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RESEARCH LETTER

Exploring EM-DAT for depicting spatiotemporal trends of drought and wildfires and their connections with anthropogenic pressure

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Abstract

In light of increasing extreme events driven by climate change, the relationship between drought and wildfire events and their impacts on society is of paramount importance, necessitating comprehensive studies to understand long-term trends. This manuscript utilizes the Emergency Events Database (EM-DAT) to gather data on drought and wildfire events, focusing on the number of affected people and human losses. The analysis covers the period from 1983 to 2022 and incorporates eco-hydro-socio-geographical variables such as gross domestic product (GDP), precipitation anomaly, population density, and forested area. The study reveals significant geographical disparities in the impacts of drought and wildfire. Asia stands out as the region most affected by these phenomena, with more than 72% of individuals experiencing their effects. In contrast, Europe and Oceania show negligible impacts, accounting for less than 1% collectively. When it comes to losses specifically caused by drought, Asia has the highest share at around 82%. Conversely, Oceania has the lowest share, with less than 0.1% of total losses attributed to drought. In the case of wildfires, Africa takes the lead with 84% of total losses. On the other hand, Oceania, Europe, Asia, and America collectively contribute only 16% to the total losses, which is considerably lower. Temporal analysis indicates an increasing trend in the number of people affected by both drought and wildfire, particularly after the early 2000s, potentially attributed to the improved reporting in EM-DAT. Correlation tests highlight the inverse relationship between GDP and the studied parameters, while precipitation anomaly exhibits an inverse correlation with wildfire-affected populations. Forested area significantly correlates with wildfire-related damages. These insights can inform policies and actions at various levels, from local to international, to address the challenges posed by climate-related disasters.

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1 Introduction

In recent decades, an increase in natural (e.g., floods, hurricanes, droughts) and technological disasters (e.g., hazardous material releases) has been observed by many researchers (e.g., Pescaroli et al. 2018; Shen and Hwang 2019; Sankaran et al. 2022). Such an increment has had significant consequences for millions of people all over the world. Indeed, many natural hazards, including meteorological, hydrological, and climatological events, may turn into disasters, resulting in physical impacts such as injuries, casualties, and property damages, as well as nonphysical effects like psychological, mental, and political wounds (Lindell 2013; Pescaroli et al. 2018). There is a growing body of literature showing that human injuries, causalities, and economic losses caused by natural hazards have been increasing over the past decades, mostly because of the intensification of human pressure on the natural environment (e.g., O'Keefe et al. 1976; Mileti 1999; Dewan 2013; Kelman 2020; Hamidifar and Nones 2023). Therefore, for appropriate disaster management, it is important to gain a better understanding of the key spatiotemporal scales at which natural hazards, and their drivers, have an impact, and what might be the correlations between such hazards (Pescaroli et al. 2018).

Among the various natural hazards, drought stands out as a particularly concerning phenomenon, and an in-depth exploration of its impacts is essential to comprehend its consequences. Drought is a climatic hazard that occurs in most world climates and can have considerable economic, societal, and environmental impacts (UNISDR 2015; Naumann et al. 2018, 2021). Drought, like other natural hazards, is driven by climate change and human pressure, but compared to other happenings like floods, events connected to such a phenomenon tend to be longer, sometimes in the order of years. Presently, there is various evidence proving that drought can be a major threat in the future, especially in the form of flash drought (Shah et al. 2022). To adequately tackle the increment of drought events, recognizable mainly at the regional scale (Dhawale et al. 2022; Shahdad and Saber 2022), more complex and long-lasting management strategies are needed (Sayers et al. 2017; Hall and Leng 2019). Like all natural hazards, droughts are complex multidimensional spatial–temporal events, and because of the diversity of geophysical variables needed to characterize droughts, as well as their consequences, such as wildfires, they are of a high level of importance.

Wildfire is another essential natural hazard that merits attention (Piñol et al. 1998). A comprehensive understanding of wildfire geographical distribution and impacts is crucial for effective disaster management and environmental preservation. Past investigations (Scasta et al. 2016; Ertugrul et al. 2019, 2021) have shown that, recently, different regions around the world were affected by an increment in wildfire size, extent, seasonality, and severity, which might relate to more prolonged drought periods driven by climate change. In this work, the authors investigated significant wildfire events that happened in 2003 and 2012, pointing out that such years were characterized by below-average precipitation and negative Palmer drought severity index values (namely, dry conditions). Such a result suggests that wildfires do not act independently of drought, but rather they interact with short-term weather and long-term climatic patterns that change over time.

