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# Harbingers of decades of unnatural disasters

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Extreme weather events and their impacts have dominated headlines throughout 2021 and 2022. The emphasis on the weather in reports of the events, often discussed in the context of climate change, has led many to believe that these disasters would not have happened without human-induced warming. However, our compilation of severe weather-related hazards and the most severe related disasters in those two years reveals that ultimately, all the listed disasters resulted from existing vulnerabilities and compounding stresses on social systems. Climate change often made the hazard worse, but much of the damage could have been prevented. We emphasise that the reporting of disasters should routinely address not only the weather-related hazards and humans' role in changing the odds, but also vulnerability in order to guide disaster risk reduction and avoid risk creation processes.

Climate change is not happening at some point in the future. Instead past and present burning of fossil fuels is contributing to disasters that kill people and destroy livelihoods here and now. 2021 brought not only devastating extreme events across the globe (see Fig. 1). But with the publication of the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC) also brought the clearest scientific evidence of what is causing these hazards[1]. 2022 brought further extreme weather (see Fig. 2) but also political reactions, most noticeably in the form of a decision to establish a loss and damage fund at the 27th Conference of the Party (COP 27) in Sharm El Sheik.

These hazards are, in many cases, not purely natural anymore, as a result of anthropogenic climate change. Nevertheless, also unnatural hazards only become disasters when they interact with exposure and vulnerability. The latter is constructed by socio-political processes, e.g. colonial structures leading to dysfunctional governments[2] and poorly designed developmental projects[3], and are in general not global but national or sub-national processes[4]. A fact that is often missing from the public discussions and even the summary for policy makers of the synthesis report of the IPCC 6th assessment report mention vulnerability only once (paragraph A2.2) in the context of current impacts but not at all with respect to adaptation.

A focus solely on climate and hazard in the context of disasters creates a discourse that deflects responsibility from the human actions that produce vulnerability and often also exposure. On the other hand, ignoring the context of climate change deflects responsibility from nations and corporations in the Global North and risks ignoring potentially dramatic shifts in the hazards that have the potential to undo any developmental gains[4].

Working on the example of extremes in the years 2021 and 2022, we show how the complex interplays between the natural world and human societies have led to some of the most devastating disasters. Many of the impacts of the extreme events we list could have been avoided[5]. Some of them have made global headlines; others have been completely ignored by the global media.

The aim of our synthesis is twofold: firstly, we provide a review of the most impactful weather and climate-related hazards and resulting disasters of the last 2 years in the context of climate change and vulnerability. Secondly, we argue that establishing a mechanism recording these types of disasters on an ongoing basis in the way suggested here, including information on the role of climate change alongside humanitarian impacts, would lead to better reporting and ultimately better responses to weather-related

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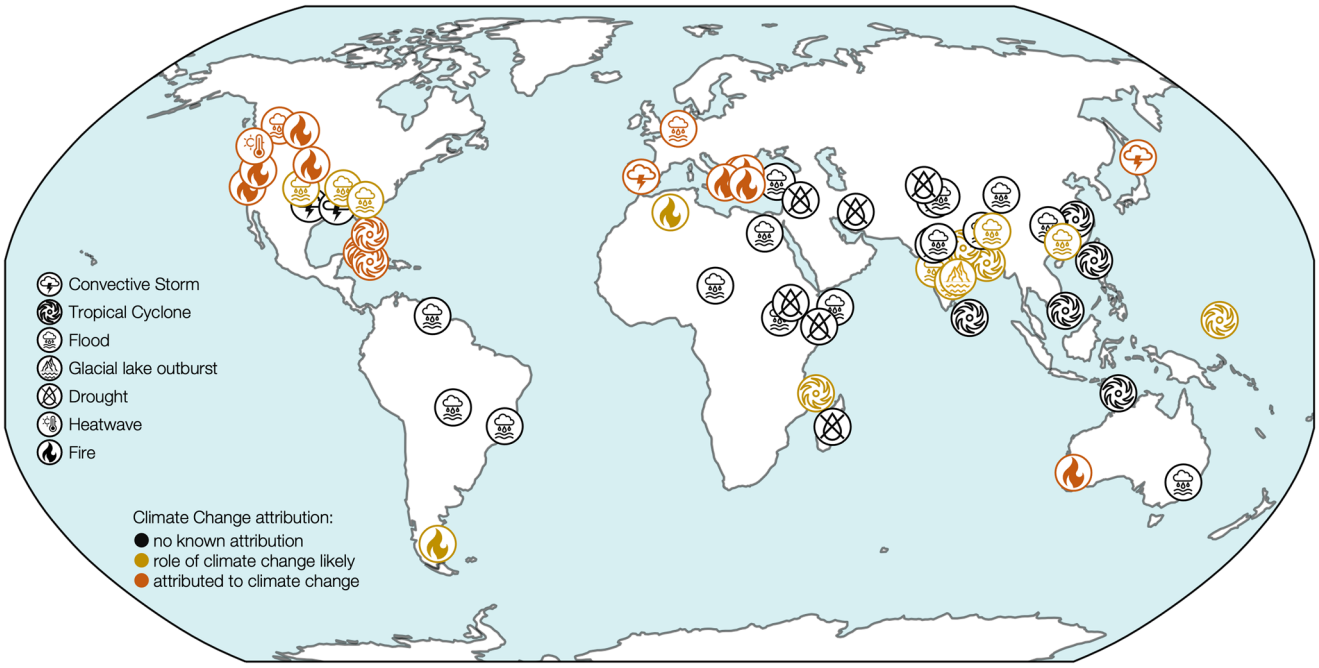


