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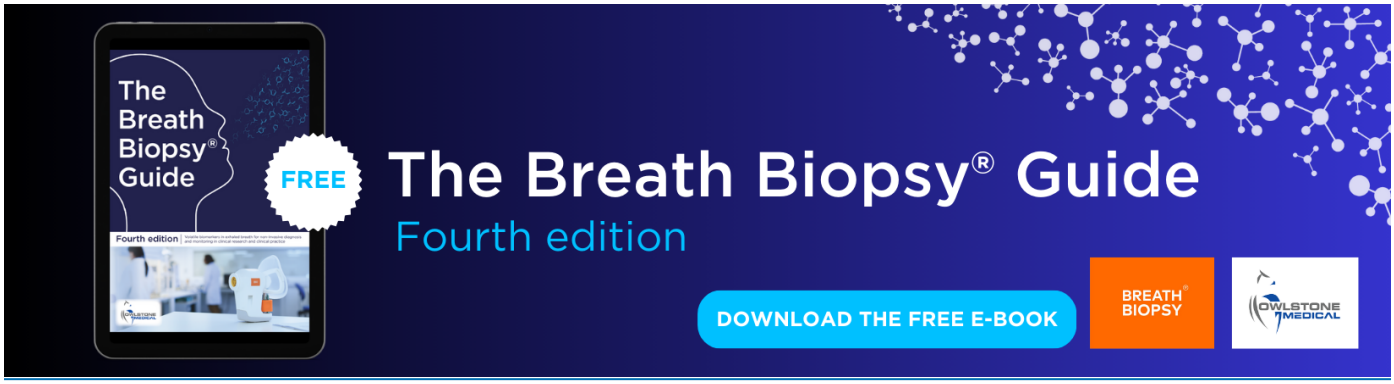

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Beyond the forecast: knowledge gaps to anticipate disasters in armed conflict areas with high forced displacement

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Abstract

Although conflict-affected populations are often exposed to and severely impacted by disasters, little is known about their perceptions and practices concerning early warning and early action (EWEA) or how EWEA strategies can protect communities affected by conflict- and climate-related disasters. This is particularly problematic as, due to the multiple challenges posed by conflict and compound crises in these contexts, early warnings of weather hazards do not often translate in early actions. This comprehensive literature review examined 384 peer reviewed papers produced between 2004 and 2022, focused on the 20 countries most affected by non-international armed conflict and exposed to climate hazards. This paper answers the question**: what is the state of knowledge of EWEA for climate hazards in countries affected by armed conflict and high levels of forced displacement?** Findings demonstrate that most research focuses on climate science rather than social science across six elements of the EWEA value chain: 1. hazards analysis, 2. understanding vulnerability and exposure, 3. warning communication and dissemination, 4. forecasting availability and monitoring, 5. early action planning, and 6. financing systems. In total, 75.65% of the research studies focused on hazard analysis, forecast availability, and monitoring. There has been a strong increase in academic research on EWEA in conflict-affected countries since 2004. However, we identify that most of this research has been in Ethiopia, Pakistan, and Nigeria which, although severely affected by conflict, also have a higher level of economic development and stability. In contrast, there is little research focused on EWEA in most of the remaining countries. Across all thematic areas, there is a lack of consideration of conflict dynamics in EWEA research. This paper contributes to evidence on the need to recognize people affected by conflict in disaster risk reduction, as called for in the Sendai Framework for Action midterm review, with the aim of enhancing EWEA investments to enable tailored approaches appropriate for conflict-affected states.

1. Introduction

Populations affected by armed conflict are highly susceptible to negative impacts caused by hydrometeorological hazards, due to the damage of conflict across human, social, natural, physical and economic elements of society. The vulnerability to disasters is increased by conflict as it erodes response capacity over time (IISS 2019). With climate change, the intensity and frequency of hydrometeorological hazards is likely to increase (IPCC 2021), making conflict-affected populations already experiencing high vulnerability even more likely to be impacted by climate related hazards (ICRC 2020). Some of

the impacts of conflict that exponentially increase the vulnerability of people to climate change include forced displacement, unemployment, gender-based violence, insecure land tenure, low literacy, poor access to social and health services, violence, and extreme poverty, among many others (Eriksen and Lind 2005, Jaspars and Maxwell 2009, UNDP 2011, Wisner 2012, Idris *et al* 2013, Chandra *et al* 2017, Quinn *et al* 2017, Olmedo and Del Miño 2019).

This research focuses on non-international armed conflict and belligerent occupation, protracted with different levels of intensity. We use the Uppsala Conflict Data Program (UCDP) definition: 'an armed conflict is a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths in one calendar year' (UCDP 2020a). Under international humanitarian law, armed conflicts are classified as international-armed conflict when there is confrontation between two states (including belligerent occupation) and non-international armed conflict (NIAC), when there is confrontation between a state and a dissident faction or, two or more organized armed groups within a state (ICRC 2019). Armed conflicts have different levels of intensity; a low intensity conflict (minor conflict) is when there are at least 25 but less than 1000 battle-related deaths in one calendar year, while high-intensity conflict refers often to when there are at least 1000 battle-related deaths in one calendar year (UCDP 2020a). Both levels of intensity can occur in protracted conflicts which are characterized by their longevity, fluctuation, intractability and mutability (Azar *et al* 1978, ICRC 2016, Policinski and Kuzmanovic 2019). For example, Cameroon has experienced a history of conflict in different facets before and after the reunification in 1961 and the recent scalation in 2017 (Kah 2015, Ezemenaka and Ekumaoko 2022).

In the absence of long term disaster risk reduction (DRR) and climate change adaptation measures in conflict contexts (Mena and Hilhorst 2020, Sitati *et al* 2021), early warning and early action (EWEA) offers possibilities to reduce residual risks (Basher 2006, GRC, Climate Centre and IFRC 2020, Sansa-Otim *et al* 2022) and can save lives, livelihoods and assets. Early warning refers to information provided in advance of a specific hazardous event to enable stakeholders to take timely action to reduce disaster risks, while early action refers to a set of measures to prevent or reduce the impacts of a hazardous event before they fully unfold, predicated on a forecast or credible risk analysis of when and where a hazardous event will occur (REAP 2022).

In 2022 the United National Secretary-General announced the early warning for all initiative, with the ambition that every person on earth be protected by early warning systems within five years (WMO 2022). To achieve this, people affected by armed conflict require EWEA services adapted to the complex contexts where they live, considering the disruptions that states affected by conflict face. In these contexts, hydrometeorological services are often affected by destruction, decay of infrastructure, and/or weak national capacities, making the monitoring of hazards and production of forecast services difficult (UKMO 2020, CREWS 2021). Early action is also jeopardized by the impacts of conflict. Often, governmental and non-governmental system are not able to disseminate warnings and act upon them (Mohanty *et al* 2019). Understanding risks in conflict-affected environments is challenging, given the limited availability of climate risk maps, data about historical impacts of climate related disasters, and increasing occurrence and severity of hazards such as heatwaves due to climate change (Jaime *et al* 2022). Field research is often limited by the difficulties of access due to violence, weapon contamination, and risk aversion by donors and governments and other actors (Mena *et al* 2019). While people living in conflict-affected countries are employing EWEA (IFRC 2009), it is unclear whether there is a sufficient body of scholarly work to support EWEA in these countries.

This paper presents evidence of which elements of EWEA have been researched in conflict contexts, and existing gaps that need to be addressed to enhance the capacity of institutions and communities to act before the occurrence of a hazard in relation to risks, weather forecasts, and anticipatory planning. This paper answers the question: **what is the state of knowledge of EWEA for climate hazards in countries affected armed conflict and high levels of forced displacement?** The aim is to guide future research, implementation strategies and investment in the key elements of the EWEA value chain, defined below.