There has been growing concern about the impact of climate change on wildfire events. For example, Marín et al. (2018) studied the relationship between drought and forest fires in Mexico from 2005 to 2015. They used georeferenced fire records and a multiscale drought index to identify four fire clusters in the study area and found that the peak in fire frequency occurred in 2011. Also, they assessed how fire activity related to the drought index for both the entire study period and 2011 specifically. Their study revealed a strong correlation between drought severity and forest fires in Mexico, particularly in the northern and central regions during the dry season. Investigating the temporal dynamics of forest fire in India by means of remote sensing methods, Srivastava and Garg (2013) demonstrated that, in this country, fires are positively correlated with the temperature and the dryness of the forested areas.

However, global warming is not the only cause of an increase in wildfires, as humans are generally the main drivers of such events. Focusing on a long-term investigation of wildfire events in the conterminous US, Strader (2018) pointed out that, in the period 1940–2010, wildfire exposure has increased substantially, mostly because of the escalating wildfire likelihood and an expanding human-developed footprint.

Wildfires can be triggered by a variety of natural and human-related factors such as lightning strikes (Chen and Jin 2022), human activities (Pozo et al. 2022), climate change (Mansoor et al. 2022), invasive species (Dennison et al. 2014), and forest management practices (Miezite et al. 2022). To address the problem of wildfire events, which are fostered by drought conditions, various strategies have been proposed, including fire suppression and prevention efforts, land management practices, and climate change mitigation measures. Fire suppression and prevention efforts involve reducing the risk of wildfires through measures such as prescribed burning, fuel reduction, and fire breaks (Jazebi et al. 2019; Bertomeu et al. 2022; Lambrechts et al. 2023). Management practices are generally developed for managing vegetation cover and reducing soil erosion to improve soil moisture retention (Mariani et al. 2022; van Leeuwen and Miller-Sabbioni 2023). Climate change mitigation measures involve reducing greenhouse gas emissions to limit the extent of global warming and its impact on drought conditions (Leverkus et al. 2022).

The spatiotemporal variations of the number of events and fatalities in different continents and regions around the world are also of importance when analyzing the relationship between drought and wildfire events. Fréjaville and Curt (2015) conducted a study examining the evolving patterns of fire activity and climate in the Mediterranean and mountain ecosystems of southeastern France over the period from 1973 to 2009. Their research unveiled dynamic fire–climate relationships that exhibited rapid variations across both space and time, likely influenced by shifts in regional land-use practices and fire management policies. However, there is a lack of comprehensive studies that investigate the long-term trends of both droughts and wildfires. To fill this knowledge gap, the present study focuses on using the Emergency Events Database (EM-DAT, emdat.be) to gather such data and provide valuable insights into this relationship. EM-DAT is a multi-hazard database that has been used as the main source of information by several researchers (e.g., Lesk et al. 2016; Guoqiang and Seong 2019; Chen et al. 2020; Hamidifar and Nones 2023) and validation tool (Winsemius et al. 2013), even if it has some limitations (Petrucci et al. 2019; Saharia et al. 2021). A comprehensive dataset (EM-DAT), spanning from 1983 to 2022, is employed, allowing for a long-term analysis of trends. Furthermore, several eco-hydro-socio-geographical variables, including GDP, precipitation anomaly, population density, and forested area are integrated to provide a holistic perspective on the subject.

2 Materials and methods

2.1 The EM-DAT database

In 1988, the Centre for Research on the Epidemiology of Disasters (CRED) launched the Emergency Events Database (thereafter EM-DAT). The EM-DAT was created with the initial support of the World Health Organization (WHO) and the Belgian Government, and contains core data on the occurrence and effects of over 22,000 disasters that happened worldwide from 1900 up to now. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes, and press agencies.

The main objective of the database is to serve the purposes of humanitarian action at national and international levels. This initiative aims to rationalize decision-making for disaster preparedness, as well as provide an objective base for vulnerability assessment and priority setting.

EM-DAT provides data subdivided into three main classes: natural, technological, and complex disasters, each of which further contains one or more types of specific disaster. The database includes disasters' identification number, place, date, and impacts in terms of total number of deaths and affected (injured, displaced, missing).

For a disaster to be entered into the database, at least one of the following criteria must be fulfilled (EM-DAT 2016; Djalante and Garschagen 2017):

- Ten (10) or more fatalities
- Hundred (100) or more people affected/injured/homeless
- Declaration of a state of emergency and a call for international assistance

The data utilized in this study were downloaded from the public repository of the EM-DAT database (public.emdat.be) using the keywords "Natural," "Climatological," "Wildfire," and "Drought."

The period 1983–2022 was selected for the present analysis, as data referring to previous years might be incomplete and therefore were not considered fully reliable. Given that both disasters may have a severe impact on the lives of other creatures than humans and the environment in general, the present analysis was limited only to the effects of drought and wildfire on people (Fig. 1).

2.2 Statistical analysis

To more comprehensively explore the potential societal impacts of natural hazards like drought and wildfire, an investigation has been undertaken to uncover potential correlations between the number of affected people or the number of life losses and eco-hydro-geographical variables including gross domestic product (GDP), precipitation anomaly, population density, and forested area. To do this, relevant data were extracted from the World Bank Database (data.worldbank.org). The Spearman's rho (SR) test was used to highlight potential correlations between the two observed phenomena.

