

Feasibility Study on the use of Forecast-Based Action (FbA) in Yemen

Study Conducted 2021-2022

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List of Acronyms

AA: Anticipatory Action

DFA: De-Facto Authority or Houthis

DREF: Disaster Relief Emergency Fund

DRR: disaster risk reduction

EAP: Early Action Protocol

ECHO PPP: European Commission's Humanitarian Aid and Civil Protection department's Pilot Programmatic Partnership

FAO: Food and Agriculture Organisation of the United Nations

FbF: Forecast-based Financing

IRG: Internationally Recognised Government

STC: Southern Transitional Council

YRCS: Yemen Red Crescent Society

Executive Summary

This scoping study explores the feasibility of introducing and scaling up anticipatory action in Yemen, and attempts to identify which actions and tools (e.g. Forecast-based Action) would be most effective.

There is a high risk of climatic and weather disasters, as well as high risk of climate sensitive infectious disease outbreaks, strongly exacerbated by the on-going conflict.

Due to ongoing conflict and demands on time and attention of the YRCS, the remote nature of this study meant there was limited time to speak and discuss anticipatory action or tools such as Forecast-based Action (FbA) with the Yemen Red Crescent Society (YRCS) directly during the course of the research. A validation workshop was held on 11 May 2022 to discuss the findings and identify next steps including the need for basic training on climate change impacts and more guidance on AA and the steps to develop an EAP.

Given the conflict, it is likely that a two-pronged solution and use of different tools (one for the north and one for the south) will be needed. There was interest in identifying aspects of conflict (i.e. the humanitarian consequences of conflict) that the YRCS may want to try and get ahead of, such as displacement. This would warrant a much deeper investigation, and direct interaction and discussion between IFRC, ICRC and YRCS, interested PNS, with the support of the Climate Centre.

There is ample opportunity for improved disaster risk reduction and the introduction of more anticipatory action-based approaches: including, importantly, via the provision of systematically shared information on weather forecasts (e.g. early warning systems) to relevant state institutions and the coordination on what early actions are needed to mitigate shocks.

Anticipatory actions could be useful to mitigate the impacts from shocks such as flash flooding, heat waves, cold waves, coastal flooding, and extreme rainfall potentially leading to infectious disease outbreaks (such as cholera). Anticipatory action for flash floods is slowly being developed within the Movement and some experience is being gained, but so far, no early action protocol addresses these due to a variety of complications in particular related to their forecastability and short lead time. The seasonal nature of flooding in the wadis may require further analysis to understand the driver of these flash flood events. It would notably be interesting to examine coping strategies usually taken by local communities during this season. Internally displaced communities, if they have no previous experience with these floods, may be particularly exposed and vulnerable. 510 and the YRCS are in discussion about the development of a cyclone EAP which would attempt to mitigate the impacts of cyclone-associated extreme rainfall (and resultant flooding).

Given the high levels of poverty, unconditional cash transfers or cash and voucher assistance (CVA) at the community level to support the existing sharing economy was highlighted by Key Informants as a very relevant and potentially powerful early action. In terms of anticipatory action for health, work on cholera is the most advanced in Yemen due to the UKMO, Unicef, UNOCHA partnership and cholera risk model. IFRC now also has a newly developed protocol for cholera AA.

YRCS's level of interest and enthusiasm for anticipatory action approaches is high as they recognise that people living in conflict-affected countries are amongst those who most require support for climate-related impacts, and especially in anticipation of further shocks as the backdrop of need is so high.

A Technical Anticipatory Action Working Group does not yet exist to cover the north or the south of Yemen. WFP have expressed interest in co-leading such a working group.

Section 1: Introduction

The Red Cross Red Crescent Climate Centre (RCCC) and the Yemen Red Crescent Society (YRCS) conducted a scoping-cum-feasibility study for the introduction and enhancement of anticipatory action approaches in Yemen under funding from the IFRC through the European Civil Protection and Humanitarian Assistance department's Pilot Programmatic Partnership (ECHO-PPP). This report summarises the findings of this study. It was conducted between December 2021 and March 2022.

1.1 What is Anticipatory Action and Forecast-based Action (FbA)?

Anticipatory action (AA) is “a set of actions taken to prevent or mitigate potential disaster impacts before a shock or before acute impacts are felt. The actions are carried out in anticipation of a hazard impact and based on a prediction of how the event will unfold” ([IFRC, 2020](#)). Forecast-based Action (FbA) (also known as Forecast-based Financing (FbF) is a mechanism that triggers humanitarian funding to be released based on climate and weather forecasts. The IFRC established the *Forecast-based Action by Disaster Relief Emergency Fund* (FbA by DREF), a central funding pool to support national societies in the development and funding of early action protocols (EAPs) for anticipated disasters. FbA by DREF maintains a high standard for approval of EAPs that leads to the creation of well-planned and executed FbF systems. The funding is released automatically after a triggering forecast to support timely humanitarian actions to the exposed population before a hazard hits. The threshold for an approved forecast is determined in advance based on impact estimations of disaster types. Funding is directed to those predicted to be most impacted by the forecasted disaster. By allowing for early action, FbF systems aim to reduce the impact from disasters on local communities and speed up the process to initiate response and recovery protocols.

The first attempt at using forecasting to preposition relief supplies in advance of the rainy season was in 2008 in West Africa by the regional office of IFRC. Supplies reached countries within days of flood reports rather than the 40 days it took in the previous year ([RCCC, 2015](#)). Since then, a wide evidence base has been established on the effectiveness of FbF and best practices for how to design and implement FbF systems.

1.2 Purpose of this study

This study had four main objectives:

- To understand the risk of 1) hydro-meteorological hazards and 2) epidemics of climate-sensitive infectious diseases (such as cholera).
- Assess forecasts of severe weather and climate (or climate-sensitive) hazards. A forecasting capacity assessment was conducted for both national and international forecast products.
- Assess the capacity of the YRCS to implement AA approaches via FbF.
- To provide recommendations on how to advance discussions on anticipatory action programming in Yemen.

1.3 How conflict affects FbA systems

People living in conflict-affected countries may be amongst those who most require support for climate-related impacts, but are often left out due to the limited capacity of local governments to comply with financing or project requirements. There is a significant financing gap between stable countries and conflict-affected countries, and as such stronger efforts are needed to address this disparity ([ICRC, 2021](#)).

Conflict is the overarching context for most (if not all) humanitarian work in Yemen and should act as a lens with which to examine all aspects of the feasibility of AA and FbA in the country. There is an important distinction to be made, however, between anticipating hydro-meteorological hazards and vector-borne diseases, and anticipating flares in conflict. This is the subject of much debate from the world's leading experts. Anticipating conflict means a range of different things to different actors, a full exploration of which is beyond the remit of this study. In general, when the RCCC undertakes work to research anticipation of conflict it is to address 1) the climate-related hazards in conflict settings, 2) the humanitarian consequences of conflict (e.g. displacement, food insecurity, etc). It is important to note that YRCS has expressed interest in anticipating the humanitarian impacts of conflict and if this is to be pursued further it would necessitate substantial conversations and detailed assessments involving joint analysis with the YRCS, IFRC, and ICRC. This said, any AA systems in conflict settings can and should be highly sensitive to conflict dynamics and aim to ensure that people experiencing chronic conflict conditions - in combination with other hazards - are also reached. Therefore, the analysis presented throughout this report ensures that the conflict is used as a framework in the hazard analysis and suggestion of possible early actions, as well as the recommendations.

Conflict will affect all components of an FbA systems, from the capacity and mandate of Red Cross Red Crescent National Societies and their partners, the analysis of hazard risk,

vulnerability, and exposure through to the potential triggers to the feasibility and design of anticipatory actions. Conflict dynamics are also highly variable over space and time, creating an even greater need for flexibility and constant adaptation of FbA programming and efforts. There are also strong effects on the stakeholders available and interested in developing such programmes, on their capacities and priorities, as well as on the existence (or not) of information and systems on which to base the more technical aspects of anticipatory action (in particular for the trigger development). Some of the key ways conflict could affect FbA delivery and potential solutions are offered in Annex 1.

1.4 Background and overview of the Yemen conflict

Yemen, located in the Arabian Peninsula, has a population of over 29 million people and a median age of 19.8 years (as of July 2020). Most of the population live in the far western region of the country (the Asir Mountains, part of the larger Sarawat Mountain region) and 38.5% of the total population live in an urban area ([CIA, N.d](#)). The two major urban areas are Sana'a (the capital) and Aden (port city).