2. Methods

We conduct a comprehensive literature review of academic literature published between 2004 and 2022. The starting date was selected as 2004 was a key year for early warning systems due to the recognition of their critical importance following the severe impacts of the 2004 Indian Ocean Tsunami and the establishment of the Hyogo Framework for action (UNDRR 2005). The framework was revised in 2015, and the Sendai Framework for action (SFDRR) was adopted by all countries in the world, with a global target to substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030 (UNDRR 2015). However, the Sendai framework has been criticized for not acknowledging the differential risks experienced by populations affected by conflict,

and by not mentioning conflict in the final agreed document (Peters 2019a, Peters *et al* 2019b, Zaman *et al* 2020).

We collected research articles relating to conflict-affected countries and conducted a thematic analysis across the six areas of the EWEA value chain: 1. hazards analysis, 2. understanding vulnerability and exposure, 3. warning communication and dissemination, 4. forecasting availability and monitoring, 5. early action planning and 6. financing systems. We conducted a chronological analysis of the relative frequency of publications between 2004 and 2022, and we analyzed at what extent conflict sensitivity and emerging topics such as remote sensing and impact based forecasting were included in the literature of the 20 selected countries of study.

We use the PICoST framework (Berrang-Ford *et al* 2021) designed to identify papers based on these criteria: population/problem (*P*), interest (*I*), context (*Co*), Scope (*S*) and time (*T*). (*P*) refers to people affected by armed conflict. (*I*) refers to peer review papers about the six areas of the EWEA value chain. Interest (*I*) also includes a chronological analysis to determine the evolution of research over the period of study and the comparison between research production and historical disaster impacts. (*Co*) refers to the 20 countries affected by armed conflict that are subject of analysis. Finally, (*S*/*T*) is related to the scientific literature time of publication (between 2004 and 2022).

Our review includes academic literature that is exclusively about early warning systems, early action, anticipatory action and forecast-based financing and only for hydrometeorological hazards (see list of terms used in diagram 1). EWEA terminology has evolved rapidly over the last years, with different or similar definitions depending on the user. The risk informed early action partnership (REAP) and the United Nations have developed glossaries to encourage discursive coherence (De Wit 2019, REAP 2022), which we have followed for the definitions used in this paper.

The review excludes literature on the prediction of conflict and does not include grey literature. The literature search focuses on EWEA research on 20 countries affected by non-international protracted armed conflict, calculated by the total number of deaths (UCDP 2020b) and the total number of people in situation of displacement (IDMC 2020). Using the UCDP data[7], we first identified those countries that have been severely affected by non-international violent protracted conflict, which often results in debilitated governance, economic and well-being systems. Then, to ensure we selected countries with high level of humanitarian needs, we used the Internal Displacement monitoring Centre (IDMC) dataset as this shows a critical number of vulnerable and exposed population to climate risks.

2.1. Countries

To identify a set of representative countries for this study two sources of data are utilized (see table 1). First, the countries with the highest number of fatalities from 1989 until 2021 are identified according to the UCDP georeferenced event dataset. This time range is selected to capture the impacts of protracted conflicts. Second, countries with the largest number of internal displaced persons (IDPs) from 2009 to 2021 are selected by using available data from the IDMC (this range of time was at the time of analysis the maximum available in the dataset).

As some countries suffer the impacts of armed conflict only in specific areas of a country (for example, the Philippines is mostly affected in the province of Mindanao, Mozambique in Cabo Delgado, and India in the Kashmir region), we excluded countries with localized conflict and limited the literature of research papers to those countries that have a wider national level impact from conflict, which was determined based on reviews of relevant grey literature, such as that published on Reliefweb and by ICRC. We do not include countries affected by other situations of violence such as Brazil and Mexico, which based on ICRC classifications do not meet the threshold for widespread conflict.

First, we analyzed countries with the highest numbers of conflict related fatalities, using the percentage of deaths in relation to the total population as a proxy to determine high severity. Then, to ensure we select countries with high levels of humanitarian needs, we used the IDMC dataset for validation. Needs are represented by the percentage of the population cumulatively displaced by conflict between 2009 and 2021. The lists of countries with the highest number of conflict related fatalities and highest levels of internal displacement due to conflict (and not climate-related disasters) are compared. We decided to limit the number of countries to 20 to have a significant sample that was also feasible to analyze based on time constraints. We split Israel and the occupied Palestinian territories to gain more granular information, given the socio-economic and political differences of both contexts. The decision to analyze countries based on internal rather than cross border displacement arose primarily as the world's top refugee-producing countries are also those with the highest number of IDPs, and thus are already covered through this review. The countries selected for study are: Syria, Afghanistan, Iraq, Yemen, Nigeria, Pakistan, Democratic Republic of Congo, Sudan, Somalia, Sri Lanka, Ethiopia, Libya,

[7] Although we recognize the value of The Armed Conflict Location & Event Data Project—ACLED, we decided to use UCDP data as it has longer time series data. ACLED started data collection in few countries and it was only until 2009 that they launched the global tool.

Table 1. Countries selected for comprehensive literature review. The countries in this table are ordered from 1 to 20 using the number of conflict fatalities from highest to lowest. The order does not have any impact in the research process itself.

	Country name	Number conflict fatalities 1989–2021 (UCDP)	Accumulated number of people internally displaced by conflict 2009–2021 (IDMC)	Population (World Bank 2022)
1	Syria	405 740	19 289 000	21 324 370
2	Afghanistan	315 171	4090 000	40 099 460
3	Ethiopia	196 259	12 424 000	120 283 030
4	Iraq	125 775	5727 000	43 533 590
5	DR Congo (Zaire)	123 421	16 713 000	95 894 120
6	Sudan	97 047	3567 000	45 657 200
7	Sri Lanka	65 628	282 800	22 156 000
8	Nigeria	63 468	4435 000	213 401 320
9	Yemen	55 794	4736 000	32 981 640
10	Somalia	54 713	3353 000	17 065 580
11	Pakistan	43 225	5144 590	231 402 120
12	Colombia	33 755	2251 000	51 516 560
13	Myanmar	22 302	1172 200	53 798 080
14	Central African Republic	14 178	3490 000	5457 150
15	Libya	13 985	1448 000	6735 280
16	South Sudan	13 579	4844 000	10 748 270
17	Mali	9954	1346 300	21 904 980
18	Israel and occupied Palestinian territories	9264	756 510	9364 000
19	Cameroon	7025	1093 000	27 198 630
20	Burkina Faso	4133	1757 600	22 100 680