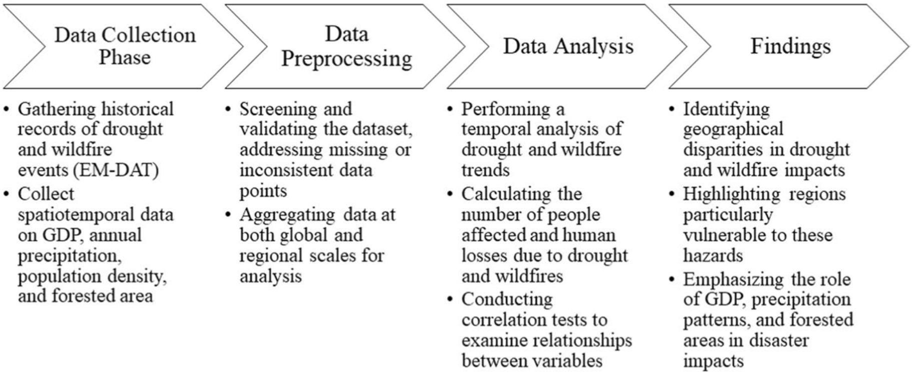


Fig. 1 Study flowchart

3 Results

To investigate the spatial distribution of losses by drought and wildfire, the events were first gathered from EM-DAT and then subdivided per continent (Fig. 2). This analysis pointed out that most people affected by them are located in Asia, followed by Africa and the Americas. It is worth noticing that EM-DAT reports a very low number of affected citizens in Oceania and Europe.

To better represent such a geographical inequality of the affected population, a world map is reported in Fig. 3, along with a histogram showing the affected population for each region. In this case, the EM-DAT data were extracted for each subregion.

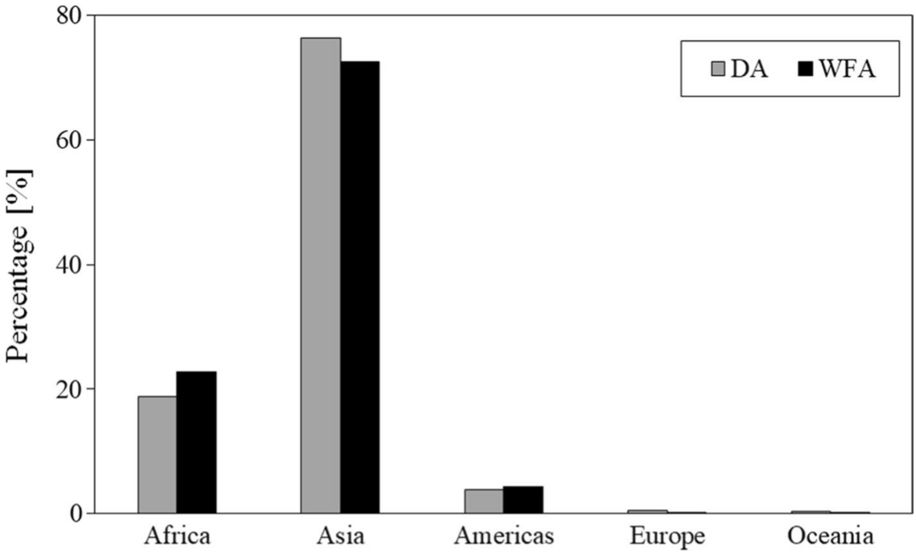


Fig. 2 The share of different continents in terms of the number of people affected by drought and wildfire. (DA = number of individuals affected by drought; WFA = number of individuals affected by wildfire)