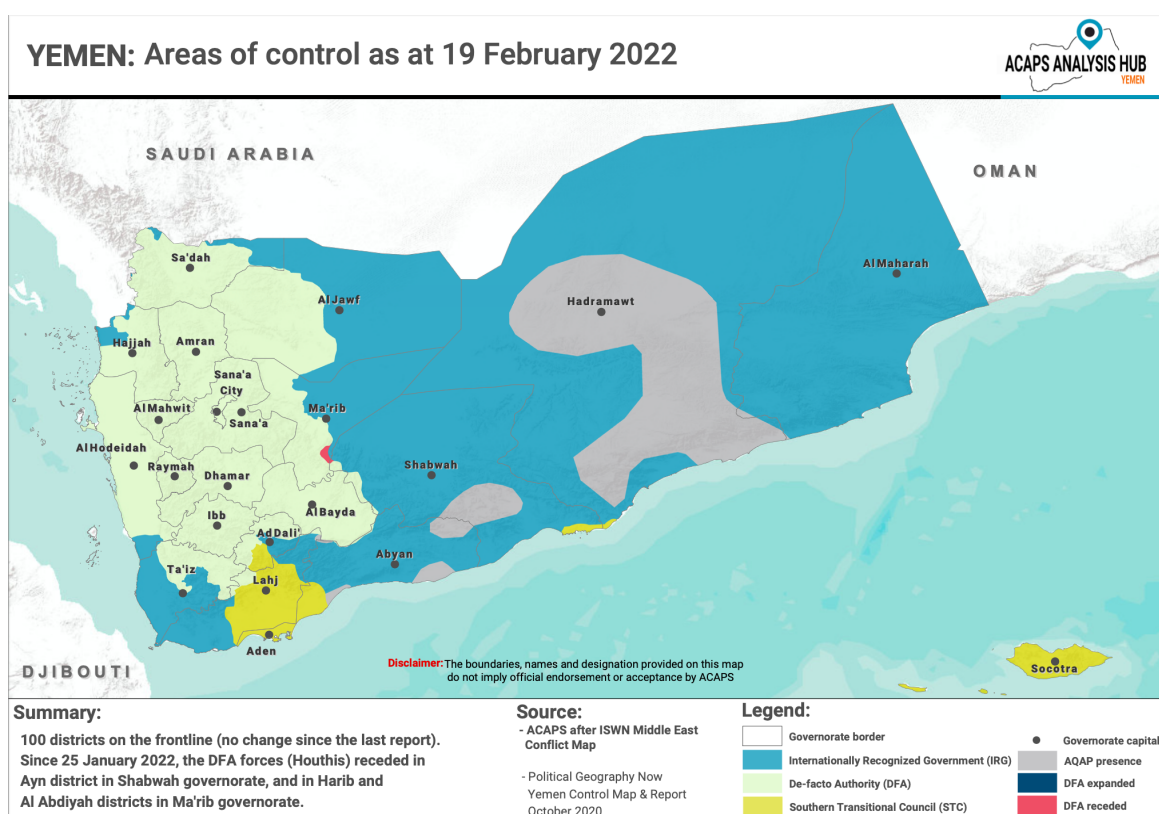
The ongoing civil war that began in 2014, with roots which stretch back to the 1990s and earlier, has resulted in **over four million internally displaced people** (equivalent to around 13% of the total population) and **66% of the population** (around 20.7 million people) **requiring some form of humanitarian assistance** ([OCHA, 2021](#)). The civil war is largely a result of conflict between two authorities, the internationally recognised Government of Yemen (IRG) and the De-Facto Authority (DFA) or Houthis [See Table 1 for a summary of key actors]. In September 2014, Houthi forces took over the capital Sana'a where the IRG led by President Hadi were based. Conflict escalated rapidly from 2015 as the US-backed Saudi-led coalition of Arab nations conducted a military intervention in support of the IRG. Active conflict tends to be waged around territorial lines of control, with new active front lines opening up as the conflict shifts and escalates. As such the conflict situation is highly dynamic. While there have been negotiations, they have suffered multiple setbacks, stalling peacebuilding efforts despite the signing of a peace treaty (the Riyadh Agreement) in 2019 and the formation of a new Cabinet in December 2020 that included both the IRG and members of the UAE-backed Southern Transitional Council (STC).

Table 1: Summary of Key Actors in the Yemen Conflict ([ACAPS, 2021](#); [ACLED, 2022](#))

The Government of Yemen (IRG) - Backed by a Saudi-led military coalition
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The De-facto Authority (DFA) or Houthis - Backed by Iran (and reportedly, Hezbollah)
Southern Transitional Council (STC) - allied with the UAE
Al-Qaeda in the Arabian Peninsula (AQAP)
A number of small actors such as: • Al-Islah - a Sunni Islamist political party (Yemeni Congregation for Reform) • Ansar al-Sharia insurgent group • Alwiyyat al-Waad al-Haq (AWH) - Iraqi militia linked to Iran • Several Southern independence movements ○ The Hadramawt Conference ○ The Southern National Coalition ○ The Reference for the Tribal Alliance of Wai Hadramawt

Figure 1. Map of the Areas of Control by Conflict Actors (Feb 2022) (ACLED, 2022).¹



¹ For up to date data and mapping of Yemen's changing political landscape including locations of violent conflict and areas of actor control see <https://data.humdata.org/dataset/yemen-areas-of-control> and <https://acleddata.com/2022/02/08/the-state-of-yemen-q3-2021-q4-2021/>

Yemen is considered the world's "worst humanitarian crisis" due to the ongoing conflict (UNOCHA). Air-strikes have been consistently carried out on Yemen since 2015 (over 24,000 from the Saudi-led coalition), resulting in high civilian casualties. Only 51% of health facilities are functioning and less than 50% of births are attended by skilled health personnel. An estimated 20.1 million people lack access to basic healthcare. More than half of the population are food insecure and 13.5 million people are at risk of starvation ([ICRC, n.d](#)). The cost of living has skyrocketed and the value of the currency is highly volatile, resulting in an economic crisis. The price of a food basket (rice, lentils, milk, flour, beans, cooking oil, sugar, salt) has increased by 150% since the conflict began. This can be partially attributed to the depreciation of the Yemeni rial resulting in commodity price increase. On top of the civil war and economic crisis, climatic disasters, such as flash floods and droughts, are exacerbating dire conditions and reducing the population's access to water, adequate sanitation facilities, food and healthcare ([ACAPS, n.d](#)). Humanitarian access continues to be constrained and challenged by the conflict. Moreover, publicly available and up to date data on specific access constraints and number of people affected continues to be either unavailable, partial or outdated, further impeding analysis and aid delivery ([ACAPS, 2021](#)).

The main humanitarian consequences of conflict, in general, are: displacement and food insecurity, mortality and injury, water insecurity and damage to shelter, loss of access to education, limited access to healthcare services, and psycho-social impacts.² The key humanitarian consequences of the ongoing conflict in Yemen are summarized in Table 2.

Table 2. Identified Humanitarian Consequences of the Conflict

Consequence	Detail
Displacement (including protracted displacement of IDPs)	4 million IDPs (equivalent to around 13% of the total population) and 66% of the population (around 20.7 million people) requiring some form of humanitarian assistance - IDPs are more likely to be living in conditions or areas more vulnerable to significant flood impact. - IDP shelter is typically weak

² These impacts are based on the main areas of work of the ICRC.

	● Often IDP settlements have fewer services available, increasing existing vulnerability. ● Risk of families being separated ● Reduces resilience to shocks due to lack of institutional support, limited access to social networks, financial impact of displacement
Food insecurity and malnutrition	● Humanitarian need in Yemen with 16.2 million people classed as being in Phase 3 of the Integrated Food Security Phase Classification (OCHA, 2021, p6). ● Conflict and economic crisis are the main drivers of acute food insecurity and malnutrition in Yemen, particularly in critical hotspots. ○ Has led to increased food prices ○ Has reduced incomes and number of labour opportunities
Water insecurity and lack of sanitation	● 15.4 million people are in need of support regarding fulfillment of basic water and sanitation needs. ● People forced to resort to negative coping mechanisms regarding WASH access and behaviours (thus also increasing risk of WASH-related disease such as cholera and dengue)
Violations of international humanitarian law and international human rights law	● Civilian casualties (over 17,500 deaths since 2015 (HRW, 2020)) ● Damage to critical infrastructure e.g. hospitals, schools, roads, markets ● Specific damage or targeting of the health sector: ○ Health facilities - suspended, closed, relocated, damaged, attacked, disruptions in service or limited in functioning. ○ Health care workers - loss of workers, changes in practice, disruptions in medical education, fear of speaking out.

	○ Essential materials - lack of materials and medicines, loss of transport, physical obstruction. ○ Administration - lack of coordination between facilities or health sectors, lack of funding. ○ Increased care demands - trauma injuries, child and infant malnutrition. ○ Increased disease - management of chronic disease, vaccine-preventable disease outbreaks, mental health. ○ Underestimation of full impacts - reporting and funding challenges. ○ Impact on health-relevant sectors - access to clean water and sanitation, adequate nutrition and shelter.
Macro-economic instability	● Inadequately capitalised central bank ● Loss of government revenue ● Depreciation of the Yemeni rial would severely affect purchasing power (currency inflation) ● GDP losses ● More than 80% of Yemenis now live below the poverty line ● Rising commodity prices especially of fuel ● Remittances have become the largest source of foreign exchange in Yemen, but an estimated 80% has ceased being sent due to the Covid-19 global economic downturn.
Violations against children	● Lack of access to education ● Family separation ● Child marriage ● Child recruitment ● Exploitative labour ● Child trafficking

Potential major oil spill	● Risk of spill if the FSO Safer Tanker is not properly maintained urgently. ● Over 1.1 million barrels (over 140,000 tonnes) of Marib light crude oil on board.
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Countries that endure sustained and complex conflict situations are disproportionately vulnerable to the risks, shocks and impacts of climate-related hazards (such as flooding and disease outbreak) as existing protective systems are stretched to breaking point ([ICRC, 2021](#)). The impact of the conflict in Yemen is unevenly distributed and exacerbates existing disparities and vulnerabilities as well as creating new ones. Marginalised people, such as those with a lower socio-economic status are more vulnerable due to more limited access to financial and social assets to leverage in times of crisis. The majority of impacts, including death, during conflicts are not directly caused by physical violence but rather are causing indirectly, through the erosion of particular systems or capacities such as:

- Economic depression
- Contraction of public finances leading to reducing state capacity to maintain, operate or repair public systems and infrastructure
- Disruption of social networks
- Erosion of social cohesion
- Compromised or highly reduced access to key resources and services
- Long term environmental damage
- Long-term physical and mental health impacts
- Reduction of resilience and capacity to deal with shocks
- Reduction of livelihood security and diversity

Thus, conflict-sensitive anticipatory action provides an essential opportunity to protect Yemeni communities through programming and funding that can help people develop hazard resilient livelihoods, settlements as well as maintain access to essential services.

1.4 Anticipatory Action activities in Yemen to date

FbF systems based on hydro-meteorological triggers have not been piloted in Yemen to date. YRCS (via Majed Mohammed - IM Coordination of YRCS, and IFRC delegate in Yemen) have however reached out to 510 to explore the possibility of establishing a cyclone early warning system (see Annex 3). YRCS indicated that the country encountered heavy damages and losses

due to cyclone hazards coming to the south of the country. This was done in the scope of 510's project "Global IM support for COVID response", during this exploratory work 510 conducted secondary data collection and analysis to understand the risk of Tropical cyclone in Yemen. Recently, the request from YRCS returns under 510's project "MENA data & digital support" with more details such as a need for an Impact-based Forecasting Portal for Yemen - a centralised system for cyclone early warning and EAP integration.

In 2014, Save the Children UK (SAVE UK) ran a pilot early warning system in Yemen to distribute cash assistance ahead of conflict escalation ([Save the Children, 2018](#)). The program was built using social triggers through a Household Economy Approach (HEA) instead of meteorological data. The Yemen pilot project used the *Situation and Response Analysis Framework* (SRAF), which outlines a process through which forecasts, local knowledge, coordination and communication can help actors predict, prepare and deliver responses in an appropriate and efficient manner. Thus, response analysis is carried out prior to the shock taking place. SRAF provided baseline information and outcome analysis (in this case from HEA thresholds) to predict hazard impacts, identify response objectives and start-up times to ensure response feasibility and timeliness. Finally it aims to create replicable, low cost solutions. SAVE UK piloted the SRAF as part of a wider crisis-modifier process in a 2014 DFID funded project in Yemen. Crisis modifiers are pre-agreed plans such as financing mechanisms that are built into existing programmes that disburse humanitarian response funding in the event of a crisis ([Lung, 2020](#)). While the pilot was deemed a success, further development was disrupted due to conflict escalation preventing access to communities, leaving monitoring and evaluation data scarce. Nonetheless, lessons learnt from the Yemen pilot were utilised to update the SRAF in 2015. This updated SRAF was rolled out in further pilot approaches in Ethiopia, Kenya and Nigeria by SCUK and included in early action processes in these three locations. Moreover, the Yemen pilot confirmed that effective monitoring and analysis systems were essential to providing early action.

