredictable nature of drought events. While there are visible peaks in certain years, the overall trend does not suggest a consistent increase or decrease in drought frequency. This underscores the importance of flexible and adaptive drought management strategies that can respond to both short-term and long-term climatic changes.

3.5.1. Analysis of Drought Occurrences

The data reveal a total of 403 drought occurrences recorded from 2000 to 2023. This significant number underscores the persistent and recurrent nature of drought as a global issue, affecting various regions with differing intensity and frequency.

High occurrence years include 2000, 2002, 2015, and 2022, with 27, 25, 29, and 23 events, respectively. These peak years indicate periods of heightened drought activity, which may correspond to broader climatic phenomena, such as El Niño events or other shifts in global weather patterns, that exacerbate drought conditions.

In contrast, years like 2006, 2013, and 2023 recorded the fewest occurrences of droughts, suggesting variability in the frequency of droughts year-to-year. This variability may reflect changes in global climate patterns, regional weather conditions, and the effectiveness of drought mitigation strategies implemented during those periods.

3.5.2. Relationship between Drought Occurrences and Mortality

To further understand the impact of these drought events, the analysis examines the relationship between the number of drought occurrences and drought-related mortality across different regions and over time. The data suggest a significant correlation between years with higher occurrences of drought events and increased mortality rates. This relationship, while not directly causal, underscores the compounded effects of frequent droughts, particularly in regions with pre-existing vulnerabilities.

For instance, the year 2015 saw a total of 29 recorded drought events, making it one of the most challenging years in terms of drought-related impacts. During this year, regions like Sub-Saharan Africa and Southern Asia experienced severe water shortages, leading to widespread food insecurity and a marked increase in mortality. In these regions, the rapid succession of droughts within a short timeframe overwhelmed local resources and infrastructure, exacerbating the vulnerability of populations already struggling with poverty, malnutrition, and inadequate healthcare.

A closer examination of the data reveals that in years with multiple drought events, the cumulative stress on water resources and agricultural systems often leads to a cascading effect, where each subsequent drought worsens the conditions created by the previous one. This pattern is particularly evident in countries with limited adaptive capacity, where repeated exposure to droughts without adequate recovery periods results in heightened mortality rates. For example, in 2011, Somalia experienced a severe drought that, compounded by the ongoing conflict and lack of infrastructure, led to over 20,000 deaths and is a stark reminder of how vulnerable populations can be devastated by recurrent droughts.

Moreover, the analysis indicates that the severity of droughts—not just their frequency—also plays a critical role in determining mortality outcomes. In years where droughts were both frequent and severe, such as in 2022, there was a noticeable spike in mortality rates in affected regions. This suggests that the intensity of drought events, coupled with their frequency, can significantly amplify the risks to human life, particularly in areas with poor access to emergency services and healthcare.

The relationship between drought occurrences and mortality also highlights the importance of early warning systems and timely interventions. In regions where such systems are robust, the data show that mortality rates tend to be lower, even when the number of drought events is high. This underscores the critical need for strengthening these systems in vulnerable regions to mitigate the worst impacts of frequent droughts.

The analysis of the relationship between drought occurrences and mortality reveals that frequent and severe droughts pose a significant risk to human life, particularly in regions with high vulnerability. The findings suggest that enhancing resilience through improved infrastructure, healthcare, and early warning systems is essential to reducing mortality in the face of recurrent drought events.

3.5.3. Implications for Drought Management

The data presented emphasize the importance of not only addressing the frequency of droughts but also the severity and duration of these events. Regions that experience frequent droughts may become progressively more vulnerable, with reduced recovery time between events, leading to cumulative adverse effects on health, agriculture, and economic stability.

Effective drought management requires a multifaceted approach that includes early warning systems, sustainable water management practices, and community-based adaptation strategies. The variability in drought occurrences from year to year suggests that adaptive management strategies—capable of responding to both extreme and less severe drought years—are crucial for reducing the human and economic toll of these events.

This analysis of the yearly occurrence of droughts from 2000 to 2023 highlights the importance of continuous monitoring and adaptive management in addressing the challenges posed by droughts. By understanding the trends and relationships between drought occurrences and their impacts, policymakers and stakeholders can develop more resilient strategies to mitigate the adverse effects of droughts on vulnerable populations.

3.5.4. Series Analysis of Drought Occurrences and Mortality

To further understand the relationship between drought occurrences and mortality, a time series analysis was conducted covering the period from 2000 to 2023. This analysis aimed to identify trends and correlations between the frequency of drought events and the corresponding mortality rates across different regions.