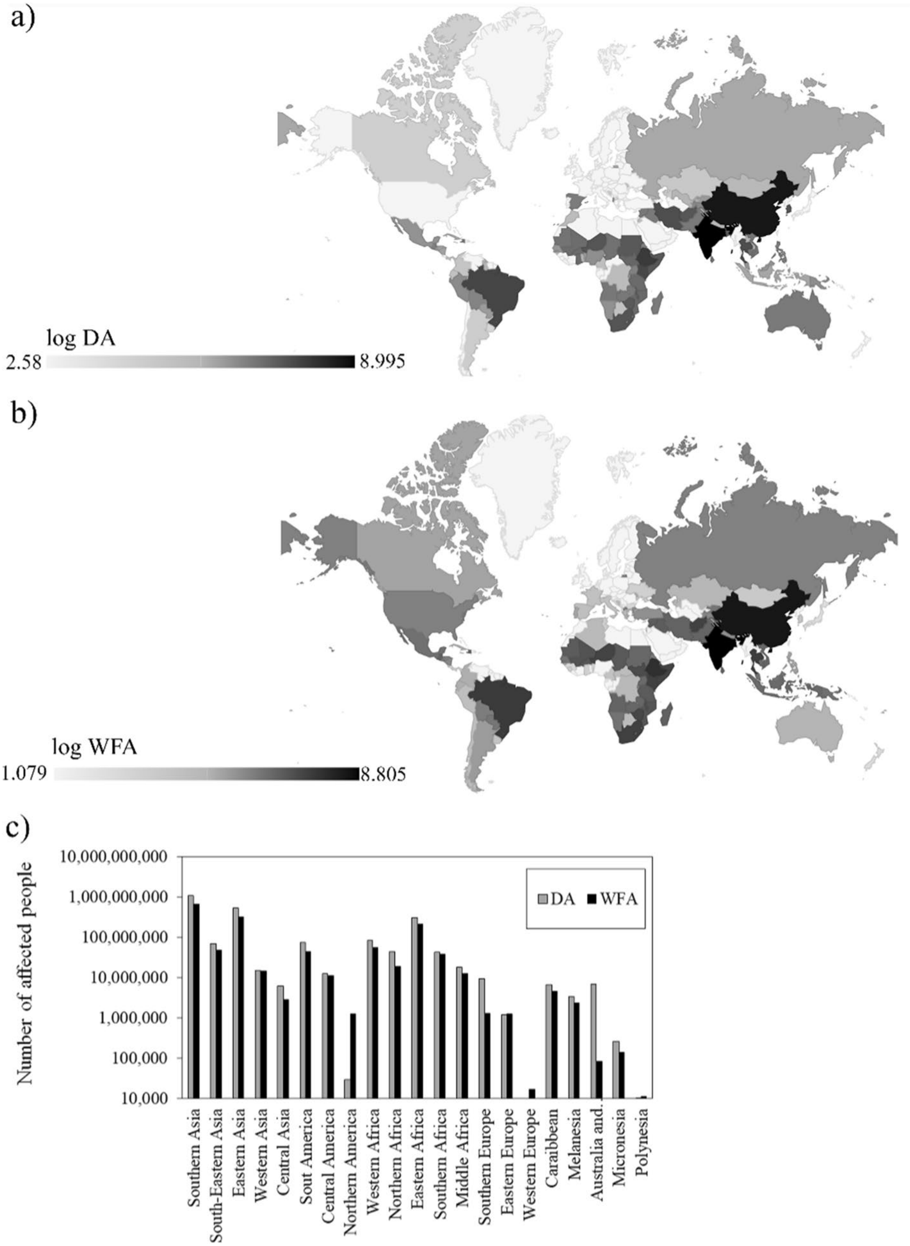


Fig. 3 Spatial distribution of individuals affected by **a** drought and **b** wildfire. Reported data are logarithmic. **c** The histogram reports the same data subdivided per region. (DA = number of individuals affected by drought, WFA = number of individuals affected by wildfire)

From the figure, it is evident that the majority of the affected people live in Asian and African regions, while Australia and Europe, especially its Eastern part, are still relatively less impacted by both phenomena. Focusing on Northern America, one can notice that, despite the low influence of drought in the region, wildfires constitute a relevant threat, probably because of the high population density in the affected areas, in agreement with literature evidence (Scasta et al. 2016).

Looking at the temporal variation of the total number of people affected by drought and wildfire on the global scale (Fig. 4), an increasing trend is observable for both events, with wildfire impacting very hard after 2002. Such a change in trend could be correlated to the increasing facility in reporting events in EM-DAT, but also to the observed changes in climate, as frequent dry periods were observed in the recent decades (Dai 2011). It is worth remembering that, following the EM-DAT Guidelines (see Sect. 2), "affected" means people affected/injured/homeless, regardless of human losses.

Focusing on human fatalities caused by drought and wildfire at the continental scale, a clear picture appears (Fig. 5): Africa suffers very much from both hazards, and the information reported in EM-DAT attributes to drought and wildfire almost 99% and 90% of African losses, respectively. This points out a potential correlation between the two phenomena, which is however less clear when looking at the data reported for the other continents, in which drought is not considered a major cause of fatalities, while wildfire might be.

Similarly to the analysis of affected people (Fig. 3), fatalities were also categorized by regions to identify potential geographical patterns (Fig. 6). In this case, African countries emerge as the most heavily impacted, particularly by drought (Fig. 6a), with Eastern Africa experiencing a significant impact from wildfires as well. These two hazards affect the other regions to a lesser extent, with some exceptions observed for Eastern Asia in the case of drought.