The United Nations Office for Coordinating Humanitarian Affairs (UN OCHA) manages 18 different *country-based pooled funds* (CBPFs) which specifically channel financing towards highest-priority projects ([OCHA, n.d.](#)). In 2019 these 18 active CBPFs received US\$956 million and more than \$807 million was allocated via the fund to 708 partners, supposing 1390 humanitarian projects. Yemen received the highest amount of funding (\$139.6 million) ([OCHA, 2020](#)). This ensures that response is in line with the priorities of relevant Humanitarian Response Plans. Generally, CBPFs are focused on rapid response, rather than cultivating preparedness, however, this is not the case in Yemen in which there is CBPF engagement with

preparedness. However, CBPF performance is linked to the quality of humanitarian structure in Yemen, and as such can be negatively impacted by delayed decision making, high transaction fees for local/national NGOs and ineffective cooperation. Furthermore, there is a risk that local/national NGOs are comparatively disadvantaged with international NGOs (INGOs) unless specific and dedicated financing windows are created for NGOs.

It would also be an interesting avenue of study to examine what anticipatory actions are already taken by communities and local actors. Whilst it was beyond the scope of this study, past experience has found that there are many ways in which anticipatory action-like systems, formal and informal, already exist within communities. This can form a solid basis of inquiry for the development of any FbA system.

Section 2: Risk analysis per hazard

2.1 Climate profile of Yemen

Yemen is a largely arid sub-tropical country where temperature is influenced by topography and adjacent sea. The country is composed of upland desert plains and a desert interior, as well as a narrow coastal plain backed by flat-topped hills and mountains. Mean temperatures vary between 16° C in the highlands to more than 30°C in the coastal lowlands. Annual mean rainfall amounts are higher in the east highlands with around 500 mm a year with relatively little rainfall received in the centre of the country. There are two rainy seasons in Yemen, the saif (April-May) and the kharif (July-September). The saif rains are governed by the north-west trade winds (entering the Red Sea Convergence Zone), while kharif rainfall is governed by mechanisms of the Inter-Tropical Convergence Zone ([GFDRR, 2011](#)).

The mean annual temperature over Yemen has increased at a rate of 0.3 °C/decade since 1961 to 2015 ([Gutiérrez et al., 2021](#)). Heatwave intensity, frequency and duration have increased since the 1950s ([Perkins-Kirkpatrick and Lewis, 2020](#)). Annual mean rainfall shows a high level of spatial variability over Yemen. During the period 1980-2015 there have been downward trends in mean annual rainfall ([Gutiérrez et al., 2021](#)).

Mean temperature over Yemen is projected to rise until 2100 by an additional 6°C for a high greenhouse gas concentration scenario (SSP5-85) and 3°-5°C for low greenhouse gas concentration scenario (SSP2-4.5). Maximum and minimum temperature will increase, and heat waves will intensify in duration and peak temperatures for every increase in global warming levels above the pre-industrial values. In line with rising mean annual temperatures, the annual number of very hot days (days with daily maximum temperature above 35 °C is projected to rise dramatically and with high certainty ([Gutiérrez et al., 2021](#); [Ranasinghe et al., 2021](#))³).

Climate models project an increase in mean rainfall and heavy rainfall for the region. This suggests that when rain storms occur in the wet season they are projected to be more intense as a result of the warmer atmosphere ([Gutiérrez et al., 2021](#); [Ranasinghe et al., 2021](#); [Seneviratne et al., 2021](#))⁴).

³ Chapter 12 of the IPCC Working Group 1 Report

⁴ Chapter 11 of the IPCC Working Group 1 Report

2.2 Previous Hydro-meteorological hazards and Epidemics

From 2012 to 2022, twenty-five natural hazard events affecting Yemen met the EM-DAT criteria⁵ for a disaster (see Annex 2). Of these, 18 were hydrological or meteorological in nature. **Flash flooding** after periods of high rainfall is the primary cause of disaster in recent years. However, **seasonal flooding of wadis** (these are drainage courses such as valleys or channels through which rainfall intermittently drains as surface water) and **cyclone-related coastal flooding** are also high risk. The secondary hazard of **landslides** as a result of flash flooding and heavy rainfall is also high risk throughout the Yemen hillsides. In addition, there have been 6 large-scale infectious disease outbreaks in the last 10 years: cholera (3), diphtheria (1), viral disease (1) and dengue (1). Conflict and the associated economic crisis have created significant humanitarian consequences which interact with these hazards.

2.2.1 Flooding

Compounding impacts of conflict and flooding

IDPs are more likely to be living in conditions or areas more exposed to flood risk. For example, in Sana'a city, IDPs mostly rent accommodation in flood-prone neighbourhoods rather than safer neighbourhoods, which can be up to four times more expensive. The vast majority of IDPs live in auto-constructed settlements making their property and shelter vulnerable to flood damage. From a UNOCHA update on the 30th of April 2020, an estimated 4,764 households have been affected by flood related impacts in IDP sites in southern governorates, including 1,812 families in Aden, 1,037 in Abyan, 917 in Taizz and 770 in Lahj governorates. Further UNOCHA updates have found that approximately 32% of identified IDP sites are at risk of flooding (OCHA, 2021). This was calculated by the inter-cluster coordination mechanism using data from Camp Coordination and Camp Management (CCCM) site reporting. CCCM coordinates the temporary assistance and protection activities of people living in camps or camp-like settlements.

The rainy season in Yemen lasts from March to October [see Fig. 3]. Yemen has no permanent rivers but has seven major wadis which flow west that carry seasonal floods during the southwest monsoon from the Western Escarpment to the sea ([REACH, 2020](#)). According to Think Hazard, river flooding has a return period of close to once in ten years in the Al Jawf, Shabwah, Amran (medium risk) and Marib (high risk) regions ([Think Hazard - Yemen - River](#)

⁵ It is important to note that while EM-DAT is one of the most comprehensive and transparent (methodologically) databases, due to the nature of its inclusion criteria, EM-DAT operates on a global observation level and national resolution level resulting in some smaller scale events being left out and making disaggregation of disasters on a local/regional scale difficult.

[flood](#)). Flash flooding, caused by heavy rainfall over a short period of time, has become a regular event in Yemen since around 2008. Kharif rains tend to fall in short events ([WB. n.d](#)). Flooding has increased in intensity and duration in recent years, with links to the changing climate and rainfall patterns. Despite a projected decrease in extreme rainfall across the MENA region, the southern tip of the Arabian Peninsula (Oman and Yemen) is projected to experience a substantial intensification of extreme and mean rainfall ([World Bank, 2014](#)). Rainfall in this region is associated with tropical convection, which is projected to strengthen under future warming. This suggests that when rain storms occur in the wet season they are projected to be more intense as a result of the warmer atmosphere ([Gutiérrez et al., 2021](#); [Ranasinghe et al., 2021](#); [Seneviratne et al., 2021](#)).

Figure 2. Seasonal calendar of rains and cyclones ([FAO, 2014](#); [WMO n.d](#))

		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Rainy Seasons (increased likelihood of flood during this time)	Central Highlands (Amran, Sana'a, Dhamar and the highlands of Sa'dah, Hajjah, Al-Mahweet and Mareb)			Saif Rainy Season (annual average 173mm)				Kharif Rainy Season					
	Southern Uplands (Ibb Al-Beida, Al Dhalaá and highlands of Taiz, Abyan and Lahj)			1 Rainy Season (annual average: 561mm)									
	Coastal Areas (Begins from Madi in Hajjah to Hawf in Almahrah)	No Distinct Rainy Season (annual average: 50-200mm)											
	Eastern Plateau (Primary Desert/arid zone (includes part of Marib)	No Distinct Rainy Season (annual average: <100mm)											
Tropical Cyclone					Cyclone Season					Cyclone Season			

Key and recurrent impacts of flash flooding include loss of life, drowning of livestock, contamination of local water sources, damage to IDP camps and building damage (houses, schools, markets, and other public buildings), and potential displacement. Furthermore, infrastructure damage to roads and bridges can result in reduced or cancelled transportation (with potential knock-on impacts on livelihood); and the disruption of food, water, health or protection services. Other infrastructural damage, such as to the electricity grid, can have

particularly strong impacts in urban regions like Aden City or Sana'a city. Farms and agricultural land can be damaged and crops and harvests destroyed. Finally, damage to sewage and drainage systems can lead to standing water and/or contamination of environment and water sources leading to an increased risk of cholera outbreak. For example, during the April 2020 floods, in some areas of Sana'a governorate drinking water and sewage combined ([ACAPS, 2020](#)).

In particular, during April 2020 heavy rains and the landfall of a tropical storm on the Southern coast caused multiple flash floods in different governorates [see Fig. 5] . The tropical storm specifically, affected approximately at least 150,000 people across 13 governorates, including 64,000 internally displaced people ([ReliefWeb, 2020](#)). Moreover, for internally displaced people (IDPs) across southern governorates, initial findings suggested that at least 5,537 displaced families were affected by the rains in 69 locations ([IFRC, 2020](#); [OCHA, 2020](#)). The floods resulting from torrential rains in late July and August 2020 caused dams to overflow, damage to water supplies, road blockages, livestock deaths and damage to homes ([OCHA, 2020](#)).

In response to conflict or the impacts of climatological hazards, especially in situations of limited or inadequate institutional support, individuals and communities utilise various coping mechanisms. This can include a change or diversification of livelihoods, adapting ways of life or moving away from their homes. Mobility tends to be the selected coping mechanism in the absence of all other viable options. Displacement tends to be temporary, due to lack of institutional support and can either be a response-based action or preventative. Often internally displaced people end up in poorer urban regions or in IDP camps, both of which open up this population to new vulnerabilities and risks. According to the Internal Displacement Monitoring Centre, in 2020 223,000 people were displaced due to hydro-meteorological disasters and a further 143,000 were displaced due to conflict and violence ([IDMC, 2020](#); [IDMC, 2021](#)). Thus, **in 2020 sudden onset disasters displaced more people than violence and conflict.**

Yemen imports 90% of its food, so flash flooding has a high chance of disrupting access to food and marketplaces. Thus ensuring consistent and unhindered provision of food supplies is essential to reducing the impact of flooding on food security. Moreover, where flash flooding has caused agricultural damage, interventions that promote restoration and recovery through the timely provision of plant material, tools, irrigation systems, seeds or livestock could reduce severity of impacts ([IPC, 2020](#)). This is especially relevant given that agriculture makes up 54% of employment ([WB, 2014](#):118).

