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Review

Two hot to handle: How do we manage the simultaneous impacts of climate change and natural disasters on human health?

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Abstract. Climate change is one of the major challenges we face today. There is recognition alongside evidence that the health impacts of both climate change and natural disasters are significant and rising. The impacts of both are also complex and span well beyond health to include environmental, social, demographic, cultural, and economic aspects of human lives. Nonetheless integrated impact assessments are rare and so are system level approaches or systematic preparedness and adaptation strategies to brace the two **simultaneously** particularly in low and middle-income countries. Ironically the impacts of both climate change as well as natural disasters will be disproportionately borne by low emitters.

Sufficiently large and long-term data from comprehensive weather, socio-economic, demographic and health observational systems are currently unavailable to guide adaptation strategies with the necessary precision. In the absence of these and given the uncertainties around the health impact projections alongside the geographic disparities even within the countries, the main question is how can countries then prepare to brace the unknown? We certainly cannot wait to obtain answers to all the questions before we plan solutions. Strengthening *health systems* is therefore a pragmatic "zero regrets" strategy and should be adopted hastily before the parallel impacts from climate change and associated extreme weather events (disasters thereof) become too hot to handle.

There is mounting evidence that climate change is affecting human health significantly. Even as the role of climate change in the rising frequency, intensity, and the expanding geographical distribution of extreme weather events remains unclear it can by no means be denied. In the absence of clear quantification and lack of information on the distribution of the simultaneous health impacts of climate change and natural disasters at a community level, public health decision makers struggle to prioritize adaptation, preparedness and response strategies. In the absence of adequate

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evidence, the onus is laid upon ad hoc reactions rather than preparedness leading to several missed opportunities to use the scant financial, equipment and human resources effectively.

The paper reviews the health and health systems impacts of natural disasters and climate change and identifies a common ground. It then focuses on how strengthening health systems could be a potential long-term sustainable solution towards combating not only the simultaneous impacts of the two but others as well – particularly in resource poor settings.

Extreme weather events or is it disasters?

The Intergovernmental Panel on Climate Change (IPCC) defines an extreme weather event as "the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable" [1]. A hazard is "a natural or human-induced physical event that has the potential to cause loss of life, injury, or other health impacts, as well as damage and/or loss to property, infrastructure, livelihoods, service provision, and environmental resources" [1] but it may or may not do so. Disasters essentially occur when hazards meet potential vulnerabilities at the individual or community levels. Furthermore, in the absence of adaptation, mitigation and/or preparedness the impacts of the hazards are magnified manifold. While a range of definitions are in use for disasters the two essential components of any of these definitions are the sudden nature of the event and its ability to overwhelm the local coping mechanisms and capacities. The Centre for Research on the Epidemiology of Disasters (CRED) defines disasters as "a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering" [2].

The impacts of natural disasters span across the health, social, demographic and economic aspects of human life. This is probably the greatest challenge in actual quantification of disaster impacts on individuals and communities. Apart from the social and economic aspects, the demography of the population, health seeking behaviour, and the status and functioning of the surviving healthcare systems dictate the final health outcomes in the affected population [3] (Fig. 1). Given the intricacies and close linkages between each of these factors, it is necessary to conduct integrated impact assessments rather than obtaining isolated individualistic views on singular aspects of the disaster impacts. This also means that successful solutions essentially need wider system-level approaches in addition to focussed interventions that manage only one or more aspects of the impacts (e.g. only economic or only health).

The health impacts of natural disasters especially earthquakes [5–8], floods [9–11], droughts [12,13], heatwaves [14–18], and wildfires [19] are well documented in the literature and mainly include the following:

1. Mortality
2. Morbidity
   - Injuries and disability (creating future vulnerabilities)
   - Increased transmission of infectious diseases (secondary failures particularly surveillance, poor hygiene, post op hospital induced)
     - Water and foodborne diseases (diarrhoea, cholera, shigella, typhoid, polio where endemic, gastroenteritis, Hepatitis A/E, wound infections, etc.)
     - Airborne diseases (overcrowding and displacement cause Acute Respiratory Infections (ARI), meningitis, moulds after floods etc.)