Considering the temporal variations of both hazards on the global scale (Fig. 7), no significant trends can be observed, even if a slight increase in reported wildfire-related

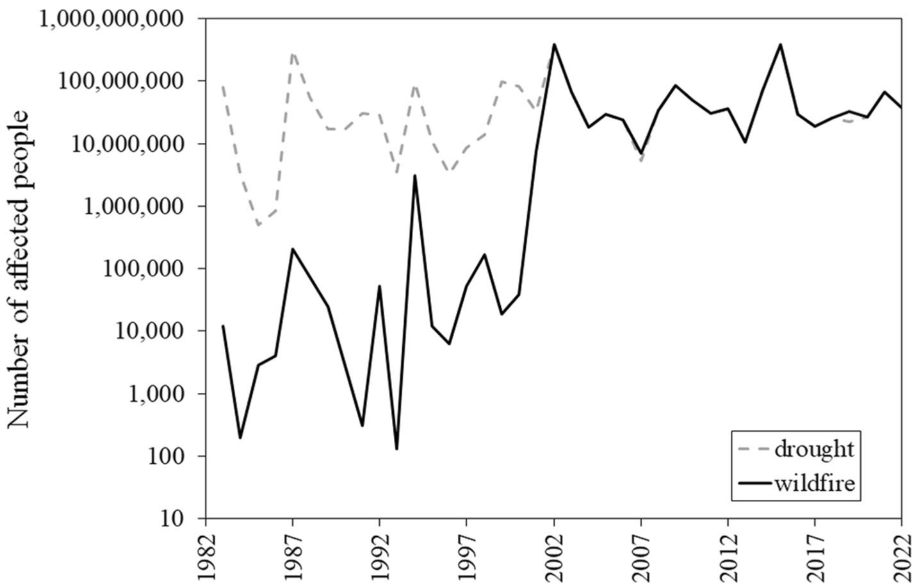


Fig. 4 Temporal variations of the total number of people affected by drought and wildfire, at the global scale

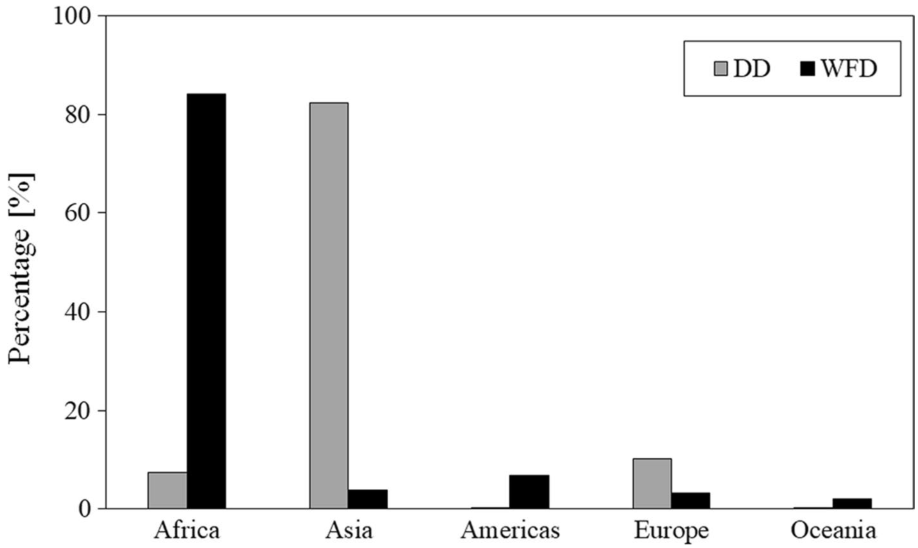


Fig. 5 The share of different continents in terms of the number of human losses by drought and wildfire. (DD = number of human losses by drought, WFD = number of human losses by wildfire)

fatalities can be noticed, and can be connected to the increase in the number of people affected by such events (Fig. 4).

Table 1 reports the key statistics of the analyzed data.

The SR test was also applied to study correlations between variables including GDP, precipitation anomaly, population density, and forested area, and wildfire and drought over the study period 1983–2022. Table 2 shows the SR test results. Among the studied variables, population density did not exhibit any significant correlation, while GDP had a significant inverse correlation with WFD (number of human losses by wildfire), WFA (number of individuals affected by wildfire), and DA (number of individuals affected by drought) parameters at the level of 0.01 and with DD (number of human losses by drought) at the level of 0.05. While no significant correlations were found between precipitation anomaly and WFD, DD, and DA, a significant inverse correlation was observed between this variable and the WFA parameter at the level of 0.05. Furthermore, forest area showed a significant correlation with DA at the level of 0.01, while it did not show any significant correlation with other parameters.

To assess the severity of wildfire events worldwide, the ratio of total losses to the total number of affected people was calculated for different countries. This analysis considered countries where the lists of affected individuals and human losses overlapped. The findings revealed that Croatia (12.2%), Lebanon (6.7%), Cyprus (2.7%), Bulgaria (1.5%), and Ukraine (0.8%) are the countries with the highest proportion of human losses compared to the number of people affected by wildfires. Conversely, China, Eswatini, the Syrian Arab Republic, India, and Brazil (collectively accounting for less than 0.0003%) have the lowest rate of human losses in relation to the number of affected individuals from wildfires.