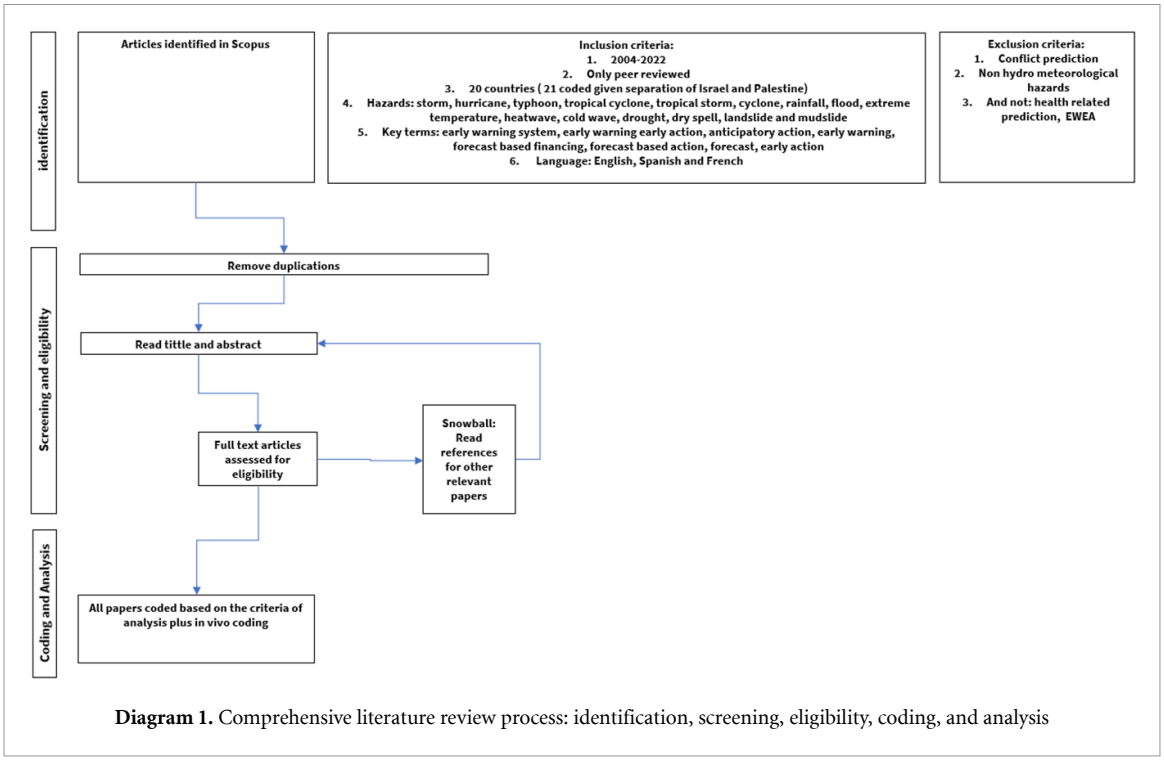


Diagram 1. Comprehensive literature review process: identification, screening, eligibility, coding, and analysis

Central African Republic, South Sudan, Myanmar, Mali, Colombia, Israel and the occupied Palestinian territories, Cameroon and Burkina Faso.

2.2. Selection process

The comprehensive literature review process to select the academic literature consisted of four steps (see diagram 1): (1) identification of academic papers, (2) screening, (3) eligibility, and (4) coding and analysis.

The identification step in the comprehensive literature review consisted first of a keyword search in Scopus that lead to the development of a database. The search included these terms: early warning system, early warning early action, anticipatory action, early warning, forecast based financing,

forecast based action, forecast, early action, and risk mapping. The advanced search engine was used to limit the query to focus on papers related to weather and hydrometeorology, consisting of the following hazards: storm, hurricane, typhoon, tropical cyclone, tropical storm, cyclone, rainfall, flood, extreme temperature, heatwave, cold wave, drought, dry spell, landslide, and mudslide. The search was limited to the 20 selected countries, however for the case of Israel and the occupied Palestinian territories the query was separate, and the term applied was Palestine. Three languages were included: English, French and Spanish. However the results only yielded one paper in Spanish and none in French. We excluded the analysis of EWEA for biological hazards in the paper, therefore these keywords were part of the exclusion criteria: disease, epidemic, pandemic, cholera, dengue, zika, malaria and Ebola. After these first steps, the comprehensive search yield 502 papers. A paper was selected for review if it met the criteria related to: 1. includes at least one of the included EWEA terminologies (REAP 2022), 2. the paper includes at least one of the countries of analysis and one of the hazards. 3. the paper focuses on any of the elements of the value chain of EWEA. We applied an expert judgment approach for the selection of the papers for screening.

In the next step, all titles and abstracts were screened to exclude non relevant papers. The exclusion criteria included: 1. not relevant country, 2. not hydro-meteorological hazard, 3. conflict prediction or conflict early warnings, 4. epidemic related to EWEA, 5. not relevant to the subject of research. At the end of the screening 350 papers were selected for full text review, coding, and snowball search. After this, due to the application of snowball methodology, 384 papers in total were selected for inclusion in the study (see appendix 1).

For the coding stage, we predefined the codes based on the six criteria of analysis: 1. understanding vulnerability and exposure, 2. hazard analysis 3. warning communication and dissemination, 4. forecasting availability and monitoring, 5. early action planning 6. financing systems. We thematically coded the findings through the qualitative software ATLAS.Ti, which allowed us to identify other relevant topics, such as additional hazards like hailstorms, humidity and dust storms, which were originally not included in the query. To capture other relevant papers, we used an iterative snowball approach; once a new paper was identified, we applied the same screening process of step 2. The coding process included the identification of relevant information, for example identification of emerging themes in EWEA, such as machine learning, remote sensing and impact-based forecasting. During the coding process we explored topics such as conflict sensitivity, challenges to implement EWEA in contexts of conflict, impacts of war on hydrometeorological infrastructure and services, communication challenges to transmitting warning messages in a war zone controlled by parties to the conflict, and lack of risk appetite by donors to invest in conflict zones.

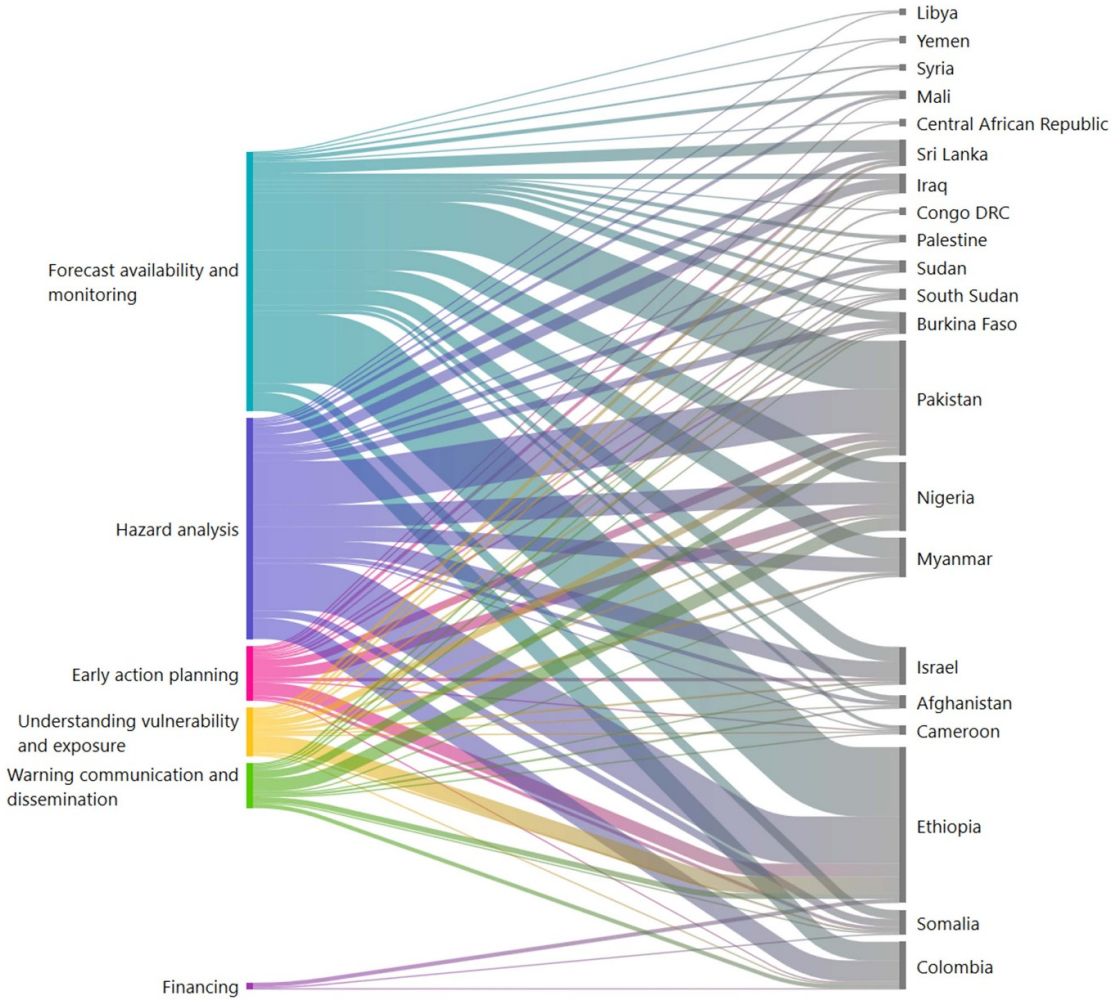
3. Results

In this section we present the results of the comprehensive literature review. First, we present the state of knowledge on EWEA by identifying what has been studied for each of the elements of the EWEA value chain. Then, we show how the volume of research has changed over the last 20 years. During the research process we also discovered relevant emerging research topics that complement or comprise the EWEA value chain, which are included here. Given its relevance we presents the results of a deep dive into hazard specific research. Finally, we present findings focused on the integration of conflict sensitivity and conflict dynamics.