Figure 3: Map showing IDP Hosting Sites in Yemen ([UNHCR 2021](#))

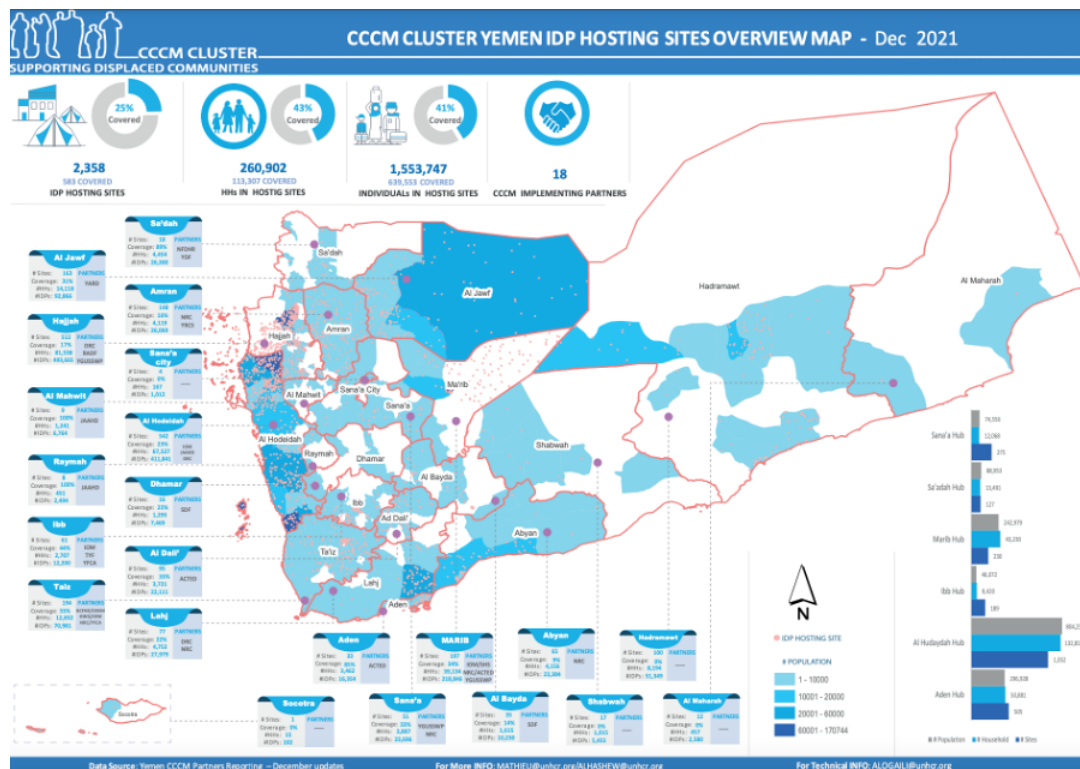
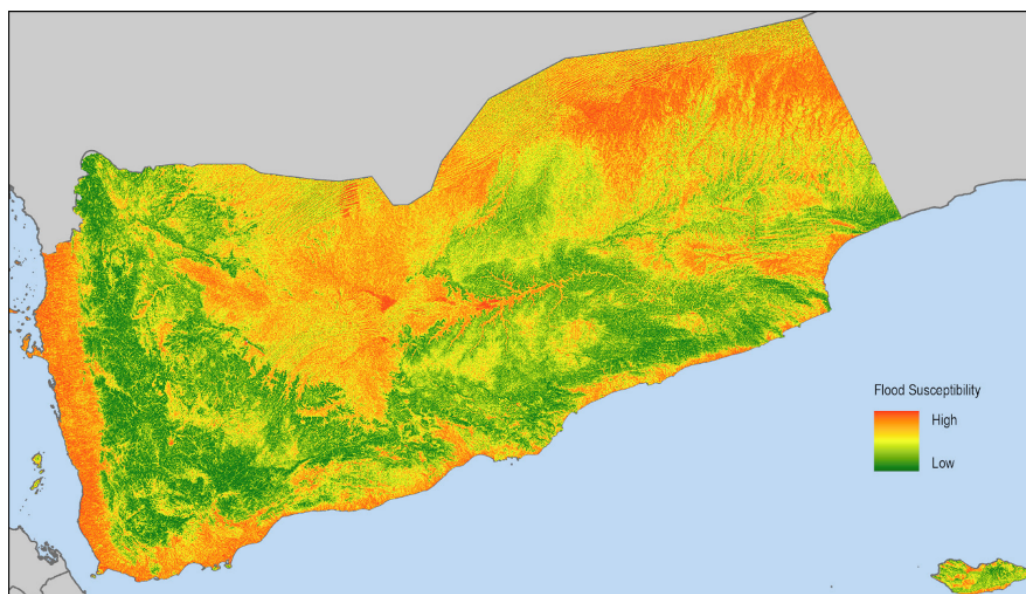


Figure 4: Map showing flood susceptibility in Yemen (REACH, 2020)



of affected HHs by Governorate

Governorate	# of affected HHs
HAJJAH	18.2K
AMRAN	5.6K
SA'DAH	0.6K
SANA'A CITY	2.6K
SANA'A	14.4K
AL JAWF	2.1K
MARIB	16.9K
HADRAMAWT	4K
AL MAHARAH	0.4K
AL MAHWIT	1.1K
AL HODEIDAH	10.9K
RAYMAH	4.9K
SHABWAH	0.4K
AL BAYDA	0.1K
IBB	0.7K
DHAMAR	1.9K
TA'IZ	1.5K
AD DALI'	0.7K
ADEN	2.7K
ABYAN	2.6K
LAHJ	3.4K

of affected HHs by district

Color	# of affected HHs
Dark Blue	4,001 - 8,100
Medium Blue	2,001 - 4,000
Light Blue	1,001 - 2,000
Very Light Blue	< 1,000

SOCOTRA

Since 2012, four Tropical Cyclones have resulted in a disaster event in Yemen. These were: Cyclone Megh in 2015; Cyclone Chapala in 2015; Cyclone Mekunu in 2018 and Cyclone Luban in 2018 (see Annex 2 for further details). Cyclone season in the Arabian Sea is from April to June, and from September to November ([WMO, n.d.](#)). There are on average only 1-2 cyclones that form over the Arabian Sea annually, and these are only rarely intense enough to be classified as very severe storms. However, over the last few decades there has been a noticeable increase in frequency, duration and intensity of cyclonic storms forming over the Arabian Sea from the early 1990s onwards, though these rarely make landfall. A study ([Evan & Camargo, 2011](#)) found that May cyclo-genesis events were associated with early south-west monsoon onset, and June storms with delayed monsoon onset. Storms in November (where the majority of post-monsoon cyclo-genesis occurs) either form in either the Arabian Sea or Bay of Bengal, but not both in the same year. [Dasgupta et al. \(2011\)](#) found that the effects of climate change would leave 1.2 million more people in Aden exposed to storm surges.



Yemen due storm surge. In particular, Socotra Island suffered significant damage to housing, livestock infrastructure and fisheries. Cyclones can lead to coastal flooding without any rainfall which, according to key informants, can be confusing and unexpected for people. Coastal flooding impacts salt harvesting, fishing, and coastal roads causing interruptions to trade (cannot transport goods to and from Aden) and markets which can affect livelihoods and food security.

2.2.3 Sand and Dust Storms

Sand and dust storms affect both the North and the South of Yemen. Sand and dust storms occur when strong winds shift large volumes of dry soil into the atmosphere. They are often caused by thunderstorms or strong cyclonic pressure gradients. While the majority of global dust emissions come from natural sources, anthropogenic contributions are increasing. In particular, human-induced hydrological changes that lead to desiccation of water bodies increases risk of wind erosion and subsequent sand and dust storms. Moreover, any factors that contribute to unsustainable land use and the reduction of vegetation cover also increase the risk of sand and dust storms.

The Middle East region has a complex mix of natural and anthropogenic sources of dust. The largest source of dust storm material is the Arabian Peninsula's Empty Quarter or Rub' al Khali ([NASA, 2013](#)). Additionally in Yemen, large dust sources are associated with river fans at the base of the coastal escarpment in the Hadramawt, the Western highlands and interior basins ([UNEP, 2016](#); [Ghalib et al., 2021](#)). February to June is the peak season for large scale dust outbreaks over the Arabian Peninsula and the Middle East ([EUMETSAT, 2008](#)). However, in Yemen dust and sand storms are most common from June to the end of September. Coastal areas (Hajjah, Hoddeidah, Taiz, Lahg, Aden, Abyan, Shabwah and Hadramout) and desert areas (Marib and Al Jowf) are affected by dust and sandstorms almost all year round ([Ghalib et al., 2021](#)).

Airborne dust, particularly those composed of mineral particulates, can modify the microphysical composition of clouds that then changes their ability to absorb solar radiation. The dust can also have an effect on the amount and location of precipitation due to their ability to act as condensation nuclei and ice nuclei agents ([WMO, n.d](#)).

Additionally, dust storms pose significant risks for human health. Particulates bigger than 10 microns tend to cause skin and eye irritation or infection. However, particles smaller than 10

microns can be inhaled and subsequently get trapped in the nose, mouth and upper respiratory tract causing issues such as asthma, allergic rhinitis and pneumonia. Damage to the nose and throat epithelial cell layer, particular in regions with hot and dry climate, may also create favourable conditions for bacterial infection ([Jusot et al., 2017](#)). Particles of 2.5 microns and below can penetrate the lower respiratory tract and enter the bloodstream. They are associated with stroke and cardiovascular disease. Fine dust particles can also carry pollutants, bacteria, fungi and allergens ([UNEP, 2016](#)).

Dust storms in Yemen can impact the main roads through sand accumulation and the creation of unsafe driving conditions. These road networks connect together highland and coastal regions of Yemen such as the urban hubs of Hoddeidah, Aden, and Hadramout. Moreover, international transport routes to Oman and Saudi-Arabia can also be affected. Dust storms can also cause crop damage due to wind force, deposition of particulate matter, obstruction of irrigation channels and the in-transport for crop diseases ([Ghalib et al., 2021](#)). Livestock death, crop damage and destruction, infrastructure damage and disruption and vehicle damage all contribute to the economic cost of dust and sand storms in Yemen. Some of the IDP population in Yemen may be living in temporary shelters such as tents that are unable to provide adequate protection during severe dust and sand storms.