4 Discussion

Climate change is expected to exacerbate drought conditions in many regions around the world, increasing the likelihood and severity of wildfires (Jones et al. 2020; Pausas and Keeley 2021). Some previous studies have shown that the severity of drought is a better predictor of wildfire activity than temperature or precipitation (e.g., Kulakowski and Veblen 2007; Abatzoglou and Williams 2016; Taufik et al. 2017). In fact, as the frequency and severity of drought conditions increased in recent decades, an increase in wildfire activity is expected (Scasta et al. 2016).

Indicators such as GDP, population density, and mean annual precipitation can provide useful information for analyzing the relationship between drought and wildfire events in different countries (Shi et al. 2016). For example, countries with high GDP and high population density, such as North America and Europe, may have more resources available for fire suppression and prevention efforts, which could eventually help in reducing the impact of wildfires (Aldersley et al. 2011). Mean annual precipitation can also be used as an indicator of drought conditions, as areas with lower precipitation are more likely to experience drought conditions and consequently increased risk of wildfire events (Russo et al. 2017; Kennedy et al. 2021). In addition, other indicators such as land use and land cover can support the analysis of the relationship between drought and wildfire events (Littell et al. 2016). For example, areas with a high percentage of forest or grassland cover may be more susceptible to wildfires, as these types of vegetation are highly flammable (Vilar et al. 2016; Coskuner 2022; Pozo et al. 2022).

In discussing the results proposed in this study, it should be noted that a more connected world is driving abundant and faster access to information and data, playing a significant role in detecting trends between natural hazards and human drivers (e.g., Wagler and Cannon 2015; Tanoue et al. 2016; de Bruijn et al. 2019; Baranowski et al. 2020). However, such a growing availability of data does not mean, per se, more scientifically sound and worldwide distributed information. In fact, cases where official reports are very uncertain in terms of the affected population and number of fatalities exist (Altez and Revet 2005; Alvala et al. 2017).

It is worth to note there that only the values of population density, GDP, and forest area corresponding to the disaster time in each country were considered in the present study. However, for the calculation of precipitation anomaly, the whole period (1983–2022) was considered. Furthermore, there are many other hydro-geo-economic variables such as water resources availability, land-use patterns, infrastructure development, soil permeability, and vegetation cover that might be correlated to the studied disasters but are not considered in the present investigation. To address this issue, future studies will consider more variables, aiming to correlate time-variant relations between flood fatalities and hydro-geo-economic factors. It is important to note that the inclusion of more variables and the exploration of time-variant relationships can also involve significant challenges. Indeed, collecting comprehensive and reliable data for a wide range of variables over extended periods may be resource-intensive and time-consuming, also involving uncertainties, especially in less developed regions (Peters et al. 2011; Davis et al. 2015; Jones et al. 2022).