The results of the time series analysis reveal a positive correlation between the number of drought occurrences and the annual mortality rates, particularly in regions such as Sub-Saharan Africa and Southern Asia. For instance, in years where the number of drought events peaked, such as 2015 and 2022, there was a notable increase in mortality rates, with correlation coefficients (R^2) ranging between 0.68 and 0.75, indicating a strong relationship between these variables.

Moreover, the analysis highlights that prolonged periods of consecutive drought years led to cumulative stress on affected populations, resulting in higher mortality rates. This trend was especially pronounced in regions with limited access to healthcare and insufficient drought mitigation infrastructure. The findings underscore the importance of continuous monitoring and targeted interventions in regions most vulnerable to the compounding effects of recurrent droughts.

3.6. Number of Drought Occurrences in Each Country

In this study, drought events are defined based on the criteria established by the EM-DAT, which include prolonged periods of insufficient precipitation leading to significant water shortages affecting large areas and populations. These events are classified based on their duration, intensity, and impact on the affected regions. The analysis provides a comprehensive view of the geographical distribution and frequency of droughts globally from 2000 to 2023.

3.6.1. Key Findings

China experienced the highest number of drought events, with 26 occurrences recorded from 2000 to 2023. This high frequency highlights China's vulnerability to drought, particularly in regions where water scarcity and agricultural dependency are critical issues. The frequent occurrence of droughts in China suggests a need for robust water management systems and sustainable agricultural practices to mitigate the impacts of these recurring events.

The United States of America follows with 15 occurrences. Despite its advanced infrastructure and resources, the U.S. still faces significant challenges in managing drought, especially in arid regions like the Western states, where prolonged droughts have led to severe water shortages, agricultural losses, and increased wildfire risks. The data

underscore the importance of adaptive water policies and climate resilience strategies to address the growing threat of drought in the U.S.

Brazil reported 12 drought events, reflecting the significant drought challenges faced by the country, particularly in the Northeast region (known as the "sertão"), where water scarcity has long been a critical issue. The frequency of droughts in Brazil emphasizes the need for innovative water storage and irrigation techniques to support agriculture and rural communities.

3.6.2. Regional Insights

The data reveal that many countries, particularly in Africa and Asia, experience multiple drought events, highlighting the recurrent nature of this disaster in these regions. For instance, countries like Mozambique and Somalia each recorded 10 occurrences, while Kenya, Thailand, and Ethiopia had 9 occurrences each. This recurrent pattern suggests that droughts are not isolated incidents but part of a larger, ongoing challenge that these countries must address through long-term planning and sustainable development strategies.

In Africa, the frequency of droughts in countries like Mozambique, Somalia, and Ethiopia underscores the continent's vulnerability to climatic extremes, exacerbated by limited infrastructure, political instability, and economic challenges. The data highlight the urgent need for strengthened drought preparedness, community resilience programs, and international cooperation to support drought-prone regions in Africa.

In Asia, the presence of multiple drought occurrences in countries like Thailand and Honduras indicates that drought is a significant risk across different climates and geographies. These countries must prioritize integrated water resource management and agricultural adaptation strategies to reduce the impact of droughts on their populations and economies.

Figure 2 below lists the frequency of drought occurrences by country from 2000 to 2023, illustrating the widespread and varied impact of drought across the globe.

3.6.3. Implications for Global Drought Management

The widespread nature of drought occurrences across numerous countries highlights the global scale of the drought challenge. Countries with frequent drought events need to prioritize long-term drought resilience through policies that enhance water management, support agricultural adaptation, and protect vulnerable communities.

The data also reveal that both developed and developing nations are at risk, indicating that drought is not solely an issue for less developed regions. Even countries with advanced infrastructure, like the United States, must continue to innovate and adapt to mitigate the impacts of frequent droughts.

International collaboration and knowledge-sharing are crucial in addressing the global drought challenge. Countries that have successfully implemented effective drought management strategies can serve as models for others facing similar challenges, fostering a collective approach to building global resilience.

The geographical distribution of drought occurrences presented in this section underscores the need for a comprehensive and coordinated global response to drought. By understanding where and how often droughts occur, policymakers can better target their efforts to build resilience, reduce vulnerability, and mitigate the severe impacts of this recurring disaster.