2.2.4 Drought

Compounding impacts of conflict and drought

The long term, and slower changes related to drought and associated environmental degradation in Yemen intersects with the more visible and immediate impacts of the conflict. The impacts of conflict on food supply reduction and cost increase can lead to insecurity, destabilised community cohesion, increased potential for intercommunal tensions, overdependence on food aid and a higher likelihood of migration in search of more agriculturally productive settlements.

The socio-economic environment of Yemen has continued to deteriorate due to a lack of macro-economic stability and adequately stabilised central bank. GDP losses from 2015-2020 are expected to double to US\$181 billion if the conflict continues through 2022 ([OCHA, 2021](#)). Furthermore, the depreciation of the Yemeni rial (YER) in southern governorates and the estimated impact of over 40% of Yemeni households having lost their primary source of income is severely affecting the purchasing power of the population, making them less able to

cope with shocks and stresses. This coupled with increasing food prices in times of conflict and drought, increases acute food insecurity in Yemen.

Meteorological droughts are classified based on the degree of rainfall deficit, and the overall length of the dry period. Hydrological drought is based on the impact of reduced rainfall on water supply such as ground water storage. Water scarcity is classified as high risk in Yemen with meteorological droughts expected to occur on average every 5 years ([Think Hazard, n.d.](#)). Drought can consist of multiple cascading events, that then by extension affect other areas such as food security and agriculture.

The risk and likelihood of hydrological drought is further exacerbated by strained water supplies and growing water demand leading to potential water insecurity. Climate change also poses further threats such as: estimated future rainfall variability resulting in more frequent periods of drought; high temperatures causing higher evapotranspiration rates; and saltwater inundation of coastal aquifers due to rising sea levels.

Yemen is also particularly vulnerable to agricultural drought, characterised by a lack of sufficient moisture in the surface soil layers to support crop growth. A study ([Allah et al. 2017](#)) examining the Tihama Plain of Yemen, which contributes to approximately 42% of the total agricultural production in the country, found that the years of 1984, 1991, 2002, 2003, 2004, 2005, 2006 and 2008 were most affected by drought between 1980-2010. During times of drought, and subsequent food and water insecurity households cope through the erosion of their livelihoods (such as the sale of productive assets such as livestock) and adopting crisis strategies (such as high reliance on assistance or credit). Moreover, when drought is coupled with low WASH coverage there is potential for an increased disease burden.

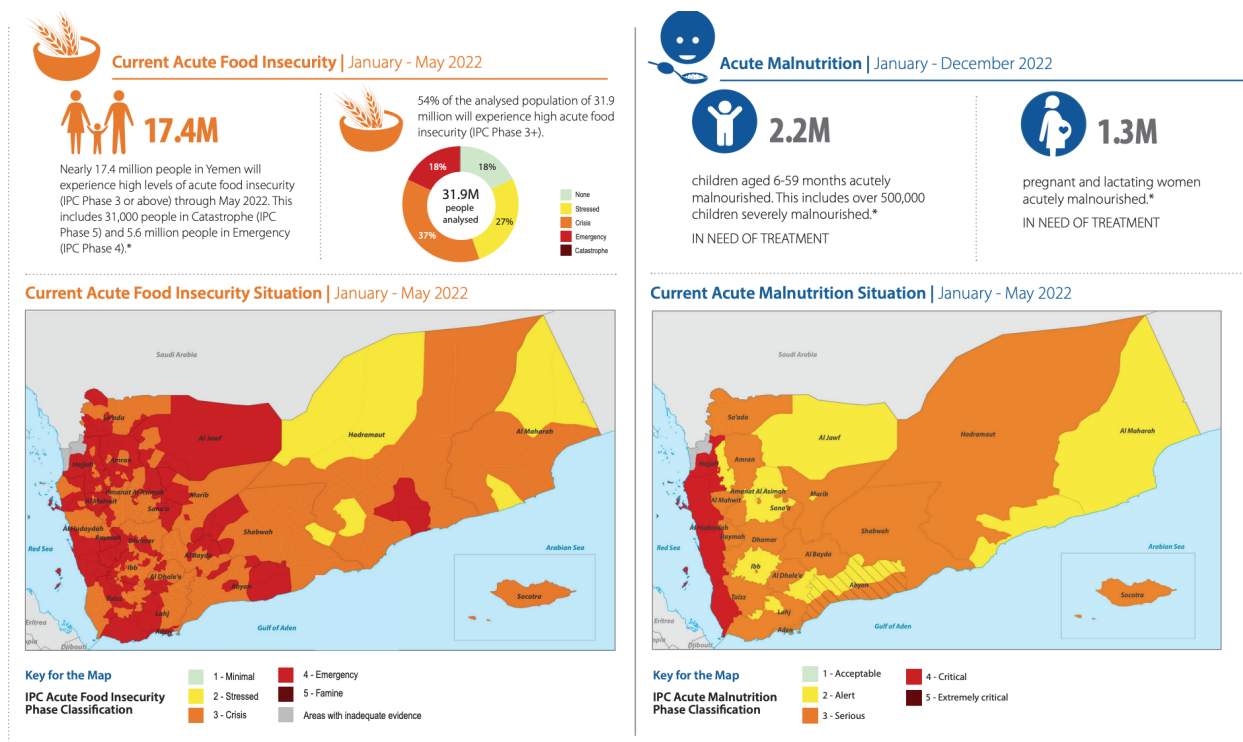
Finally, Yemen already experiences extreme water scarcity and stress due to several factors outside of drought caused by a decline in expected rainfall and increased temperatures such as:

- The overexploitation of groundwater, which in some coastal regions has led to saltwater intrusion. Currently groundwater overdraft is twice the recharge rate.
- Agriculture uses an estimated 93% of available surface- and ground-water, particularly to grow qat.
- Increased price of trucked water (delivered by public networks).
- The impact of conflict on access to improved water sources.

- Issues with the treatment and recycling of wastewater. The number of treatment plants are limited primarily to major urban centres and some have exceeded their design capacity.

Conflict and economic crisis remain the main drivers of food insecurity and malnutrition, however food insecurity can be exacerbated by the appearance of drought or extended dry periods. 151 of 333 districts in Yemen are classified as being in IPC Phase 4 (Emergency) of Acute Food insecurity; this represents 5.6 million people [see Fig. X below]. From June to December 2022 this is projected to increase by 1.6 million people (representing 233 districts). Three districts are classified as being in IPC Phase 5 (Famine). Of greatest concern are two districts in the governorate of Hajjah: Abs and Hayran ([IPC, 2022](#)).

Figure 6: Map of Current Food Insecurity Situation in Yemen ([IPC, 2022](#))



2.2.5 Heat Waves and Cold Waves

Given the arid hot climate in Yemen, extreme heat and heat waves are a hazard that can pose significant damage to people especially in terms of health. The Met Office defines heat waves as an extended period of hot weather *relative* to the expected conditions of the area at that particular moment in time. Heatwave thresholds for thermal conditions are typically nationally

determined, but the World Meteorological Organisation ([WMO, 2015](#)) requires at least two consecutive days of these relatively warmer thermal conditions. Yemen's temperature has been rising at a rate faster than the global average over the past three decades ([RCCC, 2021](#)). UNFCCC research shows that temperatures are forecast to rise by around 1.2-3.3°C by 2060. Temperature extremes are also set to rise, with the hottest day of the year by the end of the 21st century projected to be 3-7°C hotter than today. The Met Office predicts the Arabian Peninsula to have more days where temperatures reach over 40°C, temperatures at which increases risk of heat exhaustion, heat stroke and can exacerbate chronic conditions ([Met Office, 2021](#)). However, there is little to no available data on historic heat-related death or illness due to heatwaves in Yemen. Nevertheless, as extreme heat is positioned to be a high-risk hazard and cause of morbidity & mortality in Yemen as the climate crisis progresses, heat waves and extreme heat are recommended to be taken forward as potential candidate hazards for an FbF system.

Cold waves, sometimes also known as deep freezes, involve the new presence of very cold air or a significant cooling of the air ([IFRC, n.d.](#)) and whose increasing extremity has been linked to climate change ([Greenpeace, 2022](#)). There is a marked drop in average temperature and wind chill can make the temperature feel even colder. Cold waves are sometimes experienced in the mountainous and desert communities (Saada, Amran, Sanaa, Dhamar, Bayda, Ibb, Dhalea, Ibb, Taiz, Lahj, Abyan, Shabwa, Hadramout, Marib and Jawf) ([Yemen Press Agency, 2022](#)). Cold waves can have negative impacts on people, crops, property and services, and pose a particularly high level of health risk for the elderly and younger children, as well as displaced populations who live in improvised shelters which provide insufficient insulation and protection. Beyond the direct physical impacts of cold such as frostbite and hypothermia, people may also face secondary risks such as pipe freeze that reduces water access or household air pollution due to increased use of heating/cooking devices inside without proper ventilation. Moreover, livestock and crops that are intolerant to sharp drops in temperatures may die causing further negative effects on livelihood and food security.

2.2.6 Landslides

Given that addressing landslide risk tends to require longer term development activities and the ability to predict where a landslide will occur, often at extremely short lead times, it is not recommended that landslides are taken forward as a priority hazard for further investigation. Nevertheless, it is worth recognising that the mountainous terrain and high relief landscape of Yemen renders the entire country at high risk of landslides. In 2016, 20 people were killed by a

landslide in Al-Lassbah village (EM-DAT, see Annex 2). Whilst mortality from landslides may not be high, landslides do damage or block roads and prevent access to markets or humanitarian services.

2.2.7 Epidemics

Impact of Conflict on outbreak risk

The civil war has significantly damaged sanitation infrastructure, broken down healthcare service delivery and vaccination coverage, as well as causing high levels of displacement - conditions ripe for infectious disease transmission and heightened risk of major epidemics.

For the purpose of this feasibility study, we focus only on outbreaks of climate sensitive infectious diseases which may have strong hydro-meteorological drivers (i.e. diseases that are highly influenced by changing temperature, humidity or rainfall patterns) ([WHO, 2009](#); [Alcayna, 2022](#)). For these types of diseases, it may be possible to forecast an increased risk of outbreak based on weather forecasts. In the case of Yemen, these include cholera (a waterborne disease), and malaria and dengue (vector-borne diseases). A major outbreak of diphtheria has occurred, but this is more likely due to reduced vaccination coverage and the possible climate links are not well established ([Dureab, 2009](#)). People are also suffering from the COVID-19 pandemic.