3.1. From early warning to early action

The analysis shows evidence that hazard analysis and forecast availability and monitoring related research have been the most prevalent topics published on compared to the other elements of EWEA analyzed (see graphic 1). Within the 384 papers reviewed, the six EWEA elements were mentioned 538 times. Out of these occurrences, 34.39% focused on hazard analysis and 41.26% on forecast availability and monitoring. The 21[8] countries included in this study were mentioned 410 times across the 384 papers. Nigeria, Ethiopia and Pakistan contribute to the 52.44% of total research, compared with countries such as Yemen, Libya and Central African Republic, which yielded in total four papers, all of which focused on forecast analysis. In the case of Israel and the occupied Palestinian territories, we separated the search, which yielded different papers for each. Results show that there were six times more papers on Israel than on Palestine. In the case of Myanmar, most of the EWEA related papers focused on cyclone analysis (7.07%), specifically research about the 2008 Cyclone Nargis, one of the most impactful disaster events in Myanmar history (Reale *et al* 2009, Ozcelik and Doocy 2012, Adetunji 2018, Howe 2018). In addition to Nargis, the most prominent disasters studied in these conflict-affected countries include the 2010 Pakistan floods, and the 2011 Horn of Africa famine. Interestingly 26.3% of the research papers focused on historical analysis of past disaster events and agriculture related papers are also very prominent at 18.8%, many of them conducting in depth hazards analysis of rainfall and enhancing forecast capabilities.

[8] We selected 20 countries, however the analysis reflect 21, as we coded Palestine and Israel separately.



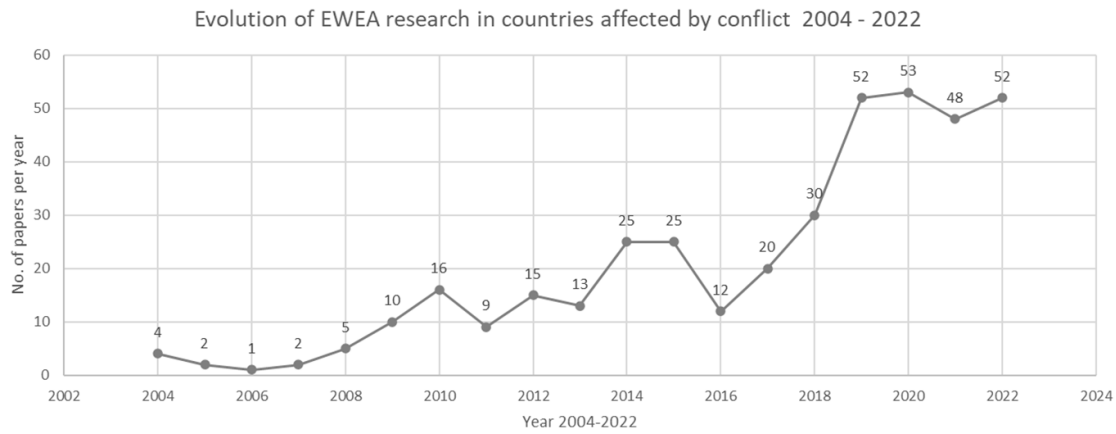
Graphic 1. Distribution research per country and per EWEA thematic area of analysis; colours do not have a significance, default colours by software used for analysis ATLAS.ti.

Research on early action planning, warning communication, dissemination and understanding vulnerability and exposure was limited (23.23%). For example, one paper focused on Ethiopia explored the use of livelihoods and socioeconomic data as part of the wider climate risks analysis process (Funk *et al* 2013), and in South Sudan Benancio *et al* (Benansio *et al* 2022) show evidence of the local perceptions of risks, such as the belief that disasters are caused by the anger of god and ancestors. In contrast, research related to financing EWEA is nascent, only yielding 1.12% of total results. Graphic 1 below presents the distribution of research per country according to the main topics of focus.

By analyzing individual country research, the three countries with highest number of published academic articles are Ethiopia (24.39%,), Pakistan (18.29% and Nigeria (9.76%). Papers are mostly focused on forecast availability and monitoring, followed by hazard analysis. Research on Ethiopia is more often focused on droughts, while the research on Pakistan and Nigeria focuses mostly on drought and floods. Overall, the research findings show a large number of research articles focused on understanding precipitation (rainfall) related to droughts and floods (35.38%).

At the bottom of the research results we found Afghanistan (2.20%), South Sudan (1.95%), Sudan (1.71%), Mali (1.71%), occupied Palestinian territories (1.22%), Cameroon (1.22%) Democratic Republic of Congo (0.73%), Syria (0.73%), Central African Republic (0.49%) Yemen (0.24%) and Libya (0.24%). For example one paper on Libya focused on dust storm analysis, a hazard that has severe health and economic impacts in the region (World Bank 2019).

Despite the fact that in recent years there has been a growing focus on translating early warnings into early action, we found limited research related to early action planning, in total 45 code occurrences, equivalent to just 8.36% of the total studied papers. In Pakistan, Shah *et al* studied the role of local flood risk perceptions as a crucial part of the EWEA value chain to assist provincial and disaster management authorities to adopt local actions (Shah *et al* 2022).



Graphic 2. Evolution of peer review papers on NIAC countries with high levels of displacement from 2004 to 2022 (Each years shows the total number of papers identified).

Forecast communication and dissemination is a key enabler to ensure populations receive timely information that allows them to take early decisions to evacuate and protect assets. We found limited research that addresses this aspect of the EWEA value chain. 7.62% of the papers investigated the delivery and efficacy of warning messages. In Southwest Nigeria, Tolulope Olayemi found that 68.1% of the farmers interviewed were willing to pay for forecast information that could enable them to act to protect their crops (Tolulope Olayemi *et al* 2015). In Mali, Zare *et al*, describe the role of radio as a main weather forecast communication channel, reaching more than 80% of the population across the country (Zare *et al* 2017); yet despite this large coverage, EWEA is described as a challenge due to insecurity and other factors (CREWS 2021).

3.2. Conflict sensitivity in EWEA research in context affected by conflict

'Conflict sensitivity involves developing understanding of the context in which activities are delivered, analyzing the relationship between those activities and the context, and adapting the way activities are delivered'. None of the papers identified mentioned conflict sensitivity as part of the research. In fact, only 13 papers (3.4%) mentioned conflict as part of the socio-political dynamics related to risk creation. Among the papers that mentioned conflict as part of the EWEA research, Montaud acknowledges the difficulty of factoring conflict dynamics into agricultural drought impact analysis in Mali (Montaud 2019). In Afghanistan, Brown *et al* describe how small declines of precipitation and irrigation water can reduce the coping strategies of poor farmers who are already vulnerable due to conflict (Brown 2009). We found that most of the research that mentions conflict as a risk factor is situated in the horn of Africa. In an East African study, Coughlan de Perez describes that factors beyond rainfall such as conflict are key determinants of whether lack of rainfall can become a disaster (Coughlan de Perez *et al* 2019). However, none of the forecast availability, monitoring and hazard analysis related papers mentioned the respective conflict dynamics in the countries studied. The climate science research related to hazards, forecast availability and monitoring analysis is evidently detached from the research on the conflict dynamics in the countries of study.