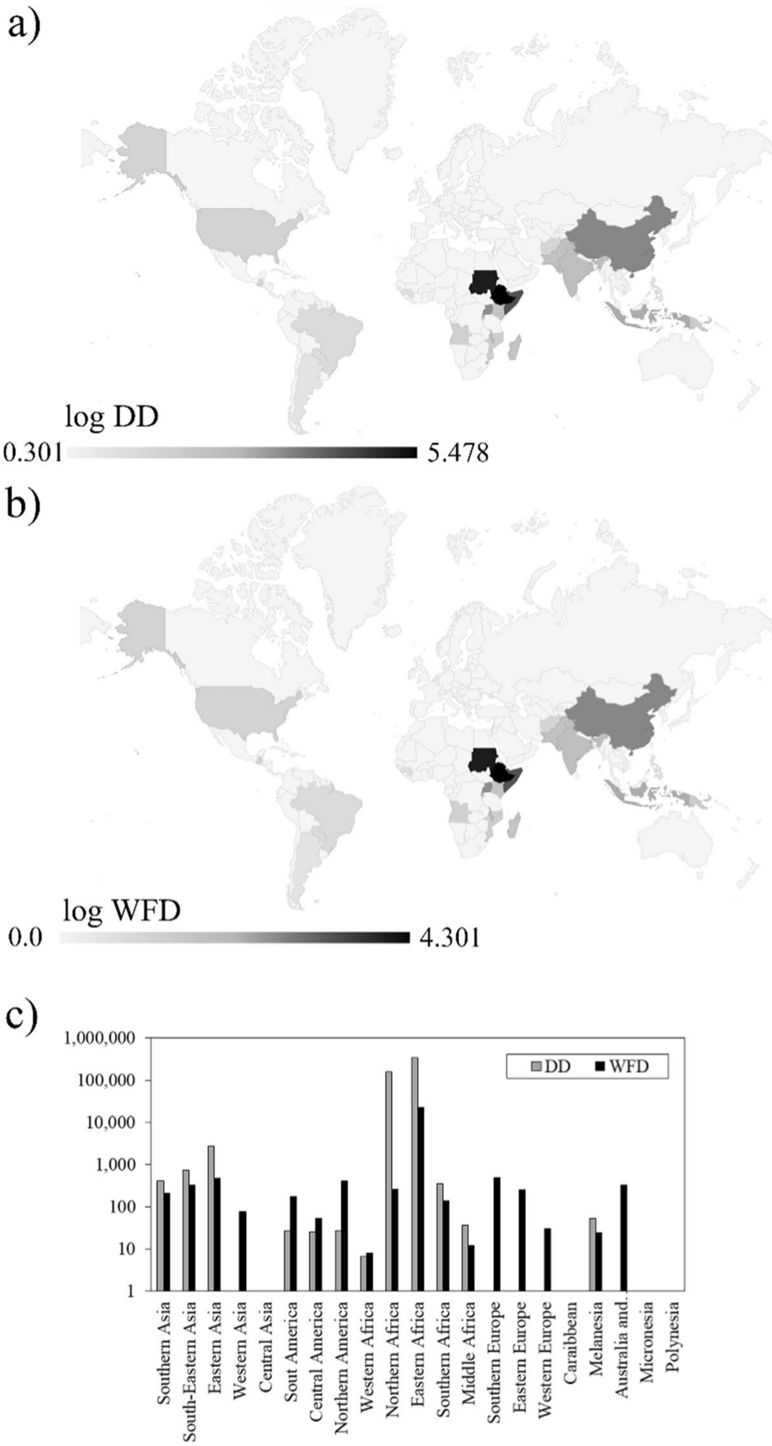
While EM-DAT is a widely used and reliable database for inferring long-term trends, it is very important to exercise caution when interpreting the data, considering their possible limitations and uncertainties (Edwards et al. 2021; Hamidifar and Nones 2023). In fact, despite technological advances in disaster surveillance and significant progress in data collection, previous studies (Jones et al. 2022) pointed out that, since 2022, EM-DAT has been

Fig. 6 Spatial distribution of the human losses by **a** drought and **b** wildfire. Reported data are logarithmic. ▶ **c** The histogram reports the same data subdivided per region. (DD = number of human losses by drought, WFD = number of human losses by wildfire)

suffering from an increase in missing data, suggesting shortfalls in the current data quality procedures. These limitations include reporting biases, inconsistencies in data quality and criteria, variations in completeness across regions and time periods, a lack of comprehensive socioeconomic data, and the absence of severity metrics for events. Additionally, the database may not provide detailed information on the underlying causes and drivers of drought and wildfire events, limiting the ability to conduct in-depth analyses. Furthermore, temporal and spatial resolution can be limited, and changes in reporting practices over time may affect data comparability (Hamidifar and Nones 2023). To address these limitations, future studies should focus on evaluating, case-by-case natural hazards, also involving more complex statistical methods.

5 Conclusions

Drought and wildfires are natural hazards with significant environmental, social, and economic implications. Understanding their spatiotemporal patterns and connections with various parameters, such as the economy, hydrology, and geography, is crucial for effective disaster risk management and sustainable land-use planning. This manuscript discusses the role of climate change in exacerbating drought conditions and wildfire activities, emphasizing the importance of indicators such as GDP, population density, and annual precipitation in understanding the relationship between these phenomena. This was done by leveraging the Emergency Events Database (EM-DAT) to depict the spatiotemporal trends of drought and wildfires over the period 1983–2022. Historical records of drought and wildfires are analyzed at both global and regional scales. The Spearman's rank correlation test is employed to examine the relationships between drought, wildfires, and parameters such as GDP, precipitation anomaly, population density, and forest area. The analysis reveals intriguing spatiotemporal patterns regarding the number of people affected and human losses caused by drought and wildfires, highlighting regions particularly vulnerable to these hazards. Significant geographical disparities in the impacts of drought and wildfire were found. Asia stands out as the region most affected by these phenomena, with more than 72% of individuals experiencing their effects. In contrast, Europe and Oceania show negligible impacts, accounting for less than 1% collectively. GDP exhibits a strong inverse correlation with both the number of people affected and human losses due to both drought and wildfires. This underscores the critical role of economic stability in mitigating the impact of these disasters. Precipitation anomaly shows an inverse correlation with wildfire-affected populations, highlighting the importance of precipitation patterns in wildfire occurrences. Furthermore, the study demonstrates the significance of forested areas in influencing the impact of drought and wildfire on human populations. Forested areas are