Cholera

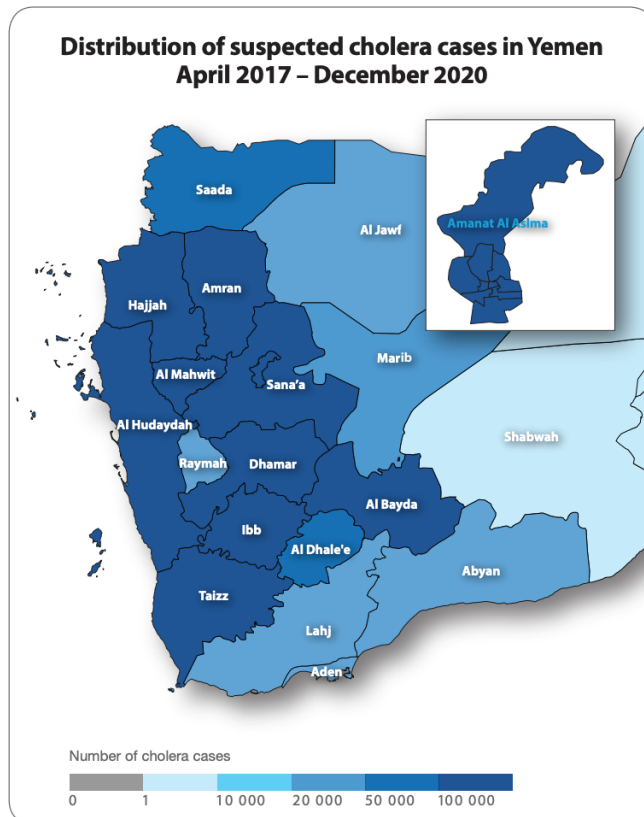
Of the 6 epidemic disasters in the last 10 years in Yemen (EM-DAT, see Annex 2), three were caused by **cholera** (a highly contagious diarrhetic infection caused by vibrio bacteria transmitted through the consumption of contaminated water or food). The high levels of poverty, poor sanitation infrastructure, widespread conflict-related displacement, chronic malnutrition particularly in children and food shortage were all risk factors that contributed to the recent major cholera outbreaks in Yemen. Between October 2016 and January 2020, over 2.3 million cases of cholera and almost 4,000 deaths were reported ([Met Office, 2021](#)).⁶ The last major outbreak was in 2019. However, 2020 saw a decline in cholera cases by 70%, and in related cholera deaths by over 90%. The 5 governorates with the highest cumulative attack rate per 10,000 people were Amran, Sana'a, Al Mahwit, Al Bayda and Al Hudayah. The governorates with the highest numbers of deaths are Hajjah, Ibb, Al Hudaydah and Taizz ([WHO, 2020](#)) The impacts

⁶

<https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/business/international/yemen-case-study.pdf>

of cholera outbreaks include: increased mortality & morbidity due to cholera (and co-morbidities); high cholera case fatality rate (CFR) for children under 5 if not treated; reduced access to safe water sources, sanitation, and hygiene facilities; overwhelmed health systems.

Figure 7: Map showing the Distribution of Suspected Cholera Cases April 2017-Dec 2020 ([WHO, 2020](#))



Dengue

Significant **dengue outbreaks** (e.g. higher than “normal” seasonal peaks) have been responded to by the YRCS. The suspected cases by the end of 2020 were seven times the cases in 2019, and six times the reported numbers in 2018 ([IFRC, 2021](#)). The war has created ideal conditions for mosquito-breeding sites due to inadequate drainage from broken infrastructure, open water containers, and discarded plastic containers in which water accumulates ([Alghazali et al., 2019](#)). A previous study found that knowledge on dengue fever (e.g. its identification compared to other febrile illnesses) was low, and many people believe it is the health authority’s responsibility to control mosquitoes ([Saied et al., 2015](#)). The study also demonstrated that

knowledge and preventive practices are linked suggesting an increase in awareness and knowledge may improve community or household based vector-control activities.

Livestock health

The health of livestock (small ruminants) was highlighted by a key informant as an important animal-human health-livelihoods (One Health) consideration. Water is scarce, and fodder is limited, meaning livestock health can rapidly deteriorate, and animals may be more susceptible to infection and disease. We were not able to schedule an interview with a livestock expert and recommend this be pursued in any future anticipatory health-livelihoods work in Yemen.

Section 3: Analysis of available forecasts

Central to the feasibility assessment of anticipatory action programmes which may incorporate FbA by the DREF systems is the establishment of which disaster events, if any, can be anticipated with sufficient reliability in order to trigger pre-disaster action. Table 3 outlines the main hazards and the available lead time from a number of different forecasting sources.

3.1 National and international forecast products for Yemen

Yemen has a National Meteorological Agency with centres in the north and the south of the country that provide 48-24 hour forecasts based on satellite information to the general population via Facebook and other social media, however, the accuracy of these forecasts is low according to key informants. The Civil Defence (which sits within the Ministry of the Interior) has an Emergency Operations Centre and access to the forecasts from the National Meteorological Agency as well as some remote sensors in the mountains and in the wadis to obtain real-time information on the amount of rain falling. These products are not publicly available. However, the YRCS and Civil Defense have signed an MoU to collaborate and improve the nascent early warning systems.

The YRCS use global forecast products such as windy.com but are unfamiliar with other more technical forecast products such as ECMWF, IMD, GLS, or ICON. They also receive forecast warnings from IFRC. This information is received by the YRCS Operations Room and disseminated via SMS to the YRCS branches. YRCS branches may also use traditional techniques to help them predict the coming weather. The YRCS is keenly interested in receiving training on how to access, use and interpret regional and global forecast products to improve their work, and as part of the MoU with the Civil Defense, would like to share this training with them.

Our ability to conduct a skill assessment as part of this study of the available forecast products was limited as there was not observational data. This means it has not been possible to assess the False Alarm Ratio (how often the forecast missed an event which transpired) or the Probability of Detection (how often the forecasts accurately predicted an event). However, certain products provide self-verification of their skill. For example, the ECMWF self-verification suggests that long-range rainfall forecasts have a low skill across Yemen (i.e. not very accurate).

The Indian Meteorological Department (IMD) produces cyclone tracks for the Arabian Sea. The IMD also has forecast verifications for track, intensity and landfall forecasts. According to this

verification, the annual track forecast skill in 2021 was 74.6% for 24hrs, 81.8% for 48hrs and 68.4% for 72hrs, which suggest medium to high skill level.

Table 3: Description of freely available forecasting products for different natural hazards.

Hazard	Forecast description and availability	Lead Time (not Yemen specific)	Source
Floods (flash)	Flash floods are a type of flood caused by heavy or excessive rainfall in a short period, generally less than 6 hours. More analysis needs to be done to understand and quantify this link as global forecasting products are able to forecast with varying skill heavy rainfall events up to 15 days in advance, but whether this translates to flash flooding events in Yemen is uncertain. Long range forecasts of heavy rainfall may have a low skill across Yemen (see skill assessment section).	1-15 days	ECMWF, GFS, ICON
Heavy Rainfall	ECMWF is able to forecast heavy rainfall events up to 15 days in advance. Long range forecasts of heavy rainfall may have a low skill across Yemen (see skill assessment section). Furthermore, as part of the Early Action on Cholera project in Yemen between UNOCHA, UNICEF and the UK Met Office (UKMO), UKMO was providing rainfall information to users in Yemen (including the UN and Government) on a weekly basis. This includes a 7-day hindcast, a 7-day forecast, a 4-week forward outlook, and a summary highlighting high impact weather. It also includes maps showing the spatial distribution of rainfall and tables giving forecast rainfall, by category, for specific locations around the country. UKMO provision of such information should be followed up in future research.	1-15 days 1-4 weeks	ECMWF UK Met Office
Drought	A number of indicators can be tracked for drought conditions including: the Root zone soil moisture, Streamflow, and precipitation via the The NASA Hydrological Forecast and Analysis System (NHvFAS) or the Standardized Precipitation index (SPI). The SPI is a drought index that is based on the probability of precipitation at any timescale (WMO User guide 2012).	5 months 15 days 4 months	NHvFAS CHC ECMWF
Cyclone	Tropical cyclone forecasts, including track, intensity and landfall forecasts, are available for the Arabian Sea region from the Indian Meteorological Department. These can be used for forecasting cyclones and also associated heavy rainfall events. The skill for these forecasts is good (see Skill assessment section)	Up to 120 hours (5 days)	Indian Meteorological Department
Landslide	Extreme rainfall can potentially be used as a proxy, for example extreme rainfall forecast data could be overlaid on risk maps. However, this is	1-15 days	ECMWF, GFS, ICON

	currently very challenging. Landslides are hard to forecast and map, and therefore caution should be taken when exploring this hazard.		
Dust storms	The Barcelona Dust Regional Centre from the WMO provides a daily dust forecast for 72 hours covering North Africa and the Middle East. It is an ensemble model and contains information from ECMWF. Further investigation is needed on whether this is forecasting ground-level dust (relevant to human and animal health) or dust higher in the atmosphere (which is more relevant for aviation), and its skill assessment.	3 days	Barcelone Dust Regional Centre from WMO
Extreme heat	Can be forecast using a Temperature and Heat Index forecast product such as produced by NOAA on the maximum forecast temperature across regions.	15 days	NOAA/NCEP GEFS ThinkHazard

3.2 Skill assessments

To understand whether a given forecast can be used in an FbF program it is critical to assess their reliability or forecast 'skill'. Global forecast data (mainly ECMWF) has been used to undertake skill assessments, as there are no national forecast products available. Furthermore, due to a lack of available observational data, quantitative analysis involving False Alarm Ratios and the Probability of Detection have not been possible, and instead alternative methods of analysis have been used.