**Fig. 1 Most impactful weather and climate-related disasters of 2021 and the extent to which we know the role of human-induced climate change.** The most impactful weather events are shown as symbols. Events which can be clearly attributed to human-induced climate change are shown in red, events for which no studies but enough background literature exists are shown in yellow and events indicated in black have either been studied, but no link to climate change has been found or no literature exists. The symbols are placed approximately in the area of the occurrence of the event. The assessment is based on published literature either of the event itself (events in red) or an event off the same category in the same region (events in yellow). The references for each individual event can be found in Table S1.

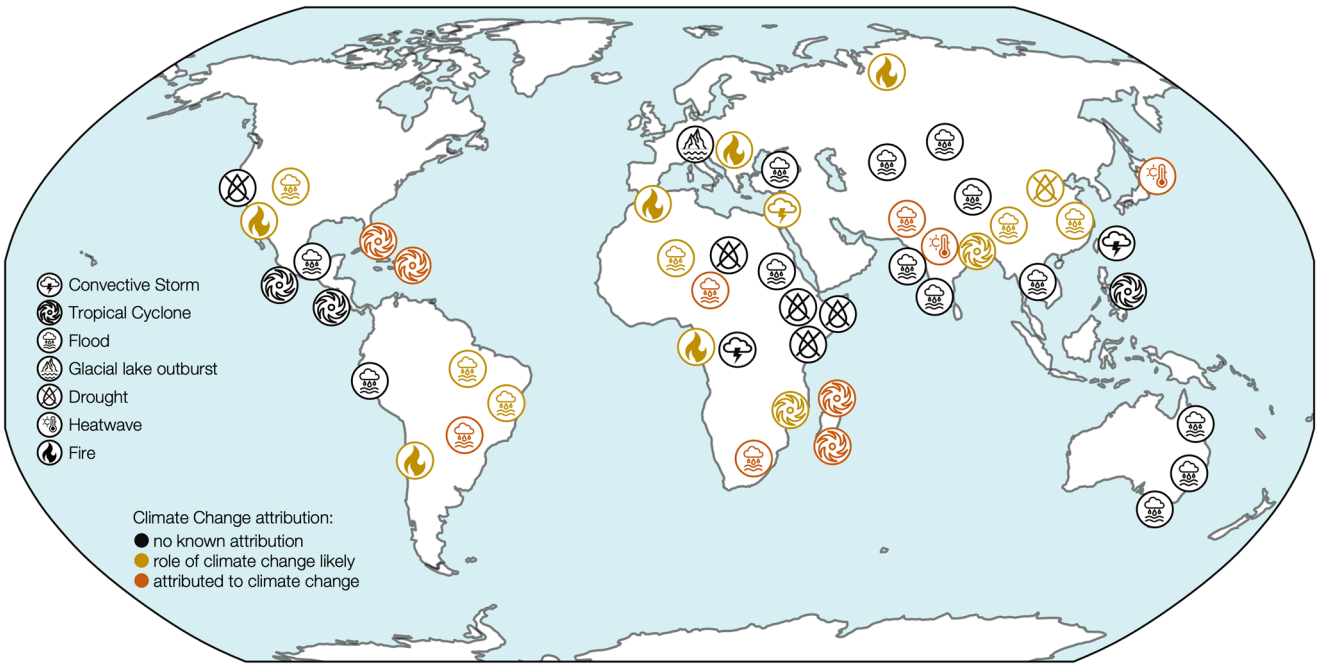


**Fig. 2 Most impactful weather and climate-related disasters of 2022 and the extent to which we know the role of human-induced climate change.** As Fig. 1 but for events occurring in 2022.

hazards and resulting disasters by neither ignoring the role of climate change nor the role of vulnerability.