3.3. The evolution of EWEA research in the last decades

Graphic 2 shows the extent to which academic research on EWEA in NIAC countries with high levels of displacement, has increased over the last decades. We show evidence of the existence of four papers in 2004 increasing to 52 papers in 2022. The results show an accelerated pace after 2016. This increase in research can be associated with the EWEA priorities adopted by governments globally in the DRR SFDRR in 2015. However, we identify that most of this research has been in countries which, although severely affected by conflict, also have a higher level of economic development and stability; this includes Colombia, Ethiopia, Pakistan and Nigeria. Countries that experience high intensity conflict (Mena 2021) and rank lower in the ND-Gain index, such as Afghanistan, Syria, Yemen, South Sudan, Iraq, Mali, Democratic Republic of Congo, and the occupied Palestinian territories, only account for 12.44% of the total research, mostly conducted after 2016. Somalia, although also a high intensity conflict state, shows a higher number of research articles over the last years, especially since 2011 after the severe famine that affected 17% of the population (Majid and Mcdowell 2012).

3.4. Emerging research topics on EWEA

As described above, between 2004 and 2022 research has been more focused on understanding the physical aspects of climate hazards and how to forecast them. However, within this time period, several

common additional topics emerged. In recent years, new themes have emerged, including machine learning (3.65%), remote sensing (15.36%), geographical information systems (5.73%) and more recently impact-based forecasting (1.04%). For example, in Pakistan and Afghanistan researchers have studied machine learning models for rainfall prediction and short term forecast of vegetation health (Ali *et al* 2018, Nay *et al* 2018). The emergence of impact-based forecasting in the value chain of EWEA, shows an important shift in the decision-making process from a forecast that describes what the weather will be to a forecast that describes what the weather will do. This approach includes analysis of hazard, vulnerability, exposure and disaster impacts information in the prediction process (WMO 2021).

3.5. Hazard research distribution

From a hazards perspective (see graphic 3), we present evidence that most of the research in countries affected by conflict have concentrated on drought (24.06%) and floods (14.62%), with a significant prevalence on rainfall analysis (35.38%). Despite the fact that extreme temperature is one of the deadliest hazards with high confidence to increase over the next years according to the Intergovernmental Panel on Climate Change (IPCC 2021), research on the topic is very limited (2.83%). We also identified limited research about humidity (1.18%). Of our sample, most of the research on extreme temperature we encountered was conducted in Pakistan, a country that has experienced severe health impacts of extreme heat over recent years. Iraq, another country enduring extreme heatwaves, has conducted pioneering research on applying deep learning and neural networks to predict temperatures in Erbil city (Al- Jumur *et al* 2021). In the snowball process, we applied expert judgement to include other hazards we did not consider originally in the key words, we identified a few papers related to dust storms, hailstorms, thunderstorms/lightning, humidity and wind.

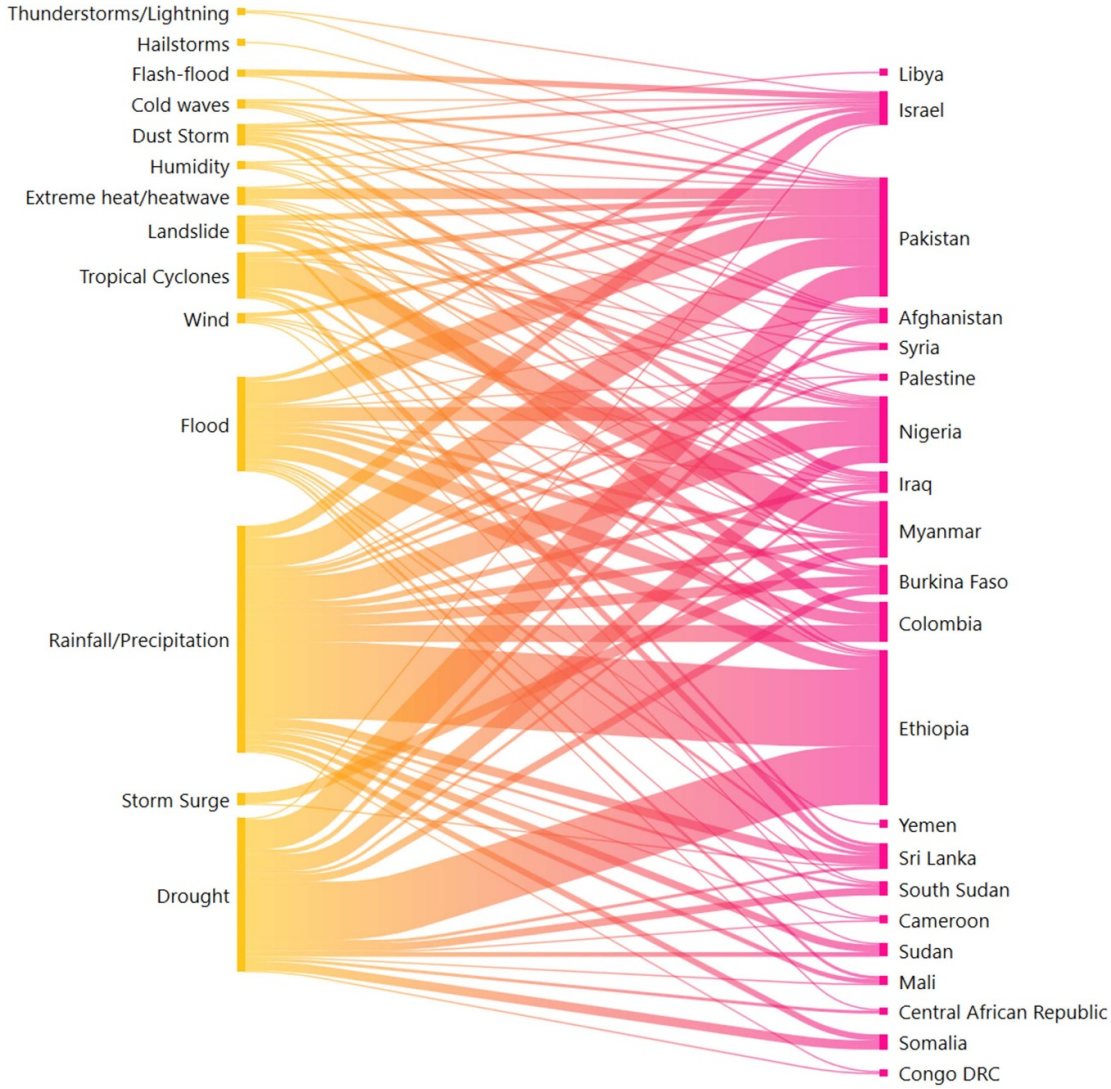
4. Discussion

This paper shows evidence of an imbalance of peer reviewed academic papers across the six thematic areas of analysis. Most of the research has been focused on understanding the physical nature of weather-related hazards, forecasting and monitoring of those hazards. There is a clear disjuncture between physical climate science (75.65%) and social science (24.35%) research articles. We argue that there is also an imbalance in the physical and social elements of included research, with gaps in areas such as governance, warning dissemination, and contingency planning, all of which help translate early warning into early action. An outlier example of pioneering multidisciplinary research focused on high risk areas in Medellin, Colombia (which is a host location for people displaced by conflict), describes the importance of combining social and physical science research and community based approaches to design early warning systems (Claghorn *et al* 2015). In contexts that experience debilitated systems, networks, and infrastructure with high levels of vulnerability and exposure due to the impact of war, it is crucial to understand the social, political and economic dynamics in the entire value chain of early warning early action. Among the small number of peer review papers addressing warning communication and dissemination (7.25%) none consider constraints due to conflict, which are critical aspects that can jeopardize the production, transmission, dissemination, acceptance, and understanding of warning messages. Power dynamics between the producers of warning messages, and the potential parties that are intermediaries in the warning dissemination are also not considered, for example the army, rebel groups or other power groups that can play a role in warning dissemination.

We identify that the state of hazard focused research has evolved over time, with a growing increase of articles on the subject, particularly since the adoption of the SFDRR in 2015. Yet, research is concentrated in countries that, although suffering severe impacts of conflict, in fact have more economic stability, including Ethiopia, Pakistan, Nigeria, Israel and Colombia, compared to the other countries included in this study. These other countries experience protracted, high intensity conflict and are at the bottom of the Notre Dame Global Adaptation Initiative index.