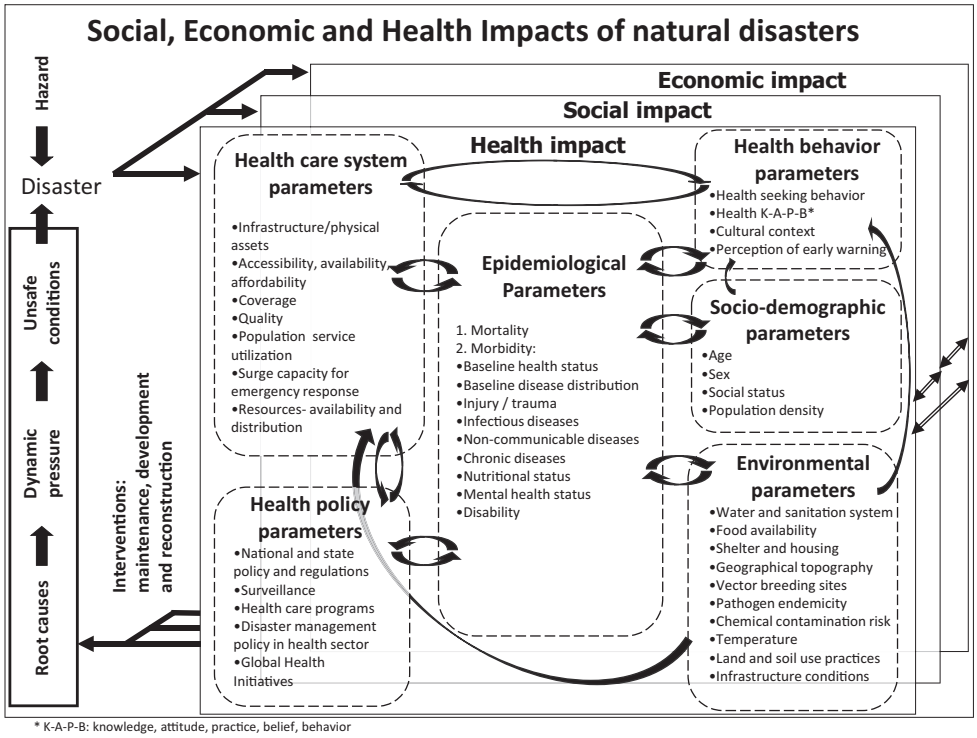

Fig. 1. Health and health systems impacts of natural disasters (Modified from [3,4]).

  - Vector-borne diseases (expansion/reduction in habitats, interrupted control programs lead to increase in malaria, dengue, Japanese Encephalitis (JE), zika virus yellow fever, schistosomiasis etc.)
  - Rodent borne diseases (leptospirosis etc.)
  - Malnutrition
  - Skin infections (primary due to wound contamination and secondary iatrogenic hospital acquired infections)
  - Tetanus (wound contamination).
- Inadequate treatment of non-communicable and chronic diseases (e.g. problem with drug procurement), and
- Psychological/mental health impacts (Post Traumatic Stress Disorders (PTSD), anxiety, neurosis, depression etc.).

3. Others (moulds, chemical contamination etc.)

A vast majority of the health impacts remain common across disasters. However, the frequency of each impact (for example mortality, morbidity, etc.) may vary according to the nature, intensity, time of strike, as well as the type of disaster in question. The injury to death ratio is pegged approximately at around 3:1 in a majority of disasters which is essential in planning effective disaster response programs [20].

As per the CRED EMDAT database [21] during the period 1985–2015, floods and windstorms were the most frequently reported natural disasters in all regions of the world and together accounted for almost 70% of the 10678 disasters. About 40% of the 461 events of droughts were reported from Africa. Heat waves were more frequently reported from both Asia (59 events, 36%) and Europe (60 events, 36%). Over 38% of all natural disasters occurred in Asia making it the worst hit continent

Table 1. Disaster occurrence by subtype and damages (1985–2015) (Data source EMDAT [21]).

Disaster Subgroup	Occurrence	Total deaths	Affected	Injured	Homeless	Total affected	Total damage in US$
Meteorological	3290 (31%)	604633	936931937	2617516	33540932	973090385	1053455974
Hydrological	4302 (40%)	236649	3102705553	1115436	74332644	3178153633	670725645
Climatological	785 (7%)	29611	1686042532	6581	127865	1686176978	196940981
Biological	1297 (12%)	205399	24893030	589168	0	25482198	229200
Geophysical	1004 (9%)	888145	148700152	1870620	19857235	170428007	721473870
	10678 (100%)	1964437	5899273204	6199321	127858676	6033331201	2642825670

(Fig. 3 Graphs 1–3 and Table 1) [21]. Needless to point that this region also houses the majority of the population in the world today.

Figures 2 and 3 below show the frequency, distribution and damages caused by natural disasters in the period 1985–2015. While earthquakes were the biggest killers (Fig. 2, Graph 1), floods and droughts affected more people (Fig. 2, Graph 2) and storms caused the maximum economic damages (Fig. 2, Graph 3) particularly in North America. However this needs to be interpreted with caution because of reporting patterns and classification anomalies in disaster databases.