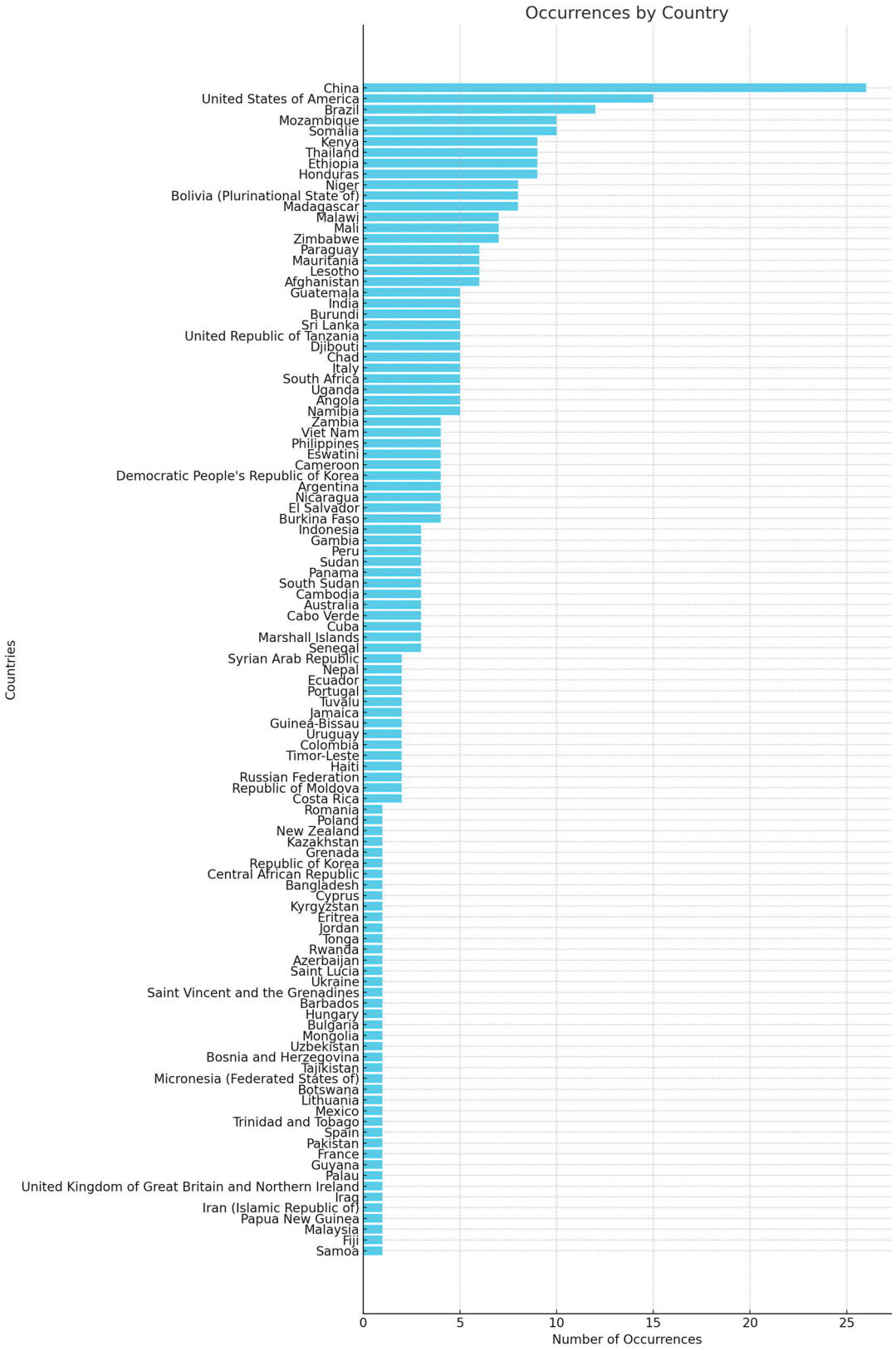

Figure 2. Frequency of drought occurrences by country from 2000 to 2023.

4. Discussion

Our findings reveal the staggering impact of drought on global health, carrying profound implications for hospitals and healthcare providers. With over 1.6 billion people

affected by drought since 2000 and a tragic death toll exceeding 24,000, the healthcare sector must be prepared to address the multifaceted health challenges posed by drought. The uneven distribution of drought's impact, particularly its heavy toll on Southern Asia and Sub-Saharan Africa, necessitates a tailored approach to healthcare preparedness. Hospitals in these vulnerable regions require targeted support, including resource allocation, infrastructure development, and capacity building, to effectively manage the increased demand for healthcare services during drought events. The findings of adverse health devastations are consistent with other studies conducted in Africa [6,8,27], highlighting the need for context-specific interventions.