a)
log DD
0.301
5.478
b)
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c)
1,000,000
100,000
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100
10
1
DD
WFD
Southern Asia
South-Eastern Asia
Eastern Asia
Western Asia
Central Asia
Sout America
Central America
Northern America
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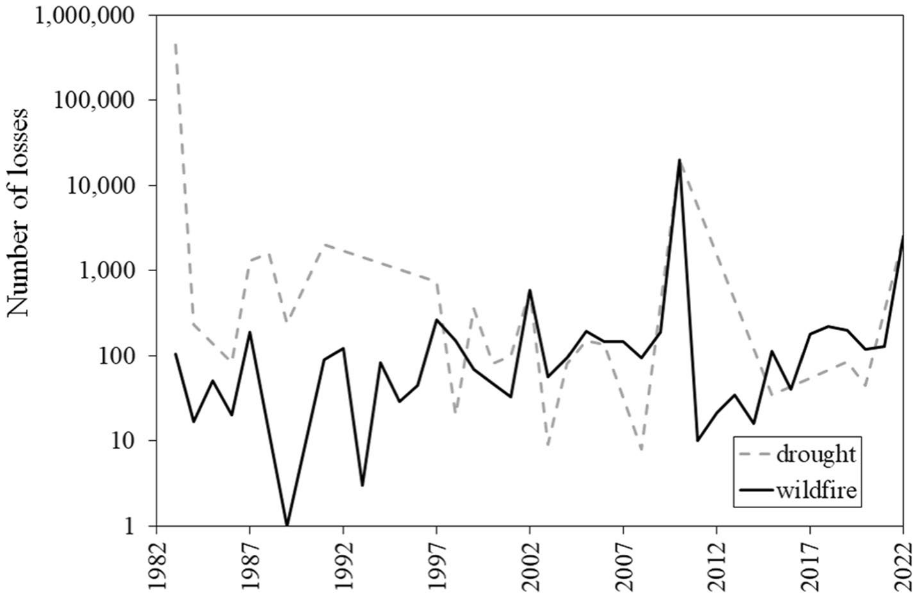

Fig. 7 Temporal variations of the total number of human losses caused by drought and wildfire, at the global scale

particularly vulnerable to wildfires, leading to higher human losses. It is worth reminding that these relationships derive from available data, therefore biases due to missing data or a lack of reporting are possible.

The present research contributes to the field of disaster risk assessment and management by showcasing the value of EM-DAT as a valuable resource for studying drought and wildfire trends. The insights gained from this study are instrumental for policymakers, land managers, and disaster response agencies in developing targeted strategies to mitigate the impacts of drought and wildfires in different regions. Additionally, the study emphasizes the need for proactive measures to address the role of hydro-geo-economical drivers on the consequences of these hazards and promote sustainable land management practices.

Future investigations that consider multiple databases and a broader set of hydro-geo-economic variables and analyze time-variant relationships have the potential to advance our understanding of the factors contributing to drought and wildfire fatalities.

Table 1 Data statistics

	Min	Max	Median	Average	Standard deviation	Variance	Skewness	Kurtosis	Coefficient of variation
DA	380	330,000,000	897,272.5	5,550,074.58	27,082,410.71	7.33E+14	10.37	117.26	4.88
DD	2	300,000	77	10,231.45	48,452.97	2.35E+09	5.39	33.40	4.74
WFA	1	330,000,000	25,710	2,767,412.04	19,948,583.00	3.98E+14	14.73	232.12	7.21
WFD	1	20,000	6	125.03	1379.20	1.90E+06	14.27	209.29	11.03

DA Number of individuals affected by drought, WFA Number of individuals affected by wildfire, DD Number of human losses by drought, WFD Number of human losses by wildfire

Table 2 Spearman's rho test results for WFD, WFA, DD, and DA parameters

Variable	Statistical parameter	WFD	WFA	DD	DA
GDP	Correlation coefficient	−0.259**	−0.386**	−0.414*	−0.310**
	Sig0. (2-tailed)	0.004	0.000	0.014	0.001
	N	120	161	35	115
Precipitation anomaly	Correlation coefficient	−0.258	−0.224**	−0.147	−0.033
	Sig0. (2-tailed)	0.160	0.005	0.493	0.627
	N	31	154	24	219
Population density (people per sq. km of land area)	Correlation coefficient	0.101	−0.007	−0.073	0.053
	Sig0. (2-tailed)	0.596	0.937	0.734	0.441
	N	30	144	24	211
Forest area (sq. km)	Correlation coefficient	−0.162	0.020	−0.349	0.161*
	Sig0. (2-tailed)	0.410	0.815	0.185	0.031
	N	28	143	16	180

DA Number of individuals affected by drought, WFA Number of individuals affected by wildfire, DD Number of human losses by drought, WFD Number of human losses by wildfire

*Correlation is significant at the 0.05 level

**Correlation is significant at the 0.01 level

Author contributions All authors contributed equally to the study conception and design, as well as to the data analysis and manuscript preparation.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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