While the individual health impacts of natural disasters have been extensively reported in the literature, the health systems impacts of natural disasters have been inadequately investigated and reported. Generally failures of individual hospital preparedness plans and their impacts thereof have been reported but system-wide investigations in large geographic areas are rare.

The health systems impacts of natural disasters mainly include primary failures due to physical damage to the health care infrastructure or the health workforce e.g. death/migration of staff, destruction or structural damages that result in the inability to function. Secondary failures on the other hand result from inadequate surge capacity, staff burnout or due to the exhaustion of supplies. Systemic failures of parallel infrastructure such as the water and sanitation systems, emergency housing systems, or the transport and communication systems could also lead to secondary failures.

Failure of primary or secondary components within a system can affect drug procurement and interrupt critical vertical disease control programs such as immunisation, maternal and child health, or infectious diseases such as tuberculosis and non-communicable diseases such as diabetes amongst others [22]. This in turn may lead to the accumulation of routine work-load over and above the emergency care requirements. It may overburden the staff or lead to the deflection of services from the much-needed emergency care. Lack of preparedness plans in such situations further deteriorates service efficiency and cause wastage of valuable resources at a time when they are most needed [23].

How does climate change worsen the situation?

The rise in temperature on land surfaces (regional variances) leads to the alteration of the hydrologic cycle making it faster. This in turn intensifies cycles of drought and floods. At higher humidity the rise in temperature also increases the incidence of tropical storms. Even though the role of climate change cannot be quantified or attributed confidently in the intensification or the occurrence of individual extreme