## The hazards of 2021/22

The most complete global data base for disasters from a humanitarian point view, em-dat[6], hosted by the University of Louvain in Belgium, collects and classifies information on disasters as they occur around the world. Next to earthquakes and technological disasters, there are three categories of disasters that are primarily linked to extreme weather events. These are: meteorological events, i.e. heat waves and storms, hydrological, i.e. floods, and climatological, i.e. droughts and wildfires[6]. For the year 2021, all three categories of climate-linked hazard-related disasters

combined have 351 separate entries, affecting over 70,000,000 people, leading to 182,479,722,000 US$ reported economic losses and 6920 reported deaths. Figure 1 summarises for each of the three categories the ten entries with most deaths, most affected people and highest economic costs (see also Table S1). As some of the disasters are simultaneously among the 10 deadliest and 10 costliest and also are linked to the same weather and climate-related event, there are fewer than 90 distinct events. We do the same for the disasters of 2022, where overall 42,372,628,000 US$ of losses were reported, 11,376 reported deaths and more than 83,000,000 people affected by disasters. The full lists as well as the tables used to produce Fig. 1 can be found in the SI following the design suggested in Clarke et al.[7]. The events are colour-coded according to the role of climate change in the hazards, with red identifying events that have a clear climate change signal, based on an explicit study (references in Table S1), yellow those that have very likely a climate change signal based on existing studies in the literature on similar types of events (references in Table S1).

In most cases, no dedicated study exists that allows attributing the role of climate change quantitatively for the specific event, however in some cases events of the same type in the same region have been assessed in an attribution study or the IPCC, in which case we are still able to provide an estimate of the role of climate change. For example, hurricanes Ida, Elsa and Fred hit the Caribbean and the US in 2021, killed over 100 people and led to very high economic damages and long-term impacts. There is no attribution study on the specific storms, but many hurricanes in the same area and season have been analysed[8,9] with all studies finding an increase in intensity and frequency of the associated rainfall attributable to human caused climate change, including the latest IPCC report where such an increase is assessed with high confidence. Therefore our assessment for hurricane Ida, as well as Fiona is also that climate change did make the impacts worse. For tropical cyclones Odette, Seroja-21, Noru and others costing many more lives in the Pacific we do however not know what the role of climate change is as much fewer studies on pacific storms exists and those that do exist have inconclusive results[10,11].

For the hydrological-related hazards and disasters, i.e. floods, we do have attribution studies, and concrete estimates of the role of climate change in the deadliest flood in the global North, leading to over 250 deaths in Germany, Belgium and the Netherlands. Also, for prominently reported floods in Pakistan and Nigeria in 2022, leading to over 2000 reported deaths. But we do not have similar estimates for the monsoon floods costing more than 1000 Indian lives in 2021 and again in 2022 or for all the other flood-related disasters occurring in the world. Flood attribution is however more difficult than the attribution of other types of extreme events as the local hydrology plays a crucial role in addition to the meteorological event, requiring bespoke models rather than state-of-the-art climate models alone[12,13]. Thus, only if studies in the same region and season exist we assess an event as "attribution suspected", as e.g. for floods on the East coast of Brazil, but not the West in 2022.

The climatological events of the last 2 years are primarily wildfires and droughts. While we often lack concrete studies for wildfires, many studies in recent years have shown that due to the strong increase in hot extremes, the risk of wildfires has also increased due to climate change[14,15]. In this case, we assign them "attribution suspected". Droughts are those events of 2021 and 2022 that have affected most people and they primarily occurred in Africa and the middle East. Attribution studies for events in the middle East do not exist, but for Eastern Africa and Madagascar, where some of the most disastrous events happened, they do, and have consistently found anthropogenic climate change to play a small or negligible role. This is in contrast to droughts in Southern Africa or the Mediterranean. Further, the two deadliest climatological events of 2021 were a different type of event however, so-called GLOFs, Glacier Lake Outburst Floods. Such events do occur naturally from time to time, but with the melting of glaciers strongly attributed to anthropogenic climate change, the increasing risk of such floods has in the past been attributed to human-caused climate change[16]. However, the more impactful of these GLOFs has later been identified as an avalanche that was not connected to a glacier lake outburst[17]. The authors suspect anthropogenic climate change to have played an important role in this avalanche as melting snow and ice destabilises the mountain system overall. How and to what extent and with what consequences is however poorly understood and given the large impacts of these events needs more research. Climatological events, despite the fact that they affect most people are thus still comparably understudied and need more research.