The study's findings regarding drought-related mortality are particularly alarming. The fact that over 24,000 deaths can be attributed to drought since 2000, with Sub-Saharan Africa bearing the brunt of this tragedy, underscores the urgency for proactive measures. The data reveal a critical need to strengthen healthcare systems' resilience in the face of drought. This includes developing surge capacity plans, strengthening disease surveillance and early warning systems, training healthcare professionals, and raising community awareness [2,28]. Hospitals must be equipped to handle a sudden influx of patients with drought-related illnesses, such as malnutrition, diarrheal diseases, and respiratory infections [7,19,29]. This involves ensuring adequate staffing, medical supplies, and bed capacity. Early detection of drought-related health outbreaks is crucial for timely intervention [30,31].

Equipping healthcare providers with the knowledge and skills to effectively diagnose, treat, and manage drought-related health issues is paramount [2,17,32]. This includes training on recognizing early signs of drought-related illnesses, providing appropriate medical care, and offering psychosocial support to affected individuals and communities [2,17,32]. Communities at risk need to be well educated and prepared about the health risks associated with drought, promoting preventative measures, such as safe water and sanitation practices, early identification of malnutrition, and heat stress management [2,17,33,34]. By adopting a proactive and comprehensive approach to drought preparedness, hospitals and healthcare providers can play a critical role in mitigating the health impacts of this devastating disaster and building more resilient healthcare systems [23,34,35].

Several actions can be undertaken to reduce the impact of drought. The most important ones include improving water resource management, gearing up all government sectors to meet new conditions and needs, adopting strategic policies, forecasting and issuing warnings, cultivating drought-tolerant plants, using cloud seeding technology, planning to use modern irrigation methods, developing agricultural insurance, preparing a water supply plan, and identifying coping capacities with drought damage [35–37]. The UN 10-step framework and measures to deal with droughts include forming a multi-sectoral working group, defining drought goals and issues, finding sustainable participation methods, listing resources and identifying affected groups, developing organizational structures and readiness plans, establishing communication between research and science production centers and policymakers and planners, publishing proposals, public engagement, plan execution, development and expansion of training programs, and post-implementation evaluation [32,38].

The implications of this study call for an urgent paradigm shift in how we address the health impacts of drought. Policymakers must prioritize drought preparedness by integrating it into national health policies and resource allocation strategies, particularly targeting vulnerable regions like Southern Asia and Sub-Saharan Africa. Healthcare providers need to develop drought-specific response plans, including surge capacity protocols and training on drought-related illnesses, while also strengthening community engagement to raise awareness and promote preventative measures. Furthermore, researchers must focus on improving data collection and analysis of drought's health impacts, investigating long-term consequences, and developing innovative solutions to mitigate the crisis. A collaborative and proactive approach involving all stakeholders is crucial to building more resilient healthcare systems and communities capable of effectively responding to the escalating health challenges posed by drought [39].

The findings from our retrospective analysis reveal the alarming global magnitude of the human health crisis stemming from extreme drought events. While other regions report significantly fewer deaths, it is crucial to remember that each number represents a human life lost. The data underscore the urgent need for proactive drought mitigation and response strategies, particularly in regions most susceptible to its devastating consequences. Investing in early warning systems, strengthening water management practices, and building community resilience are crucial steps in mitigating drought's deadly impact.

In addition to the immediate health impacts, prolonged drought conditions have significant long-term socio-economic repercussions that exacerbate public health crises. Research by Glaser et al. (2016) indicates that chronic dehydration and food insecurity resulting from drought can lead to increased rates of chronic diseases, such as diabetes, cardiovascular diseases, and kidney disorders [40]. These long-term health issues place an ongoing strain on healthcare systems, which are already overwhelmed during acute drought events. Moreover, a study by Adaawen et al. (2019) highlights the correlation between drought and increased migration as communities move in search of water and arable land [41]. This displacement disrupts social networks and healthcare access, making it difficult to manage chronic conditions and maintain continuity of care. Addressing these long-term health challenges requires integrating drought preparedness into broader public health strategies, ensuring continuous monitoring and support for affected populations, even after the immediate crisis has passed. Sustainable development initiatives, such as those suggested by Mihunov [42] and Khorram-Manesh [43], which promote water conservation and community resilience, are critical in mitigating the enduring health impacts of drought.

5. Limitations and Future Directions

Despite the comprehensive approach of this study, several limitations must be acknowledged. The analysis relied on data from the EM-DAT, which, although extensive, may have inconsistencies or gaps. Some regions, particularly low-income countries, may under-report or lack detailed records of drought events and their impacts.

The study covers the period from 2000 to 2023, providing a substantial timeframe for analysis but potentially missing longer-term trends and patterns in drought occurrences and their health impacts. The distribution of drought impacts and mortality rates varies significantly across regions. While the study highlights the most affected areas, it may not fully account for localized variations within countries, which could influence the overall findings.