Understanding the vulnerability and exposure variables that determine who and what is more likely to be impacted by climate hazards is an essential part of decision making to ensure early actions are effective. Our results show a very limited focus within the EWEA research of such vulnerability and exposure analysis. Only 7.62% of the academic papers reviewed mentioned or had a specific focus on this topic. This is in particular contrast to a much larger body of literature (outside the purview of this review) that analyses climate-security and explores how climate-related disasters impact the risk of armed conflict (Schleussner *et al* 2016, Mach *et al* 2019, 2020, Ide *et al* 2020). It is important to note that to build effective EWEA, vulnerability and exposure analysis could be products of wider DRR and adaptation processes to understand risks. The design of EWEA is a collaborative process and can build upon other fields. Further research is needed to determine to what extent vulnerability and exposure analysis have been conducted, at what scales, for what sectors and importantly how those could be used in the design of EWEA systems.

Early action planning is a fundamental aspect of the early warning early action value chain. In contexts affected by conflict, challenges to effective planning



Graphic 3. Distribution research per country and per hazard (colours do not have a significance, default colours by software used for analysis Atlas.ti).

include an appropriate targeting process of the most vulnerable, data protection measures, considerations to ensure that early actions do not cause harm and exacerbate existing conflict, considerations of accessibility due to potential violence or lack of infrastructure, the consequences of false alarm ratios which can lead to a lack of credibility in warning messages and effects on perceived neutrality and access of humanitarian organizations, among other challenges. Our results illustrate a significative statistical gap in this thematic area.

Planning is crucial to identify what actions can be effective to reduce risks and prepare for an effective disaster response, given the forecast lead-times available. Planning is also crucial to identify how feasible early actions are and to enable the defining of roles and responsibilities of different actors, ranging from the producers of warnings, logistics, implementation of actions, and monitoring to others. Academic research adds value to the early action planning stage, as it can inform robust evidence-based approaches, methods and alternatives that can enable actors to improve their delivery capacity of early action in conflict affected contexts. Academic research on conflict sensitivity for EWEA can also offer robust evidence and case studies to enable principles of do no harm and peacebuilding. For example in Honduras, (Peters *et al* 2022a) studied the experiences of an NGO integrating an inclusive social process into the EWEA implemented in neighbourhoods in Tegucigalpa affected by gang violence (Peters *et al* 2022b). This research shows the importance of integrating a conflict sensitivity lens into the design of EWEA, with important resulting recommendations documented by the UCL Research Warning centre (Peters *et al* 2022b).

This comprehensive literature review yielded only six papers on financing for EWEA in conflict settings (1.12%). Although there is a growing number of grey literature outputs on this thematic area (REAP 2023),

academic research is low. Countries affected by conflict are well known for not being able to access climate funds (Alcayna 2020, ICRC 2022), and for not prioritizing DRR investments given other competing priorities (Mena and Hilhorst 2020). Climate finance policy dialogues are advancing to advocate for more funding streams that enable adaptation for people affected by conflict (ICRC 2022), while within the academic literature this topic is nascent.

Finally, we argue that research on EWEA on conflict contexts is important to support decision making processes to decide the extent to which EWEA can in fact be carried out or not. Conflicts are diverse in intensity and scale, ranging from intercommunal tensions to regional to international conflicts, and with varying levels of intensity. Considerations of scale and intensity must be taken into account in the EWEA design and implementation.

5. Conclusion and recommendations

With a likely escalation of vulnerabilities and exposure of populations already affected by conflict, due to the compound effects of COVID-19 (2020–2023) that exacerbated a global socio- economic and political crisis, the Russia–Ukraine (since 2022) which has global cascading effects, plus impacts of climate variability and human induced climate change, it is essential to advance research that can be translated into practice and policy. The comprehensive literature review presented in this paper has focused on the state of **scientific evidence about EWEA for climate hazards in countries affected by non-international armed conflict.**

Overall, the following six conclusions drawn from our comprehensive literature review are as follows:

1. There is an imbalance of research across the six elements of the EWEA value chain. The follow order presents the thematic areas, from the highest to the lowest appearing in the academic literature: 1. hazard analysis, 2. forecasting availability and monitoring, 3. warning communication and dissemination, 4. early action planning, 5. understanding vulnerability and exposure, and 6. financing systems. 1 and 2 are the most prevalent across all the 20 countries of study, representing 75.65% of code occurrence in the 384 papers screened.
2. The screened papers focused on Ethiopia, Pakistan and Nigeria account for more than half of the total research part of this study (52.33%). In contrast, 12.44% of research focused on a much broader range of (generally poorer and more fragile) countries: Afghanistan, South Sudan, Sudan, Mali, occupied Palestinian territories, Cameroon, Democratic Republic of Congo, Syria, Central African Republic, Yemen and Libya.
3. There is a large gap between physical climate science (75.65%) and social science (24.35%) research focused on the subject. Most of the research focused on the physical aspects of the hazards and forecasting, and not on how to translate early warning into early action.
4. Conflict sensitivity and considerations of conflict dynamics in the context of EWEA research was very limited: only 3.4% of papers explicitly referred to conflict, insecurity or violence.
5. Hazards research is concentrated on floods, drought and rainfall, accounting for 74.96% of all occurrences in the screened papers. Extreme heat and humidity research account for 4.01% of the research.
6. There is growing evidence of the evolution of EWEA research in conflict affected contexts, from four papers identified in 2004 to 52 in 2022.
7. We show evidence of the emergence of research in new topics in the context of EWEA, such as the use of remote sensing (15.36%), machine learning (3.65%) and the application of impact based forecasting (1.04%). However, published research on these areas is limited.

Contexts affected by conflict are often laden with complex socio-economic, political factors and power dynamics, which can jeopardize initiatives and investment in risks reduction and adaptation. Joining other literature calling for a wider recognition of political factors in disasters in conflict areas (Siddiqi 2018) and the need for wider recognition of the climate-fragility-conflict nexus(Vivekananda *et al* 2014), we argue that national, regional and global research institutions and academics can produce research to offer a significative added value to (1) enhance evidence based decision making, (2) analyze in depth the socio-economic and political factors that can and cannot influence risks reduction efforts in the window of time between a forecast and a shock, and (3) contribute to design robust early action plans and financing processes and approaches to manage power dynamics and promote do no harm principles. This can ultimately ensure that people already affected by conflict are not again exposed to other conflict dynamics as a result of negative effects of EWEA interventions (or the lack of them).

Hazards research and forecast analysis and monitoring are still a massive gap in most of the countries analyzed. A 2022 historical analysis of weather forecasting in conflict affected countries showed that historically it would have been possible to use global weather forecast models to anticipate several crises (Jaime *et al* 2022). However in this paper we argue that it is equally important to continue investing in analyzing climate hazards, especially under a changing climate, as well as advancing forecast and monitoring capabilities with a focus on countries that have very limited research so far, as presented above.

We show limited research in relevant emerging topics such as impact based forecasting, an approach that in contexts affected by conflict could enable decision making for early action by considering the compound impacts of climate and conflict, given the physical aspects of hazards and the potential societal and humanitarian impacts they could have in already fragile populations.