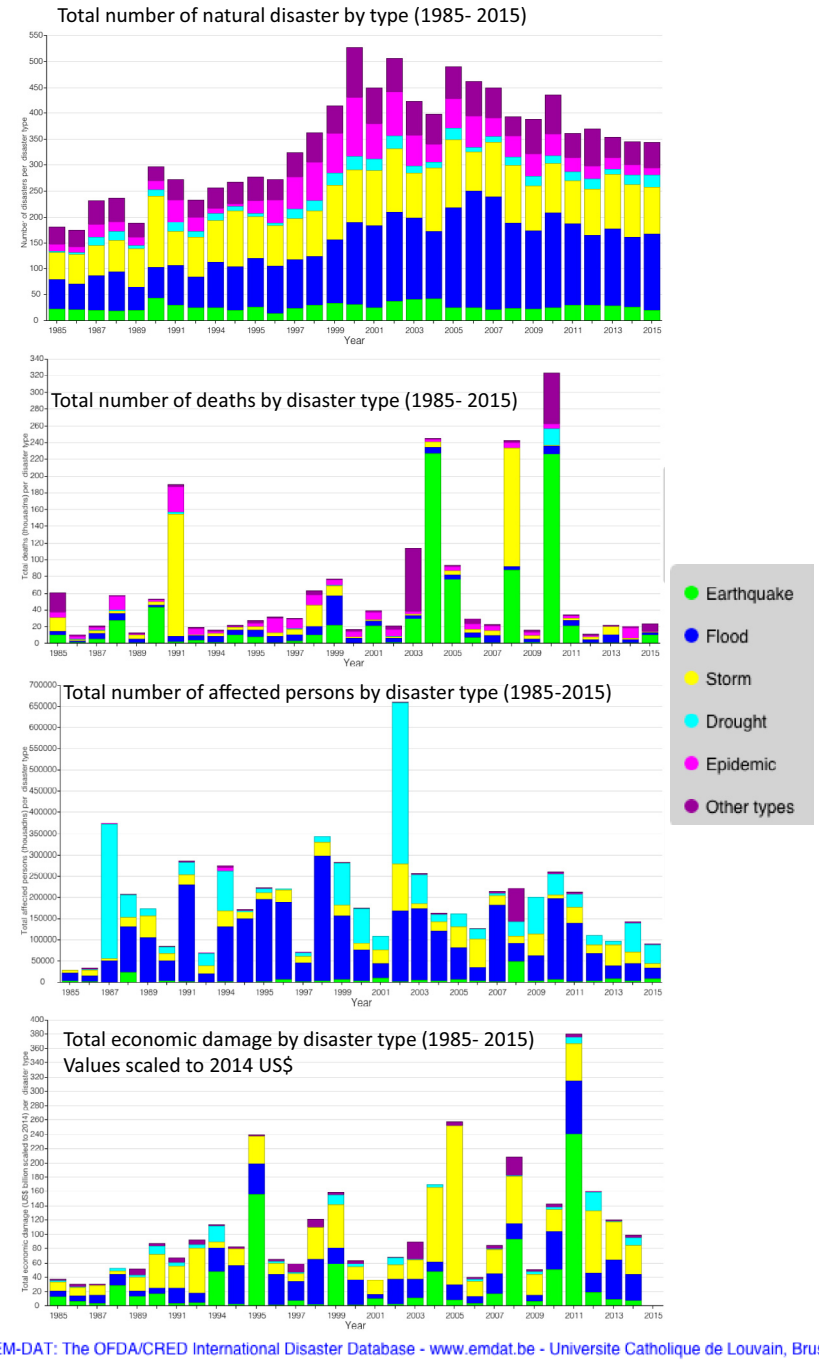

Fig. 2. Analysis of natural disasters by disaster type (1985–2015) (Data source EMDAT [21]).

weather events (and the disasters thereof), it can by no means be excluded in wake of the mounting evidence and rapidly changing statistically significant trends.

There is undeniable evidence that the frequency (Fig. 2, Graph 1), intensity, spatial distribution, timing and duration of all natural disasters have been on the rise

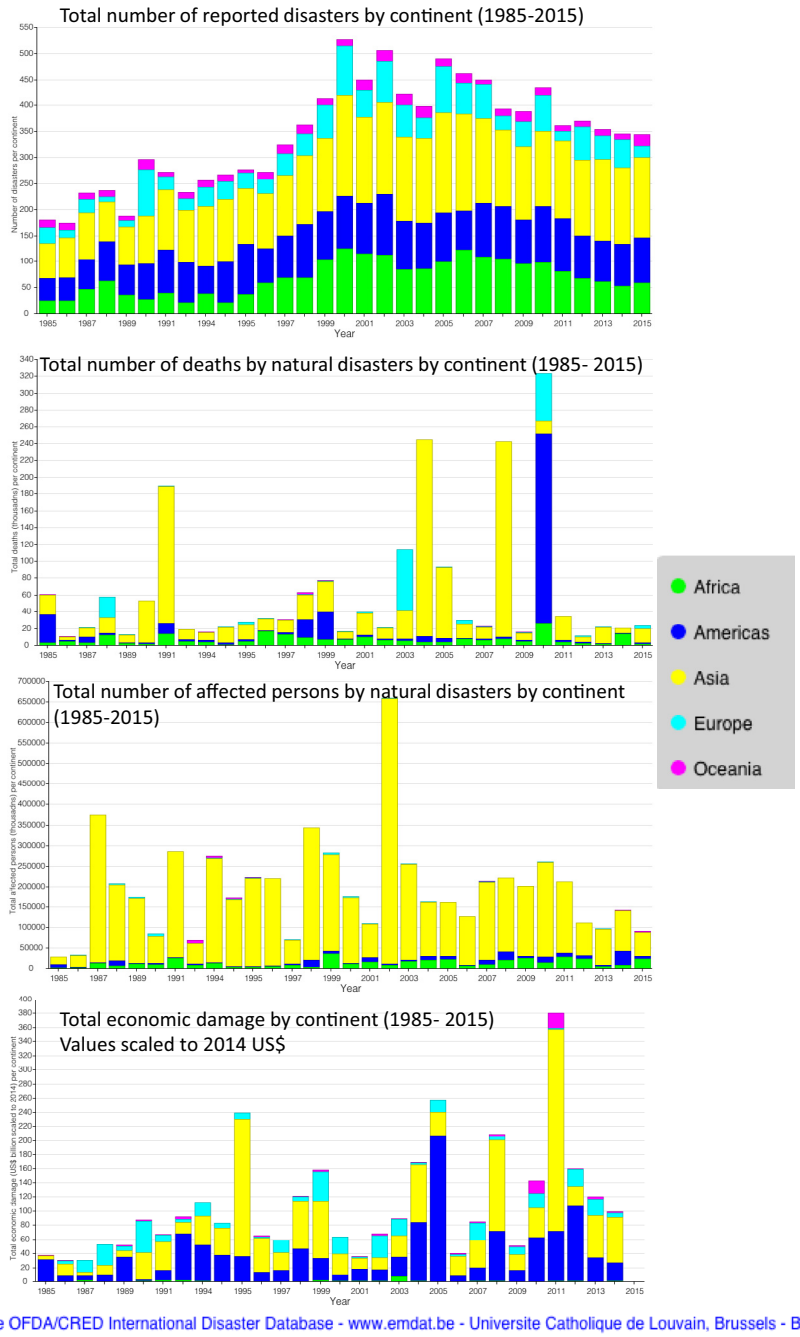

Fig. 3. Analysis of natural disaster occurrence by continent (1985–2015) (Data source EMDAT [21]).

in the last thirty years [24]. Furthermore if we look at the types of natural disasters as classified by CRED [2] all but the geophysical type of disasters (earthquakes, volcano and dry mass movements) are vulnerable to changes in local weather and climate [2,25].