Firstly, ECMWF and GloSEA6 have a number of self-verification resources that are available for a number of hazards. The ECMWF self-verification uses 25 ensemble models and is based on a hindcast period of 1981-2014. Long-range forecasts are the only forecasts available for the ECMWF self-verification on a local scale. There is no assessment of forecasts with a shorter lead time. The GloSEA6 forecast is a seasonal forecast from the UK Met Office global long-range model. The self-verification uses 42 ensemble models and is based on a hindcast period of 1993-2016. For both of these forecast assessments, ROC skill scores are used. ROC (Relative Operating Characteristic) scores provide a statistical summary for the performance of the forecast, and are based upon the hit rate and false alarm rates. A score of 1 describes a perfect forecast where all events will be correctly predicted; a score of 0.7-0.9 indicates a relatively good skill; a score of 0.6-0.7 indicates skill at lower levels but that it still better than guessing; and a score of 0.5 or less denotes a forecast with little or no skill. Although these verifications are calculated on a global scale and therefore are not specific to Yemen, which reduces their accuracy, they do provide an estimation of the global forecast's skill.

Secondly, impact-based assessments have been possible, using disasters logged in the EM-DAT database. Here, ECMWF forecast data has been retrieved for the dates of the biggest impact (based on 'total affected') events. This method is used to determine whether forecast data would have predicted previous events at lead times of 10, 5 and 3 days.

Heavy rainfall

ECMWF long-range forecasts of precipitation in the upper tercile (above average rainfall) show ROC skill scores ranging from 0.2-0.6 over Yemen. The central highlands and southern uplands have a score of 0.4-0.6, meanwhile the desert and eastern plateau regions have a lower score of 0.2-0.3. (These skill scores are for the 3 month period March-April, which coincides with the Saif rainy season in the central highlands and the rainy season in the southern uplands). Therefore, the ECMWF self-verification suggests that long-range precipitation forecasts have a low skill across Yemen.

GloSEA6 long-range forecasts of precipitation in both the upper tercile (above average rainfall) and the outer quintile (well above average rainfall) show ROC skill scores ranging from 0.5-0.8 over Yemen. In the upper tercile, the central highlands and southern uplands have a score of 0.5-0.6, and in the outer quintile they have a score of 0.6-0.8. Meanwhile, in the upper tercile the desert and eastern plateau regions have a score of 0.5-0.8, and in the outer quintile they have a score of 0.5-0.6. (These skill scores are for the 3 month period March-April, which coincides with the Saif rainy season in the central highlands and the rainy season in the southern uplands). Therefore, the GloSEA6 self-verification suggests that long-range precipitation forecasts have a medium to good skill across Yemen.

Four major heavy rainfall events have been identified to undertake an impact-based assessment: 16-17th August 2013, 11-14th June 2019, 15th-30th April 2020, 16th July-17th August 2021. These events were the 4 events with the highest 'total affected' in the time period available from the EM-DAT database (2007-2021). Of these events, 3 of the 4 were forecasted at a 3 day lead time, 3 out of 4 were forecasted at a 5 day lead time, and 3 out of 4 were forecasted at a 10 day lead time. This would suggest that the ECMWF forecasts are of relatively good skill. However, it is important to remember that these results are estimates, as exact observed daily precipitation values have not been compared to the forecast data due to a lack of availability.

Cyclones

The Indian Meteorological Department (IMD) produces cyclone tracks for the Arabian Sea. The IMD also has forecast verifications for track, intensity and landfall forecasts. According to this verification, the annual track forecast skill in 2021 was 74.6% for 24hrs, 81.8% for 48hrs and 68.4% for 72hrs (good skill). For the annual average intensity forecast the skill in 2021 was 60.2% for 24hrs, 78.4% for 48hrs and 85.6% for 72hrs (good skill).

3.3 Risk prediction models for infectious diseases

Cholera

Models that attempt to forecast cholera epidemics based on hydro-meteorological indicators are under development. During the massive cholera outbreak from 2016 - 2020 a number of organisation were attempting to predict cholera risk in Yemen including NASA researchers ([NASA, 2020](#)) and a partnership of UNOCHA, UNICEF, UKMO and Uni. Maryland and Uni. Florida ([UKMO, 2021](#)).

For the Early Warning on Cholera Project via the partnership of UNOCHA, UNICEF, UKMO and Uni. Maryland and Uni. Florida, the UK Met Office produced a rainfall forecast for Yemen that determines the specific amount of rain that will fall and where within a 10km radius. The lack of rain gauges in Yemen is offset with satellite derived observational data (NASA Global Precipitation Measurement). The Cholera Risk Model (CRM) then provides an indication of cholera risk with a 4-week validity time, algorithmically calculated using this rainfall data as well as temperature data, population density information, population movement information and WASH data, where available, to calculate a risk score. In the most populous governorates (comprising about 80% Yemeni population), the CRM's predictions were accurate 60% of the time, however, this accuracy was lower in more rural settings ([UKMO, 2021](#)).

A protocol for anticipatory action on cholera has been developed by an IFRC Working Group for cholera endemic areas. They propose two triggers. Trigger 1 relates to Readiness and Preparedness, it may be activated in a cholera hotspot area with a long lead time (3 months) based on two amplifying factors: weather related or population related. Weather related factors include: forecasts for heavy seasonal rain, or extreme weather event (flooding, drought), and especially indications that drought will be followed by heavy rain, against a backdrop of elevated temperatures. Population related factors include: migration and displacement, over-crowding/ camps with inadequate water and sanitation/ poor nutrition. Trigger 2 is for Early Response

when a cholera case is confirmed. It would trigger stronger surveillance and readiness based on one confirmed cholera case in a neighboring district or bordering country (Scenario A) or trigger a rapid response if one cholera case is confirmed within the prioritized district, and rapid scale-up (scenario A) in the surrounding districts.

Dengue

A number of risk prediction models developed in other contexts exist for dengue (510 IBF Portal in the Philippines; IBF for Dengue in Barbados, and Lowe et al 2018). These have not yet been used in Yemen. They rely on forecasts of minimum temperature and the standardised precipitation index, an indicator used to monitor drought and extreme rainfall. Drought conditions were found to positively influence dengue relative risk at long lead-times of up to five months while warmer temperatures and excess rainfall increased the risk at shorter lead times between 1-2 months. Therefore, periods of drought followed by a combination of warm and wet weather several months later could provide optimum conditions for imminent dengue outbreaks.

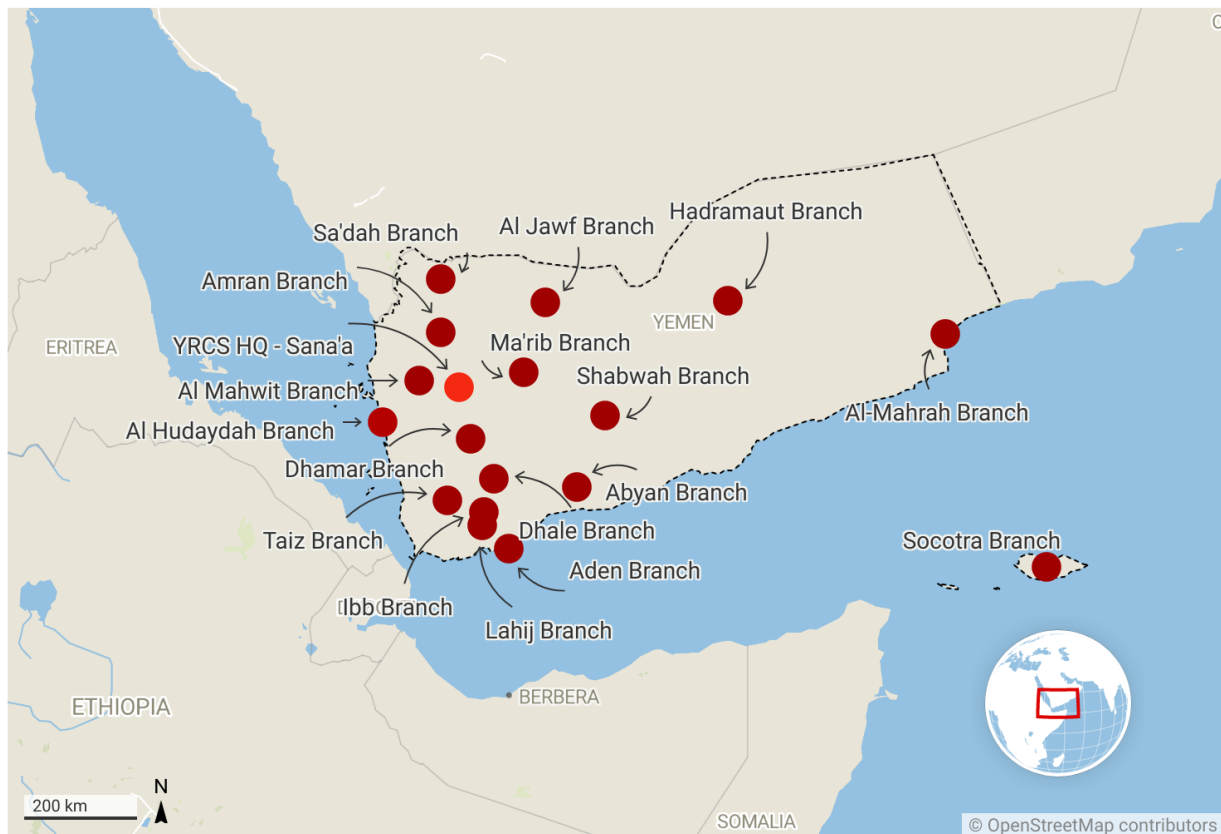
Section 4: Capacity Assessment

4.1 National Society Capacity

The Yemen Red Crescent Society (YRCS) has faced increasing social, political, and economic challenges that have hindered progress of the National Society. The ongoing political unrest, civil war, and economic collapse has exponentially increased the number of people and families in need of humanitarian assistance while simultaneously restricting the ability of humanitarian actors to achieve their goals. Despite these challenges, YRCS has been committed to strengthening their capacity through a number of timely initiatives. YRCS has undertaken a Preparedness for Effective Response (PER) analysis to identify gaps in their disaster response. The results were finalized in December 2019. Strengths that could help in the development and execution of a FbF system include collecting primary data and risk assessments, branches with experience in cash transfer, affected population selection, and coordination with movement partners and external agencies.

YRCS is well located and connected throughout the country with 22 branches, 14 sub-branches and over 8000 volunteers. They have a number of warehouses strategically located with relief supplies. YRCS is working to strengthen partner relationships that will provide necessary support, supplies, and funds. Priority areas include strengthening branch procedures, need assessment and cash assistant capacity. Branch offices are in the process of strengthening their disaster management and revising contingency plans.

Figure 8: Map of YRCS Branches⁷



Created with Datawrapper

The limitations include weak coordination with national authorities on hazards, no communication protocol for alerts, lack of safety and security reporting structure, and no formalized organization with community-based teams. YRCS is working to improve some of these limitations, however, the ongoing conflict restrains progress especially with national systems. Addressing these limitations and initiating formalized procedures across the national society and partners will be integral to the success of a FbF system.