Based on our findings, the following recommendations are intended to advance EWEA in contexts affected by armed conflict:

1 Invest in research co-produced between multidisciplinary research teams, including conflict experts and EWEA implementing actors who can lead robust evidence based approaches to enhance the entire value chain of EWEA. There is evidence of this in contexts not affected by conflict and there is an opportunity to invest and enable such collaborations in conflict-affected countries. Funders must ensure this approach is at the center of research opportunities.
2 Make social science research an integral part of EWEA research projects. Researchers specializing in peacebuilding, conflict sensitivity, and protection from the fields of sociology, anthropology, and international development can have a substantial impact on the design of EWEA systems. Awareness about the importance of these fields of research in the value chain of EWEA is crucial.
3 Put people affected by conflict at the center of the design of research of each of the thematic elements of EWEA to determine the effective use of warnings and its intended benefits, ensuring conflict sensitivity in all stages of the EWEA value chain.
4 Focus on further investment in hazard and forecast analysis in the countries with higher gaps presented in this paper, including Afghanistan, South Sudan, Sudan, Mali, occupied Palestinian territories, Cameroon, Democratic Republic of Congo, Syria, Central African Republic, Yemen and Libya.
5 Hazards and forecast related research must also include an acknowledgement of conflict dynamics in respective studies. Climate science cannot be detangled from socio-economic and political factors.
6 Increase process research on early and anticipatory planning and implementation to include documentation and analysis of issues relating accessibility, neutrality and impartiality when engaging with national governments and institutions (e.g. national hydro met services) in conflict contexts.

As a hallmark review of EWEA research focused on countries affected by non-international armed conflict, this paper contributes much-needed evidence about the need to recognize people affected by conflict in international climate and DRR frameworks such as the SFDRR midterm review. The findings presented here have the potential to inform EWEA investments and to promote tailored approaches appropriate for conflict-affected states.

Data availability statement

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References

Adetunji J 2018 *10 Years After, Cyclone Nargis Still Holds Lessons for Myanmar* (The Conversation) (available at: https://theconversation.com/10-years-after-cyclone-nargis-still-holds-lessons-for-myanmar-95039) (Accessed 11 February 2021)

Al- Jumur R K, Wahhab Kareem S M and Yousif Z R 2021 Predicting temperature of Erbil City applying deep learning and neural network *Indones. J. Electr. Eng. Comput. Sci.* **22** 944

Alcayna T 2020 *How Chronic Gaps in Adaptation Finance Expose the World's Poorest People to Climate Chaos AT WHAT COST?* (available at: https://floodresilience.net/resources/item/at-what-cost-how-chronic-gaps-in-adaptation-finance-expose-the-world-s-poorest-people-to-climate-chaos/) (Accessed 8 April 2022)

Ali M, Deo R C, Downs N J and Maraseni T 2018 Multi-stage hybridized online sequential extreme learning machine integrated with Markov Chain Monte Carlo copula-Bat algorithm for rainfall forecasting *Atmos. Res.* **213** 450–64

Azar E E, Jureidini P and Mclaurin R 1978 Protracted social conflict; theory and practice in the middle east *J. Palest. Stud.* **8** 41–60

Basher R 2006 Global early warning systems for natural hazards: systematic and people-centred *Phil. Trans. R. Soc.* **364** 2167–82

Benansio J S, Funk S M, Lino J L, Balli J J, Dante J O, Dendi D, Fa J E and Luiselli L 2022 Perceptions and attitudes towards climate change in fishing communities of the Sudd Wetlands, South Sudan *Reg. Environ. Change* **22** 78

Berrang-Ford L *et al* 2021 The global adaptation mapping initiative (GAMI): part 1—introduction and overview of methods *Protocol Exchange* pp 2–9

Brown M E 2009 Biophysical remote sensing and climate data in famine early warning systems *Geogr. Compass* **3** 1381–407

Chandra A, McNamara K E, Dargusch P, Caspe A M and Dalabajan D 2017 Gendered vulnerabilities of smallholder farmers to climate change in conflict-prone areas: a case study from Mindanao, Philippines *J. Rural Stud.* **50** 45–59

Claghorn J, Orsini F M, Restrepo C A E and Werthmann C 2015 Rehabitar la Montaña: strategies and processes for sustainable communities in the mountainous periphery of Medellín *urbe, Rev. Bras. Gest. Urbana* **8** 42–60

Coughlan de Perez E, van Aalst M, Choularton R, van den Hurk B, Mason S, Nissan H and Schwager S 2019 From rain to famine: assessing the utility of rainfall observations and seasonal forecasts to anticipate food insecurity in East Africa *Food Security* **11** 57–68

CREWS 2021 *CREWS Report 2021. Rising to the Challenge in Complex Crises* (available at: www.designplus.hr)

De Wit S 2019 'Getting ahead of crises: a Thesaurus for anticipatory humanitarian action' (June) pp 1–40 (available at: https://cerf.un.org/sites/default/files/resources/Thesaurus_singlecolumn_WORKING_DRAFT.pdf)

Eriksen S and Lind J 2005 *The Impacts of Conflict on Household Vulnerability to Climate Stress: Evidence from Turkana and Kitui Districts in Kenya* Asker (available at: http://eprints.lse.ac.uk/24839/) (Accessed 6 June 2020)

Ezemenaka K E and Ekumaoko C E 2022 Beyond language: further issues in the Anglophone Cameroon conflict *Soc. Identities* **28** 200–16

Funk C *et al* 2013 Blending local scale information for developing agricultural resilience in Ethiopia *Climate Vulnerability* (Elsevier) pp 165–75

GRC, Climate Centre and IFRC 2020 *Forecast-Based Financing Manual* (available at: https://manual.forecast-based-financing.org/) (Accessed 16 June 2020)

Howe B 2018 'Cyclone Nargis in Myanmar: The Perfect Storm? *Security, Development and Human Rights in East Asia* (Springer) pp 111–32

ICRC 2016 *Protracted Conflict and Humanitarian Action: Some Recent ICRC Experiences, International Committee of the Red Cross* (available at: www.icrc.org) (Accessed 18 March 2020)

ICRC 2019 *International Humanitarian Law a Comprehensive Introduction* (available at: https://shop.icrc.org/international-humanitarian-law-a-comprehensive-introduction-2891.html)

ICRC 2020 *When Rain Turns to Dust: Understanding and Responding to the Combined Impact of Armed Conflicts and the Climate and Environment Crisis on people's lives* (available at: www.icrc.org/en/publication/4487-when-rain-turns-dust) (Accessed 9 July 2020)

ICRC 2022 *Embracing Discomfort: A Call to Enable Finance for Climate-Change Adaptation in Conflict Settings* (available at: https://shop.icrc.org/embracing-discomfort-a-call-to-enable-finance-for-climate-change-adaptation-in-conflict-settings-pdf-en.html) (Accessed 22 January 2023)

Ide T, Brzoska M, Donges J F and Schleussner C-F 2020 Multi-method evidence for when and how climate-related disasters contribute to armed conflict risk *Glob. Environ. Change* **62** 102063

IDMC 2020 *Global Internal Displacement Database* (available at: www.internal-displacement.org/database/displacement-data) (Accessed 9 October 2020)

Idris A *et al* 2013 *Conflict Management and Disaster Risk Reduction: A Case Study of Kenya* (available at: www.irinnews.org/photo/) (Accessed: 17 June 2020)

IFRC 2009 *World Disaster Report 2009: Focus on Early Warning, Early Action* (available at: www.ifrc.org/PageFiles/99875/2009/WDR2009-full.pdf) (Accessed 16 June 2020)

IISS 2019 *When Disaster Meets Conflict. International Institute of Social Studies* (Erasmus University Rotterdam) (available at: www.coursera.org/learn/whendisastermeetsconflict/lecture/mu5mb/disaster-risk-reduction-in-drr-in-high-conflict-scenarios) (Accessed 8 June 2020)

IPCC 2021 *Climate Change 2021: The Physical Science Basis* (available at: www.ipcc.ch/report/ar6/wg1/) (Accessed 8 June 2022)

Jaime C, Coughlan de Perez E, van Aalst M, Raju E and Sheaffer A 2022 What was known: weather forecast availability and communication in conflict-affected countries *Int. J. Disaster Risk Reduct.* **83** 103421

Jaspars S and Maxwell D 2009 *Food Security and Livelihoods Programming in Conflict: a Review. 65* (available at: www.researchgate.net/publication/284727467_Food_security_and_livelihoods_programming_in_conflict_a_review) (Accessed: 9 May 2020)