- **Geophysical:** events originating from solid earth e.g. earthquake, volcano, and dry-mass movement (rock fall, landslide, avalanche, etc.)
- **Meteorological:** events caused by short lived/small to meso-scale atmospheric processes (in the spectrum from minutes to days) e.g. storm (tropical and extra-tropical cyclone)
- **Hydrological:** events caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind set up e.g. general, flash and coastal flood, storm surge and wet mass movements (rock fall, landslide, avalanche, etc.)
- **Climatological:** events caused by long-lived meso to macro scale processes (in the spectrum from intra seasonal to multi decadal climate variability) e.g. extreme temperature (heat and cold wave), drought, wildfire, forest fire etc.
- **Biological:** disaster caused by the exposure of living organisms to germs and toxic substances (viral, bacterial, parasitic, fungal infections; epidemic, insect infestation, animal stampede).

In the years 1985–2015, only 10% of the over 10,600 natural disasters reported to the EMDAT disaster database were of geophysical classification (unsusceptible to changes in weather and climate) [21].

What are the main health impacts of climate change?

Apart from its probable role in aggravating the incidence of extreme weather events and their impacts, climate change has its own set of health impacts on human health. These have been well documented in the literature and include [26,27]:

- Direct impacts:
  - Extreme weather events (floods, droughts)
  - Temperature related illness and death (heat and cold)
- Effects mediated through natural systems:
  - Air pollution related health effects
  - Water and food borne diseases
  - Vector and rodent borne diseases
- Effects mediated by human systems:
  - Occupational health (work productivity etc.)
  - Nutritional impacts (food and water shortages due to crop yield change)
  - Mental health impacts
- Other health impacts (especially internal and international displacement voluntary and involuntary migration).

While individual assessments of the health impacts of climate change and weather variability are widely available in the literature, joint assessments of multiple health impacts are few. Similarly very few studies investigate the health systems impacts of climate change. Those available are mainly from high-income countries (e.g. UK and Australia) and barring a few focus mainly on energy efficiency issues within these systems rather than their preparedness to manage the simultaneous health impacts [28–32]. This is a significant gap in the current climate change and health impacts research.

What does the future hold?

The IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) 2012 [24] and the IPCC AR5 [25]

project the following in the next few decades [33]:

1. The length, frequency and/or intensity of warm spells or heat waves will increased with higher temperatures when extremes occur. We have already witnessed this with the global mean surface temperatures rising by 1 °C last year and 2015 recorded as the warmest year since 1850 (World Meteorological Organization 2015). Although a part of the warming is attributed to the effects of the El Niño weather pattern.
2. Increases in the frequency and distribution of heavy precipitation, particularly in the high latitudes and tropical regions, and in winter in the northern mid-latitudes. Heavy rainfalls associated with tropical cyclones are likely to increase with continued warming. There is medium confidence that, in some regions, increases in heavy precipitation will occur despite projected decreases in total precipitation in those regions. Statistically significant trends in heavy precipitation events in some regions (increases more than decreases) have already been observed.
3. Increases in average tropical cyclone maximum wind speed are likely, although increases may not occur in all ocean basins. Low confidence in tropical cyclones activity has been noted.
4. Medium confidence that droughts will intensify in some seasons and areas and last longer, due to reduced precipitation and/or increased evapotranspiration, particularly in southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern and West Africa.
5. There is limited to medium confidence that projected increases in heavy rainfall could contribute to increases in local flooding in some regions.

Apart from the health impacts, a recent review by the climate vulnerability monitor and DARA [34] initiative reported that the economic losses from all natural disasters will rise further. Except for heat related deaths and vector borne infectious diseases all other major health impacts from climate change for example diarrhoeal diseases, air pollution related conditions, undernutrition resulting from crop yield failures, and meningitis will rise (Table 2). As per the report majority of the impacts will be felt in Asia (especially China, India and Bangladesh) and in Africa (Nigeria, Ethiopia, DR Congo and Tanzania amongst others).

Drought: Extreme weather event, natural disaster, or a complex emergency?

Droughts are defined as "a period of abnormally dry weather long enough to cause a serious hydrological imbalance" [24]. Based on the timing, severity and scope, droughts are classified as "meteorological drought (abnormal precipitation deficit), hydrological drought (shortage of precipitation leading to reduced runoff and compromised ground water and other water supplies), agricultural droughts (shortage of water during growing seasons affecting crop production), and mega-droughts (pervasive long standing event affecting socio-economic and other spheres of human life)" [33]. By their nature droughts are special type of disasters that have their origins in natural causes but very complex human factors determine their progression and outcomes.