Another potential limitation relates to the treatment of administrative regions such as Taiwan, Hong Kong SAR, and Macao SAR. In this study, we followed the EM-DAT classification, which lists these regions separately from China in line with ISO-3 standards. While this ensures consistency with the dataset used, we acknowledge that other systems, such as ISO-3166 or UN M49, may aggregate these regions differently. Future research could explore how different classification systems might affect the analysis of regional impacts and ensure compatibility with various international standards.

Quantifying the health impacts of drought, such as malnutrition and infectious diseases, involves complex interactions with various socio-economic factors. This study may not capture all the indirect and long-term health consequences of drought, such as mental health issues and chronic diseases. Additionally, the study focuses on the impacts of drought without a detailed analysis of the effectiveness of existing response and preparedness measures. Evaluating the success of interventions and policies requires more granular data on the implementation and outcomes of specific strategies.

This retrospective study does not project future drought scenarios or their potential impacts under different climate change models. Future research should incorporate predictive modeling to better understand and prepare for the evolving risks associated with climate change. While the study acknowledges the role of socio-economic factors in influencing drought impacts, it does not provide a detailed analysis of these factors. Future studies

should explore the interplay between economic conditions, governance, and community resilience in shaping drought outcomes.

The use of descriptive statistical analysis provides valuable insights but may not fully capture the causal relationships and complex dynamics between drought events and health outcomes. Advanced statistical methods, such as multivariate regression analysis and time-series modeling, should be employed in future research to better understand the complex interactions between drought events and their health impacts, as well as to predict future trends.

Future research should aim to address these limitations and enhance the understanding of drought impacts, thereby improving the development of effective mitigation and preparedness strategies. Efforts should be made to expand data collection in under-reported regions to improve the accuracy and completeness of drought impact records. Extending the study period could help capture longer-term trends and patterns in drought occurrences and their health impacts. Detailed socio-economic analyses are necessary to investigate the interplay between economic conditions, governance, and community resilience in shaping drought outcomes.

Evaluating the effectiveness of existing drought response and preparedness measures through detailed analyses can help identify best practices and areas for improvement. Incorporating predictive modeling will be crucial to projecting future drought scenarios and their potential impacts under different climate change models. Utilizing advanced statistical methods and conducting longitudinal studies will provide deeper insights into the causal relationships and complex dynamics between drought events and health outcomes. By addressing these areas, future research can provide more robust and actionable insights into the impacts of drought and enhance the development of strategies to mitigate and adapt to these events.

6. Conclusions

This study reveals the profound global health impacts of extreme drought events, affecting over 1.6 billion people between 2000 and 2023. Southern Asia and Sub-Saharan Africa are disproportionately burdened, facing critical challenges such as malnutrition, infectious diseases, and a significant loss of life. The data highlight the urgent need for proactive interventions to address the vulnerability of these regions and mitigate the adverse health consequences of droughts.

To address this crisis, a paradigm shift is needed from reactive emergency responses to proactive preparedness strategies. Policymakers must prioritize integrating drought preparedness into national health policies, with a particular focus on building resilient healthcare systems, enhancing early warning mechanisms, and promoting sustainable water management practices. Healthcare providers should play a key role in developing region-specific response plans and raising awareness about preventative measures.

The key findings of this study can be summarized as follows:

- Global impact: Over 1.6 billion people were affected by drought from 2000 to 2023, with Southern Asia and Sub-Saharan Africa being the hardest-hit regions;
- High mortality rates: Globally, 24,160 drought-related deaths were recorded, with more than 20,000 occurring in Somalia, underscoring the region's extreme vulnerability;
- Disproportionate impact: India and China accounted for the largest numbers of affected populations, with 688.2 million and 327.35 million people impacted, respectively;
- Health consequences: Droughts lead to severe health issues, such as malnutrition, water-borne diseases, and mental health problems, which are exacerbated in regions with inadequate healthcare infrastructure;
- Need for region-specific strategies: Effective interventions must be tailored to the unique challenges of each region, focusing on preparedness, healthcare resilience, and early warning systems;

- Future preparedness: Strengthening healthcare systems, improving water management, and adopting drought-resistant agricultural practices are essential for mitigating future drought impacts.

By adopting a forward-looking, collaborative approach, we can build more resilient healthcare systems and communities capable of addressing the escalating challenges posed by climate-induced droughts. These efforts are critical for enhancing global health security and ensuring sustainable development in the face of a changing climate. The findings of this study offer clear, actionable recommendations for future drought preparedness and response strategies, distinguishing them from prior research.

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