Overall, this analysis of climate and weather-related hazards of the last 2 years that led to disasters reveals a few important patterns, illustrated in Figs. 1 and 2. First, there is only one heatwave in 2021 that has been classified as such, and that is the one affecting Canada and the north western US[18] underlining the lack of reporting and awareness of heatwaves in the global South, particularly in Africa[19]. Second, there is a huge discrepancy between our knowledge of the role of climate change for events occurring in the global North compared to the global South with many more attribution studies conducted in the former[20,21]. Third, floods and droughts are affecting a particularly large number of people compared to, e.g. tropical cyclones in the global North which are however the costliest disasters in terms of known economic damages. There are many countries, in particular in the middle East and Asia, that suffered several floods and droughts in 2021 and in 2022, including Afghanistan and Iran. No attribution studies exist for that part of the world, nor does the IPCC assessment allow for any conclusions on the role of climate change to be drawn, nor have these events received any media attention despite the wide reporting on political events in 2022 in the region.

While no systematic global media analysis exists yet, we observed the extremes that led to disasters in 2021 and 2022 making headlines not only in local and national news, but internationally when they occurred in the global North. This includes events like the drought in Europe in 2022 that is not in the table as humanitarian impacts are small. This is clearly not the case for disasters in the Global South, with one notable exception, the drought in Madagascar and the floods in Pakistan which coincided with the COP 27. Thus, 2021 and 2022 media followed the pattern observed before[22] with a focus on climate change on global North events and with little focus on vulnerability in the global South. Below we provide details about the drought in Madagascar, the tropical cyclone Yaas, that hit India and Bangladesh in 2021 and the heatwave that affected parts of India and Pakistan in 2022, to show that both, vulnerability and climate change are important to understand these disasters and corroborate our hypothesis that we need better reporting on both to ultimately adapt better and avoid further risk creation.

**Three disasters, four countries, very different vulnerabilities**. Yaas made landfall on the Indian coast in West Bengal and Odisha on the 26th of May, reaching the West coast of Bangladesh in the evening of the same day where it led to particularly high tidal waves of 6–8 feet above normal high tides. The storm also struck areas that were hit by Cyclone Amphan in 2020 and were still struggling with the aftermath and thus not only led to additional damage but impeded the ability to recover[23,24].

A key obstacle in understanding the role of climate change in tropical cyclones is the lack of a clear theoretical understanding of how cyclones change in a warmer world, given that two effects are competing: warmer oceans provide conditions for stronger cyclones to develop while a more stable tropical atmosphere is associated with a decrease in cyclones[25]. Furthermore reliable observations of tropical cyclones exist only for a short timespan outside of the North Atlantic, rendering the testing of theories as well as attribution studies difficult. There have thus not been attribution studies for Cyclone Yaas, or Amphan or the Bay of Bengal more broadly. However, while the role of climate change on tropical cyclones in this area clearly needs more investigation, the studies that do exist in other parts of the world still allow some conclusions that apply outside of the North Atlantic to be drawn.

Heavy precipitation associated with tropical cyclones is increasing as well as storm surge heights due to sea level rise[25]. Both of these factors mean that for any given storm damages associated with tropical cyclones like Yaas are worse due to human-induced climate change. This is relevant for Yaas, given the storm surge was particularly damaging and storm surges have been shown to have become worse due to climate change in the Bay of Bengal[26]. In addition, while globally the overall frequency of tropical cyclones is not changing, and might even be declining[27] we do observe an increase in the proportion of major tropical cyclones[1] globally which again points to an increase in the damages in the wake of tropical cyclones because of human induced climate change.