Droughts are generally slow building disasters (therefore benefit for early warning systems), often affect large geographic areas, and result mainly from complex socio-economic, socio-demographic, socio-psychological, socio-cultural, and socio-structural and geo-political variables [3]. Between the years 1985 and 2015, a total of 461 droughts were reported in the EMDAT database leaving over 27,500 dead and

Table 2. Projected hotspots for disaster losses and deaths from disease (Data source: based on information from Climate Vulnerability Monitor: A Guide to the Cold Calculus of a Hot Planet by DARA).

Disaster losses				
Disaster type	Losses / year 2010 US$	Losses / year 2030 US$	Confidence	Hotspots
Drought	5 billion losses	20 billion losses	Indicative	China, India, Iran, United States, Spain
Floods and landslides	10 billion losses 2750 deaths/year	95 billion losses 3500 deaths/year	Indicative	India, China, Bangladesh Vietnam, Pakistan
Storms	15 billion 2500 deaths/year	100 billion 3500 deaths/year	Speculative	Bangladesh, Myanmar India, Madagascar Philippines
Wildfires	15 million	90 million	Indicative	Russia, Mongolia Nicaragua, South Africa Canada
Health conditions				
	Deaths/ year 2010	Deaths/year 2030	Confidence	Hotspots
Diarrheal infections	85000	150,000	Robust	India, Nigeria Pakistan, Ethiopia DR Congo
Heat and cold illnesses	35,000	35,000	Indicative	India, Nigeria Russia, Ukraine Bangladesh
Hunger	225,000	380,000	Indicative	India, Pakistan, Bangladesh, Nigeria Indonesia
Malaria & vector borne	20,000	20,000	Indicative	DR Congo, Mozambique Tanzania, Uganda, Nigeria
Meningitis	30,000	40,000	Speculative	India, Nigeria, DR Congo Ethiopia, Tanzania
Air pollution	1.4 million	2.1 million	Speculative	China, India Pakistan, United States Russia

1.6 billion affected [21]. Currently, about one-third of the world's population lives in water-stressed countries and the number is projected to rise from the current 1.7 billion to 5 billion people by the year 2025 [35]. Similarly the occurrence, duration and intensity of droughts is also expected to worsen in some areas especially West Africa.

Given the lack in the clarity of the time of onset, actual detection and final declaration of a drought disaster, it is rather difficult to attribute health and other impacts directly to the drought event. A majority of impacts are mediated indirectly and as highlighted in Fig. 1 for all other types of disasters, economic and social factors play a major role alongside other geopolitical and environmental factors. A number of valuable studies have documented the main health impacts of droughts [12] and these include undernutrition resulting from inadequate calorie intake leading to wasting, stunting, underweight as well as micronutrient deficiencies. Droughts can also lead to water-related disease such as E coli infection, cholera and algal bloom), airborne disease such as coccidioidomycosis, and increased transmission of vector borne disease like malaria [36], dengue and West Nile Virus and mental health effects [13] amongst others. Voluntary and involuntary migration leading to national or international displacement of people is probably amongst the most serious impact of droughts on human societies [37].

In addition, droughts have been long suspected to be associated with civil conflicts. A comparative analysis of the CRED EMDAT disaster database and the Uppsala conflict database indicated that about 157 events of droughts and 520 non-state conflicts were reported concurrently during the period 1989–2013 in Africa. Although this may be coincidental, deeper analysis with regard to the onset and duration would be useful. Water availability has also been strongly associated with the recent conflict in Syria [38]. Another meta-analysis reported that "for each SD of increased rainfall or warmer temperatures, the likelihood of interpersonal violence increased by 4% and intergroup conflict increased by 14% on average" in Africa [35,39,40]. In view of the projected increase in the frequency, duration and severity of droughts concrete measures need to be put in place to prevent their long-term impacts on human lives particularly in high-risk areas. Given the complex nature of droughts not just the assessments of their impacts but also the interventions to manage them will require systematic system-wide approaches at the local, sub-national, national and regional levels.

Climate change, disasters, food security and malnutrition

Malnutrition is a major challenge to the health and wellbeing of populations globally [41]. Undernutrition (underweight, wasting and stunting) as well as overnutrition (overweight and obesity) and micronutrient deficiencies (which potentially occur in both groups) pose specific challenges to maternal and child health across societies. The UNICEF framework identifies a causal change that runs from basic factors (quantity, quality, and control of human/economic/organizational resources) to underlying factors (insufficient/inadequate access, inadequate health services, etc.) to immediate factors (inadequate dietary intake and disease) for childhood undernutrition [42]. Malnutrition like climate change and natural disasters is a result of complex political, social, economic, cultural, health and demographic factors at both the individual as well as the household level. These factors interact dynamically and are heavily interdependent. They may act interchangeably as determinants, confounders (positive or negative) or as effect modifiers. This is the main challenge when investigating and quantifying the nutritional impacts of climate change as well as natural disasters apart from the difficulties in establishing causality.