Kah H K 2015 Understanding Conflicts in Cameroon History through' Awilo' s' Song' Contri Don Spoil' *East West J. Bus. And Soc. Stud.* **4** 80–97 (available at: www.academia.edu/68817013/Understanding_Conflicts_in_Cameroon_History_through_Awilos_Song_Contri_Don_Spoil)

Mach K J *et al* 2019 Climate as a risk factor for armed conflict Katharine *Nature* **571** 1–26

Mach K J *et al* 2020 Directions for research on climate and conflict *Earth's Future* **8** e2020EF001532

Majid N and Mcdowell S 2012 Hidden dimensions of the Somalia famine *Glob. Food Secur.* **1** 36–42

Mena R 2021 *Disaster Response and DRR Inhigh-Intensity Conflict Settings* (available at: www.iss.nl/en/media/2021-01-hic-brief-final) (Accessed 8 March 2022)

Mena R and Hilhorst D 2020 The (im)possibilities of disaster risk reduction in the context of high-intensity conflict: the case of Afghanistan *Environ. Hazards* **20** 1–21

Mena R, Hilhorst D and Peters K 2019 *The Case of Afghanistan* (available at: www.odi.org/publications/) (Accessed 18 March 2020)

Mohanty A, Hussain M, Mishra M, Kattel D B and Pal I 2019 Exploring community resilience and early warning solution for flash floods, debris flow and landslides in conflict prone villages of Badakhshan, Afghanistan *Int. J. Disaster Risk Reduct.* **33** 5–15

Montaud J-M 2019 Agricultural drought impacts on crops sector and adaptation options in Mali: a macroeconomic computable general equilibrium analysis *Environ. Dev. Econ.* **24** 506–28

Nay J, Burchfield E and Gilligan J 2018 A machine-learning approach to forecasting remotely sensed vegetation health *Int. J. Remote Sens.* **39** 1800–16

Olmedo C A and Del Miño P G G 2019 The Sahel: cross-border dimension and geopolitical dynamics *Geopolitica(s)* **10** 281–303

Ozcelik C and Doocy S 2012 Storm surge modelling with geographic information systems: estimating areas and population affected by cyclone Nargis' *Int. J. Climatol.* **107** 95–107

Peters K 2019a *Disaster Risk Reduction in Conflict Contexts An Agenda for Action* (available at: www.odi.org/publications/) (Accessed 18 March 2020)

Peters K *et al* 2019b *Pursuing Disaster Risk Reduction on Fractured Foundations The case of Chad* (available at: www.odi.org/publications/) (Accessed 18 March 2020)

Peters L E R, Clark-Ginsberg A, McCaul B, Cáceres G, Nuñez A L, Balagna J, López A, Patel S S, Patel R B and Van Den Hoek J 2022a Informality, violence, and disaster risks: coproducing inclusive early warning and response systems in urban informal settlements in Honduras *Front. Clim.* **4** 937244

Peters L E R, McCaul B and Caceres G 2022b *Warnings in Violence and Conflict: Coproducing Warnings With and for Those Most at Risk* (available at: www.ucl.ac.uk/sts/wrc)

Policinski E and Kuzmanovic J 2019 Protracted conflicts: the enduring legacy of endless war *Int. Rev. Red Cross* **101** 965–76

Quinn J, Stoeva P, Zelený T, Nanda T, Tomanová A and Bencko V 2017 Public health crisis: the need for primary prevention in failed and fragile states *Cent. Eur. J. Public Health* **25** 171–6

Reale O, Lau W K, Susskind J, Brin E, Liu E, Riishojgaard L P, Fuentes M and Rosenberg R 2009 AIRS impact on the analysis and forecast track of tropical cyclone Nargis in a global data assimilation and forecasting system *Geophys. Res. Lett.* **36** L06812

REAP 2022 'Glossary of Early Action Terms' (available at: www.early-action-reap.org/glossary-early-action-terms-2022-edition)

REAP 2023 *Early action—The State of Play 2023* (available at: www.early-action-reap.org/sites/default/files/2023-02/20230214_REAP_StateofPlay_FINAL.pdf)

Sansa-Otim J *et al* 2022 An assessment of the effectiveness of weather information dissemination among farmers and policy makers *Sustainability* **14** 3870

Schleussner C F, Donges J F, Donner R V and Schellnhuber H J 2016 Armed-conflict risks enhanced by climate-related disasters in ethnically fractionalized countries *Proc. Natl Acad. Sci. USA* **113** 9216–21

Shah A A, Ajiang C, Khan N A, Alotaibi B A and Tariq M A U R 2022 Flood risk perception and its attributes among rural households under developing country conditions: the case of Pakistan *Water* **14** 992

Siddiqi A 2018 Disasters in conflict areas: finding the politics *Disasters* **42** S161–S172

Sitati A *et al* 2021 Climate change adaptation in conflict-affected countries: a systematic assessment of evidence *Discov. Sustain.* **2** 42

Tolulope Olayemi O, Oyekale A and Oyedepo J 2015 Farm households' perceptions on climate change and willingness to subscribe for advisory weather forecasts in South West Nigeria *Disaster Adv.* **8** 8–19 (available at: www.researchgate.net/publication/362015762_Farm_Households'_Perceptions)

UCDP 2020a *No Title, Department of Peace and Conflict Research, Uppsala University* (available at: www.pcr.uu.se/research/ucdp/definitions/) (Accessed 17 June 2020)

UCDP 2020b *Uppsala Conflict Data Program Dataset* (available at: https://ucdp.uu.se/downloads/index.html#ged_global) (Accessed 9 October 2020)

UKMO 2020 *WISER MENA Scoping Report: Opportunities for Improved Weather and Climate Information in the MENA Region* Exeter (available at: www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/business/international/wiser/wiser-mena-scoping-study-external-v2.pdf) (Accessed 8 January 2023)

UNDP 2011 *Disaster-Conflict Interface analysis Comparative experiences* (available at: www.undp.org/cpr) (Accessed 23 January 2020)

UNDRR 2005 *Hyogo Framework for Action 2005–2015* (available at: www.unisdr.org/wcdr) (Accessed 17 June 2020)

UNDRR 2015 *Sendai Framework for Disaster Risk Reduction 2015–2030 | UNDRR* (available at: www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030) (Accessed 8 June 2020)

Vivekananda J, Schilling J and Smith D 2014 Climate resilience in fragile and conflict-affected societies: concepts and approaches *Dev. Pract.* **24** 487–501

Wisner B 2012 Violent conflict, natural hazards and disaster *The Routledge Handbook of Hazards and Disaster Risk Reduction* 1st edn (Routledge) pp 65–76

WMO 2021 *Guidelines on Multi-hazard Impact-based Forecast and Warning Services Part II: Putting Multi-hazard IBFWS into Practice* (available at: https://library.wmo.int/index.php?lvl=notice_display&id=17257) (Accessed 18 August 2022)

WMO 2022 *The UN Global Early Warning Initiative for the Implementation of Climate Adaptation* (WMO Website) (available at: https://public.wmo.int/en/our-mandate/climate/early-warnings-for-all) (Accessed 6 October 2022)

World Bank 2019 *Sand and Dust Storms in the Middle East and North Africa Region—Sources, Costs, and Solutions* (available at: https://documents1.worldbank.org/curated/en/483941576489819272/pdf/SAND-AND-DUST-STORMS-IN-THE-MIDDLE-EAST-AND-NORTH-AFRICA-MENA-REGION-SOURCES-COSTS-AND-SOLUTIONS.pdf)

Zaman S, Sammonds P, Ahmed B and Rahman T 2020 Disaster risk reduction in conflict contexts: lessons learned from the lived experiences of Rohingya refugees in Cox's bazar, Bangladesh *Int. J. Disaster Risk Reduct.* **50** 101694

Zare A, Barbier B, Bologo-Traore M, Diarra A, Mahe G and Paturel J-E 2017 Climate forecast perception and needs in wetlands: a case study in the inner Niger Delta in Mali *Wetlands* **37** 913–23