Therefore, even in the absence of concrete attribution studies we can conclude that anthropogenic climate change is an important driver of the damages resulting from Yaas, even if it is uncertain if the storm intensity itself is affected we cannot quantify the contribution in the hazard itself without a dedicated study. This is further supported when looking at some of the most impactful tropical cyclones occurring in 2022, also in the Indian Ocean, hitting Madagascar, Mozambique and Malawi for which an attribution study confirmed that climate change indeed increased the intensity of the associated rainfall (see Table S2).

The role climate change is playing with respect to cyclone Yaas and other extremes of 2022 that have hit particularly South Asia[28] is in contrast to other devastating extreme events of 2021, notably the drought affecting Southern Madagascar. Over the 24 months from July 2019 to June 2021 rainfall was very low, estimated as approximately a 1-in-135 year dry event, and in the observed record only surpassed in severity by a severe drought in 1990–92. Based on a recent attribution study conducted by a large group of scientists[29], the occurrence of poor rains as observed from July 2019 to June 2021 has not significantly increased due to anthropogenic climate change. Importantly, this result is consistent with previous research on droughts in the region[30,31] and in line with the IPCC's Sixth Assessment Report[1] which does not expect changes in drought frequency and intensity at current warming levels. Only if global mean temperatures exceed 2 °C above pre-industrial levels an increase in drought is projected.

As described in Zachariah et al.[28], temperatures during the pre-monsoon season 2022 across large parts of India and Pakistan were consistently 3–8 °C above average, breaking many decadal and some all-time records in several parts of India, including the western Himalayas, the plains of Punjab, Haryana, Delhi, Rajasthan and Uttar Pradesh. In Pakistan many individual weather stations recording monthly all-time highs in March. By April almost 70% of India was affected by the heatwave. In Pakistan, temperatures above 49 °C were recorded in Jacobabad in Sindh, and 30% of the country was affected by the heatwave. Towards the end of April and in May, the heatwave extended into the coastal areas and eastern parts of India. An attribution study[28] estimated that while still an extreme event today, this heatwave would have been extremely rare without climate change but is expected to very regularly in a 2C-world. This is remarkable as the Indian subcontinent has until as late as 2016 seen little increase in extreme heat in large areas[32]. The last 2 years have shown that even if maximum temperatures show small trends in some parts, this does not hold for average temperatures and trends in maximum temperatures are emerging[25,28].

## The disasters of 2021/22

The section above highlights that in regions, not new to disasters, the nature of these disasters has changed and will continue to do so with anthropogenic climate change.

While disasters are not new, it is important to stress that disasters occur when natural (and unnatural) hazards meet vulnerability. Countries such as India and Bangladesh have successfully implemented cyclone preparedness programmes as well as heat-action plans in many areas with significant reduction in loss to life. However, loss of livelihoods, property and other non-economic losses and damages (Boyd et al.[33]) continue to exist as seen during Yaas and other disasters that affect this region every year. Vulnerabilities are constructed over a long period of time. For example, in South Asia, caste based discrimination continues to exist which deter certain groups of people in moving towards upward social and economic mobility. This has also been seen during disasters such as Cyclone Yaas where some upper caste families did not allow dalits to enter the evacuation shelters in Mayurbhanj district[34]. Many parts of Southern Bangladesh had faced some of the worst impacts during cyclones Aila in 2009 and Sidr in 2007[31] continue to struggle. During one of the author's field visit to Sathkira in 2011, which was also one of the affected areas during Yaas, it was observed that disasters were considered part of an annual process and people living with risks continue to be caught between cyclones and tigers in Sundarbans[35]. This highlights, that reporting on longstanding vulnerabilities and understanding how they change with climate change is both crucial to understand today's unnatural disasters.

In Madagascar, particularly the "le Grand Sud" region, although the meteorological drought has not been made more likely by climate change, it is a disaster with devastating consequences for the local populations. Madagascar ranks 164 on the Human Development Index, with signs of progress on the economy and political stability[36]. However, the drought potentially puts Madagascar's slow progress in jeopardy as disasters tend to set back development processes. Unfortunately, this did not receive global attention for a long time. Like in many other places, the visible impacts of droughts such as food insecurity, malnutrition, hunger, agrarian distress are only occurring towards the end of a period of suffering, when preparedness that would have been possible earlier is hardly seen but immediate disaster response is required. Many updates from The Famine Early Warning Systems Network (FEWS NET) in 2020, highlight loss of wages, people on the move going back to the rural areas due to loss of work, and the drought situation being complicated with the pandemic restrictions[37]. The Southern region is poorly connected in terms of infrastructure[38] which makes it hard for humanitarian aid to reach, again highlighting a development problem. This drought spanning over a long period of time, complicated with the ongoing COVID-19 pandemic has thus further exacerbated people's poverty (see Harrington et al.[29]), including a lack of seeds to plant in the next season, potentially prolonging the cycle of poor harvests and extreme poverty well beyond the end of the physical hazard. Yet another case to highlight that disasters are rarely natural and that only taking the hazard as well as different aspects of vulnerability into account

allows to identify the important drivers of disasters and consequently where to focus development and adaptation efforts. Below important dimensions of vulnerability, that ideally would be part of a systematic reporting, are highlighted.