Food availability (production and supply, trade, and food aid), stability (demand and supply), access (both physical and economic access to adequate amounts of nutritious, safe, and culturally appropriate foods), and utilization (dietary diversity, child-care practices, sanitation, annual infectious disease episodes etc.) are four essential dimensions of food security [33]. Substantial but uneven gains have been made so far in reducing undernutrition globally (Fig. 4). O ver 30% reduction in stunting has been noted globally but majority of these gains have been uneven and primarily in South and South East Asia [43–49].

Even as the percentage of stunted children under-five decreases in all regions of the world, the absolute number of stunted children in Sub-Saharan Africa is actually on the rise. While stunting (chronic malnutrition) remains the main concern in Africa, wasting (acute malnutrition) is the main concern in Asia [45]. This also correlates to the EMDAT database data that reports a higher number of floods from Asia and higher number of droughts from Africa and needs to be investigated.

Climate change is expected to worsen the situation further by reducing the per capita calorie availability in already food insecure regions mainly through its impacts on crop yields. It is expected to affect not only the quantity, but also the quality of the food grains. Recent evidence points that elevated CO_2 reduces the concentration of micronutrients (zinc, iron and proteins) in food crops adding to the "hidden hunger" crisis [50]. It is estimated that climate change will add over 25 million additional

Progress made so far: global overview

	Stunting (HAZ below -2 SD)	Wasting (WHZ below -2SD)	Overweight (WHZ above +2SD)
Number (2014)	159 million	50 million	41 million
% of <5y children in the world	26%	7.5%	6.1%
% change from 1990	35% decrease	11% decrease	54% increase

Source: UNICEF- WHO-World Bank Joint Child Malnutrition Estimates 2014 (http://www.who.int/nutgrowthdb/estimates2014/en/).

Reality: increase in absolute number of undernourished in Africa (esp. stunting)

Number of undernourished and prevalence (%) of undernourished

	1990-2 No.	1990-2 %	2012-4 No.	2012-4 %
World	1,014.5	18.7	805.3	11.3
Developed regions	20.4	<5	14.6	<5
Developing regions	994.1	23.4	790.7	14.5
Africa	182.1	27.7	226.7	20.5
Sub-Saharan Africa	**176.0**	33.3	**214.1**	23.8
Asia	742.6	23.7	525.6	12.7
Eastern Asia	295.2	23.2	161.2	10.8
South-Eastern Asia	138.0	30.7	63.5	10.3
Southern Asia	291.7	24.0	276.4	15.8
Latin America & Carib.	68.5	15.3	37.0	6.1
Oceana	1.0	15.7	1.4	14.0

Source: FAO The State of Food Insecurity in the World 2014 p. 8.

Partial reversal of gains so far!

Region	**# of undernourished children <5y (millions)**			**Additional # from climate change**
(Developing countries only)	**Base climate**	***No* climate change**	***With* climate change**	
	2000	**2050**	**2050**	**2000-2050**
Sub Saharan Africa	32.7	41.7	52.2	**10.5**
South Asia	75.6	52.3	59.1	6.8
East Asia/Pacific	23.8	10.1	14.5	4.4
Latin America & Caribbean	7.7	5.0	6.4	1.4
Middle East/ N-Africa	3.5	1.1	2.1	1.0
Europe and Central Asia	4.1	2.7	3.7	1.0
Total	147.9	113.3	138.5	**25.2**

Number (in millions) of undernourished children under-five years in 2000 & 2050 using the National Center for Atmospheric Research (NCAR) climate model and the A2 scenario. Modified after Nelson (2009) and Phalkey (2015).

Fig. 4. Global undernutrition trends, progress made so far and future impacts. **(Modified from [43–48].)**

undernourished children globally by 2050 (over ten million in Africa and seven million in Asia respectively) (Fig. 4). The impacts will be disproportionately borne by rural farming households that are least adapted to local weather variability or natural disaster impacts leading to crop failures. The children under-five in these households remain the most vulnerable to repeated nutritional insults [51].