Research on Bangladesh highlights that cyclone shelters also independent of a pandemic can be considered unsafe due to range of factors by different groups of people making evacuation difficult for particular demographics and in turn increasing the impacts on these populations[39]. Due to this security issue, women and girls may not consider going to the cyclone shelter as an option.

Taking gender as an example, a recent review highlighted rigid gender beliefs and gender roles of women, discriminatory policies and practices against women, and lack of women's leadership in socio-economic and political environments influenced women's capacities and vulnerabilities to disasters. A study from Ambovombe Androy in Madagascar[40] highlights social structures, existing norms, lack of importance to girl child education as some of the key factors contributing to vulnerability and these factors always have long-term repercussions, thereby increasing vulnerability to disasters. Another example, highlighted during the pandemic showed that men seem to migrate within the country for work and this could have made matters worse during the pandemic lockdowns and less availability of work.

In India, there has been huge impacts on household remittances and women headed households in the rural areas during the pandemic[41]. These impacts may have been seen in other places such as Madagascar too. It is very common during disasters to use existing savings to cope with immediate impacts. However, these savings may not last very long and affected populations may start borrowing from less formal sources such as local money lenders. Over a long period of time, this results in disaster debts which are a common phenomenon in India and Bangladesh. A recent study highlighted that micro-credit provides for immediate coping and may leave populations with "increased debt (microcredit and/or informal credit), and loan default, 'trapping' at-risk people in indebtedness"[42]. While gender dimensions and coping strategies that increase vulnerability are studied in disaster research, they are not categories commonly used in reporting on weather and climate-related hazards and disasters and are rarely considered sufficiently in adaptation strategies[42].

Effective communication is key for successful disaster evacuation and disaster preparedness[43,44]. India and Bangladesh are hailed as disaster evacuation champions and have very successful examples of evacuating over a million people to safety. This has been a result of long-term investments in early warnings, community level communication and evacuation procedures. Early-warnings are also well established in the United States and Germany, both the heatwave and the floods in these countries in 2021 have been well forecast[45]. However, in Germany, these warnings did not reach the affected population, leading to a significant number of deaths in an economically prosperous region, highlighting, that the communication with the potentially affected population is at least as important having established early warning systems. While there is an increase in use of different social media during disasters, research shows that most of the focus remains on technology and less on the people impacted by disasters[46].

In Madagascar, while there has been progress in making disaster risk management plans[29], the response to the drought nationally and globally highlights that vulnerability reduction has not been a priority. Another example from South Asia, the Nepal floods of 2021 during the COVID-19 pandemic also sends the same message to address different forms of vulnerability[47]. Nepal was devastated during the 2015 earthquake, a textbook example of how disasters and development are inter-connected. Nepal is faced with landslides and floods every year and vulnerability remains a constant problem. Therefore, disaster risk reduction will not be effective with only disaster preparedness that does not address the root causes of vulnerability and lack of capacities[48]. This conclusion can also be drawn when looking at the heat wave in parts of India and Pakistan[28] which has shown that the same vulnerable populations and many others affected disproportionately during COVID-19 are also affected during the heatwave. Lack of access to basic health and other social protection infrastructure has shown to exacerbate disaster impacts.

The type of livelihood activity clearly determined people's exposure to heat and the lack of choice to escape the heat is a sign of vulnerability contributing to risk. Communities dependent on agriculture were worst hit due to low crop yield. Further, the heatwave also had far reaching compounding risks such as fires and energy crisis (Zachariah et al.[28]). We need better disaster reporting and documentation on heatwaves as most heatwave deaths go under reported[49]. Much more work needs to be done for heat action plans to be effective across the region and in many other parts of the world. This does not only hold for heatwaves in the global South but also the global North. Highlighted by Human Rights Watch[50], Canada was not prepared to protect the most vulnerable part of the population from the extreme heatwave 2021, similarly during the 2022 heatwave in the UK[51], economically poor people suffered the most severe impacts as London is a city where the urban heat island effect is particularly unequal affecting lower-income neighbourhoods far worse than the rest of the city[52].

A discussion on disaster governance and vulnerability to disasters is not only about the impacts seen but also about the factors that lead to these impacts[4,53]. Lack of disaster-related insurances, insufficient compensation to rebuild livelihoods makes disaster recovery a never ending process of disaster risk (re)creation; and further marginalisation. For example, all disasters in 2021 occurred while countries were also going through the COVID-19 second or third wave which made disaster evacuation and relief challenging. All disasters of 2022 occurred in countries where health-services and other social infrastructure was severely weakened by the pandemic.

The example of Germany shows economic prosperity alone is no guarantee for low impacts. Similarly not for low vulnerability as in the UK or US where inequity within country is high. The disaster-development nexus continues to be a huge challenge as most of the discussions within disaster risk management continues to be around disaster response and/or on the natural hazard component. Discussions around the Sustainable Development Goals continue to remain a rhetoric and isolated from reporting on climate change and extreme weather. Research shows that adaptation projects overlook important factors of vulnerability and also have create new forms of vulnerability[54]. All examples show that without reducing structural vulnerabilities, adaptation will not be efficient and not address what matters to people[55]. In all countries, including the champions, there is a long way to go in reducing structural vulnerabilities which make disaster impacts worse and thus needs to be central to any adaptation planning. For the latter, changes in the hazard vis a vis existing and changing risks and vulnerabilities are equally important.

## Towards better extreme reporting

Better reporting can be done, even without dedicated studies needing to be developed for individual hazard events. The examples, e.g., the drought in Madagascar and the heat wave show that some comparably easy to access scientific knowledge[21]

on the expected role of climate change in these very different events is available. While this does not replace attribution studies, the knowledge we have now goes a long way to avoid over and understating the role of climate change in disasters and can be used to inform messaging in the immediate context of the event, in particular to avoid focussing solely on the climate aspect of the disaster but similarly to avoid ignoring the human influence on the climate aspect[56]. This is crucially important as blaming disasters on climate or nature alone is not different to categorising them as "acts of god", it ultimately takes agency and responsibility away from local contexts and hinders resilience building[4]. Similarly, ignoring climate change when it is in fact a major factor in the hazard has implications for loss and damage and climate justice in general[33,57]. This may lead to continued lack to attention to increase in losses and damages and lack of preparedness if events thought to be rare are not rare anymore.

2021 was a year that surprised many with high-impact disasters that led to a large death toll in countries like Canada and Germany. Repeated in 2022 by e.g., extreme heat in the UK, but also in India, Pakistan and Nigeria. Scientifically these extreme events were no surprises[58] but they hit unprepared populations, and many concluded these disasters to be new. However, while these examples are certainly partly caused by anthropogenic climate change, and thus having not entirely natural hazards as their driver, root causes of disasters are largely due to dimensions of socio-political inequities as shown in decades of disaster research. Depending on the region of the world, the type of hazard and the presence of other crises, e.g. the pandemic, the large inflation in 2022 the relative importance of individual drivers of disasters and their impacts can differ dramatically, and is often poorly understood as is exemplified through assessing the role of climate change above.

The 2022 extreme heatwave in the UK provides an example of how the provision of information on warnings for particularly vulnerable groups have led to a noticeably different reporting[59], with governments and health agencies issuing warnings for specific groups that were widely reported in the media, including the right-wing press, even though some commentators were accusing the government of taking the heatwave too seriously. Figures 1 and 2 illustrate the result of the information from the em-dat expanded with information on climate change, demonstrating how relatively easily a global inventory on impacts of human-induced climate change could be achieved roughly following[7,60]. Other drivers of disasters could be systematically assessed in addition: was there early warning?; did the warning reach those most vulnerable?; who was affected the most and how often? What factors made a certain group of people more vulnerable and how?[61] Analysing and presenting this information, that often is available systematically, and including the dimensions of risk, preparedness, impact and response[1,60,62] will allow better reporting of disasters, a better understanding of the interplay between vulnerability and climate change and thus ultimately better adaptation.

## Data availability

All data used are downloaded from em-dat. The SI details the criteria for including data in the tables and figures.

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## Author contributions

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