Although a large part of the current global undernutrition is attributed to calorie insufficiency i.e. inadequate food consumption alongside increased susceptibility to infectious diseases and related mortality, overnutrition is also a rising concern. Populations in peri-urban and urban areas may have increased food affordability (compared to some of their rural counterparts) but face the problems of food deserts and

distorted food shopping practices. Studies demonstrate that small drops in incomes lead to proportionate increases in consumption of low-priced, calorie-dense, nutrient-poor processed foods irrespective of the level of income or education. Climate change and associated extreme weather events (droughts and floods) [52] alongside other market factors are expected to push food prices higher. This means healthier foods will be replaced by processed foods even more- first for the poor and gradually amongst the higher income groups fuelling the obesity and hidden hunger epidemics in both adults and children in urban areas. On the other hand a significant proportion of urban poor will be worse-off because of inadequate physical and economic access to food. Malnutrition creates future vulnerabilities, higher infectious disease susceptibility at all ages and is one of the top concerns for public health responders dealing with the impacts of both climate change as well as natural disasters.

Challenges with investigating climate change and disaster impacts on health simultaneously

Although the health impacts of natural disasters and climate change show significant overlap and commonalities, the time scales, data demands, analytical approaches and most importantly data availability differ considerably. In the absence of long term (at least ten years) data on a range of household and individual- demographic, socio-economic, health and weather/climate variables the three main challenges with investigating the health impacts of climate change are- quantification of the impacts, assessing the causality (since large proportion of health impact studies are cross sectional surveys) and direct or indirect attribution of the impacts to climate change.

Disaster data on the other hand has shorter time scales and requires data to be collected appropriately but rapidly in the immediate aftermath of the events. Lack of standardization of the disaster terminology (definitions and classifications) makes data processing a challenge and the results less accurate. Use of diverse methods to investigate disaster impacts makes meta-analysis less feasible. Impacts are most often studied in living persons (serious injuries amongst dead unlikely to be investigated) and amongst those who actively seek care. A majority of the studies report single hospital data and moreover, multiple conditions in a single patient are rarely documented [53]. Probably the most inherent flaw of disaster data is its incompleteness. Missing variables compromise the quality of the data. Publication bias like most other research areas is another aspect in both climate change and disaster studies. Last but not the least, the impacts of both climate change and disasters involve simultaneous impacts on the social and economic aspects of individuals and communities. Nonetheless integrated impact assessments are scarce alongside investigations from low and middle-income countries where the impacts of both climate change and natural disasters are most significantly and disproportionately felt!

Moving away from Linking Relief, Rehab and Development (LRRD)

Given the complexity of both climate change impacts on health and disaster impacts on health, we face methodological challenges in unpicking the double whammy. To date more questions remain than the answers we have already found for both. Is the link between climate change/ weather variability and undernutrition linear or is there a threshold? How much more of over and undernutrition will we have and where – given the rise in droughts and floods? Will the impacts of floods be larger than that of air quality or floods or heat related morbidity? What will be the % distribution of infectious diseases and non-communicable diseases in the next decades? What role will economic growth play in mediating the health impacts and healthcare demand and supply in these countries?

Given the scale of the problem and the speed with which it progresses, it is less pragmatic to wait for all answers before we initiate action. But what can be done? Appropriate and timely adaptation and response of course- but how do we achieve these simultaneously at the individual and the population levels globally? Would a mere redistribution of responsibilities help? What locally specific solutions can be found and realistically implemented? As a first step we need to move away from the disaster response approach of "Linking Relief, Rehab and Development (LRRD) [54]" towards more of a "Linking Adaptation, Prevention, Preparedness to Relief, Rehab and Development (LAPP-RRD)" approach. Climate change adaptation, disaster preparedness and disaster response teams need to join hands alongside humanitarian and development aid agencies in order to find synergies and exploit the strengths of each other at the local, national, international and regional levels. Efforts in these directions are already underway but should be speeded up in order to gather the required momentum.

Taking the health systems approach: A "zero regrets strategy"

Findings of the mini-review confirm that there is a considerable overlap between the health impacts from climate change and natural disasters. However the location, frequency, scale, or the severity of these impacts cannot be currently projected or predicted with the desired level of precision. Health systems in low and middle-income countries therefore face moving targets annually. One year it may be a heat wave and the next year a flood or a drought or an infectious disease outbreak to be managed in the backdrop of the silent epidemics of nutritional, epidemiological and demographic transitions in the population. In the wake of these uncertainties and the inability of the healthcare systems in these countries to prepare separately for individual impacts (given the limited resources) it is probably pragmatic to take the "health systems strengthening" approach which allows the effective management of these impacts irrespective of their causes [32,55,56]. In the long run, this is a no regrets strategy and countries should prioritise this before the simultaneous impacts of climate change and natural disasters become too hot to handle!

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The authors declare no conflicts of interest.

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