4.1.1 Financial

YRCS financial systems are limited and they have been supported by PNS for their financial procedures. YRCS branches have some experience with cash based interventions and voucher programs. These programs have increased in recent years due to the escalation of poverty and need-based assistance. [more on financial capacity, money distribution etc]

⁷ Exact location not disclosed due to security risk.

4.4.2 Ability to implement

YRCS currently has standardized procedures for rapid needs assessments at 24 hour, 72 hours and one-month timeframes. Based on key informant interviews there is an attempt to provide a forecasts of flood risk via a communication system between YRCS and HQ (EOC in Sana'a) and the DRM at the branch level, to volunteers.

YRCS have a number of warehouses strategically located with relief supplies, however, YRCS feels they need two more warehouse locations in order to provide sufficient coverage for preparedness across the country. YRCS also highlighted during discussions that access to relief supplies is challenging due to price volatility and availability of commodities in the markets.

4.4.3 MEAL

YRCS has one reporting personnel and has established an official reporting form as of 2017. The society reports difficulty in getting branches to send reports consistently or at all. Increasing information sharing within YRCS could help strengthen learnings and capacity within the organization. YRCS notes a lack of commitment to systematic learning procedures.

Section 5: Actions Analysis

Selecting appropriate actions is vital to ensure the FbF system reduces the disaster-specific negative impacts it is intending to address. The selection of actions must consider the lead time available for the National Society and partners to carry out the action, the effectiveness of the action to reduce specific disaster impacts, the benefit in doing the action before the disaster rather than after the disaster, the suitability of the action to the context, the experience and skills of the locally engaged staff and volunteers to complete the specific action, and the complementarity of the actions (if more than one action is being implemented).

Given the civil war, pre-agreements for the movement of goods and staff are required from the different authorities. The transportation of relief materials within the country is another challenge and risk, especially for distributing across different governorates which are in conflict zones. The IFRC, YRCS with ICRC are experienced in navigating these challenges.

Emergency operations conducted by the YRCS, supported by DREF, in the last 10 years included responses to flooding, malnutrition and dehydration amongst forced migrants, food insecurity and dengue fever. Five of seven DREF reports deal with the effects of flooding through the provision of:

- First aid and evacuation
- Psycho-social support
- Distribution of food and non-food items (e.g. hygiene kits, jerry cans, mattresses, blankets, kitchen sets)
- Short-term emergency shelter provision

The YRCS have historically taken the following humanitarian actions::

- Pre-agreements for the movement of goods and staff
- Pre-positioning stocks of emergency supplies and relief items
- Ensuring local procurement of essential relief items
- Coordinating with the authorities most relevant the location of implementation
- Ensuring strong lines of communication between YRCS HQ and branches
- The development of contingency plans and mitigating measures
- Detailed briefing (and training) of volunteers

Furthermore, the civil war is creating very different conditions in the north and south of the country. For example, there is a huge difference in the exchange rate in the south compared to

the north (1USD – 13-1400Rial in the south vs 1USD to 800-900Rial in the north). As economic, conflict, social and political conditions vary so drastically, we advise a two-pronged approach ensuring that actions and plans are appropriate to the differences in the north and south.

Based on activities from previous DREF activations, the YRCS has a wide range of experience with response actions, including cash, to a range of different hazards. Shifting a focus from response towards anticipation provides the opportunity for YRCS to do their usual response activities earlier (ie. before the disaster complexity) and think of innovative ways that impacts of these hazards can be addressed proactively.

In particular, **cash assistance** may be a highly appropriate anticipatory action as the underlying poverty affects all aspects of disaster risk management. For cultures in which there is a high sharing economy, such as in Yemen, unconditional cash transfers enable this economy to continue functioning. Unconditional cash means that people can give back and stay as participants in the sharing economy. Key informants highlighted that cash is an important early action which could help individuals and communities cope with the dual impacts of conflict and natural hazards. A previous report on the sharing economy in Yemen by Mercy Corps indicated that the social sharing networks are extremely important to people's survival and should not be destabilised. They found that it might be better to provide blanket targeting even if this means on a per capita basis people received less assistance, as the social networks would redistribute goods on their own terms to people who are most vulnerable. This approach does a much better job of empowering communities. Though this is not common practice, key informants familiar with the Yemen context advocated for cash transfers to be provided at the community level to ensure this kind of community empowering redistribution is facilitated. However, they acknowledge that this may come with risks (of elite capture) especially if savings groups in the communities are not well established. Whilst cash overall was felt to be a good action, getting money to communities in practice is difficult as there is not a strong digital economy and currency volatility means that prices change rapidly. Other possible early actions that YRCS could take into consideration when planning for an FbF programme are listed below.

Table 4. Suggestions of possible anticipatory actions per hazard.

Conducted using a theory of change framing, including a consideration of the implications conflict would have on exacerbating the hazard impacts and the potential challenges created by the conflict for the implementation of early actions.

Hazard	General impacts	Conflict implications for compound risk	Possible anticipatory actions	Examples of desired outcomes	Conflict implications for early action feasibility/desirability
Flooding (flash)	- Primary: - Deaths and injuries - Infrastructure damage - Crop and other livelihood damage - WASH impacts - Cascading hazards (e.g. landslides) - Secondary: - Psychosocial impacts - Disease outbreaks - Short and medium term economic impacts - Food insecurity	The informal settlements where IDPs and migrant populations often reside are often places of high hazard exposure, where local populations do not live based on local knowledge which these displaced communities may not have. These communities are therefore at greater risk of being impacted by flooding and have less resources to receive warnings, less likely to be assisted, and lower resilience to bounce back after these hazards hit.	Early warning communication Creating water barriers, fixing embankments or cleaning water drainage canals Information on risky behaviours to avoid (e.g. routes to avoid). As evacuations may be very temporary (<24 hours) provide some food and water which is easily carried. Pre-positioning of response stocks at HQ Unconditional cash assistance	- No one dies from flash floods. - Infrastructure is protected - Economic damages are limited. - Disease outbreaks are prevented. - Food security is maintained	Access issues due to damaged roads or communication channels Unplanned scarcity of fuel Rumours circulating quickly
Sand and Dust Storms	- Primary: - Deaths and injuries	IDPs and migrant populations living in temporary shelters that provide	Early warning communication	No deaths or serious injury related to dust	Access issues (in some governorates still affected by ongoing

	○ Infrastructure damage ○ Crop and other livelihood damage ○ Damage to temporary shelters ● Secondary: ○ Health impacts, increased exposure to disease ○ Short and medium term economic impacts ○ Supply chain impacts	inadequate protection during severe dust and sand storms.	Soil stabilisation e.g. increasing vegetation Using plants and trees as pre-positioned wind buffers. Building design that accounts for air infiltration Prepositioning of response supplies such as dust masks. Information on precautions to take during a dust storm and warnings around risky behaviours e.g. driving.	storms ● Limited economic damages ● Agricultural livelihoods and food security are maintained ● Reduction and/or prevention of health impacts ● Reduced desertification and topsoil erosion.	conflict/restrictions on movement) Supply chain issues
Meteorological drought	● Primary: ○ Decrease of water quality and availability ○ Crop and pasture land desecration ● Secondary: ○ Short-long term economic impacts ○ Migration ○ Food insecurity	Assumptions about drought-driven food insecurity can obscure the conflict-drivers of food insecurity and lead to maladapted programming. Notably, most of the food insecurity currently experience in Yemen is a result of increased food prices, low currency value, disruptions to food chains etc.	Pre-positioning and delivery of water (if possible) Borehole rehabilitation and/or other similar water storage actions If analysis shows that drought causes food insecurity, a range of possible food security early actions are possible (e.g. grain store replenishing, trainings on climate-smart agriculture) Unconditional cash transfers to	● Water quality is maintained ● Crops and livestock are protected ● Economic impacts are mitigated ● Migration is limited ● Food insecurity is maintained	Access issues Unplanned scarcity of fuel Rumours circulating quickly

			communities or households		
Cyclonic storm (leading to coastal flooding and flash flooding)	- Primary: - Deaths and injuries - Infrastructure damage - Fishery damage - Livelihoods damage (salt harvesting) - WASH impacts - Secondary: - Psychosocial impacts - Disease outbreaks - Short and medium term economic impacts - Food insecurity		Evacuations Prepositioning of response stock Strengthening of coastal infrastructure Unconditional cash transfers	- No one dies from coastal flooding/flash flooding - Disease outbreaks are prevented. - Economic damages are limited. - Food security is maintained	Access issues Unplanned scarcity of fuel Rumours circulating quickly
Flooding (wadi)	- Primary: - Deaths and injuries - Infrastructure damage - Crop, livestock and other livelihood damage - WASH impacts - Secondary: - Psychosocial impacts - Disease outbreaks - Short and medium term economic impacts		Evacuations Protection of assets and livestock Unconditional cash transfer Protection measures (e.g. sandbagging) Pre-positioning of stock and response mechanisms (e.g. volunteer mobilisation)	- No one dies or is injured during floods. - Infrastructure is protected - Economic damages are limited. - Disease outbreaks are prevented. - Food security is maintained	Access issues Unplanned scarcity of fuel Rumours circulating quickly

	○ Food insecurity				
Extreme heat	● Primary: ○ Heat related morbidity and death ○ Economic impacts ○ Crop and livestock damage ○ Water quality and availability decrease ● Secondary: ○ WASH ○ Short-medium term economic impacts ○ Psychosocial impacts		Creation of cooling stations Crop and livestock protection given (e.g. increase water supply) Warning information Unconditional cash to outdoors labourers	● No one dies from extreme heat. ● Crops and livestock are protected ● Water quality and availability remains ● Economic situations are maintained	Access issues Unplanned scarcity of fuel Rumours circulating quickly
Cholera	● Primary: ○ High case fatality ratio in under 5 without treatment ○ Increased mortality and morbidity ○ Increase in malnutrition ○ Reduction in available water due to risk of contamination decrease	Population displacement and crowding, destruction of WASH infrastructure, overwhelmed health services or disruption to healthcare access.	Water, sanitation and hygiene facilities and equipment, Water filters, handwashing facilities, hygiene kits, Increase Community Based Surveillance Pre-emptive Oral cholera Vaccination Health and WASH Community Engagement and accountability		Access issues Unplanned scarcity of fuel Rumours circulating quickly

Dengue	- Primary: - Increased case incidence - Increased death and morbidity - Secondary - Reduced livelihoods	Population displacement, storage of water in containers increasing vector breeding sites, overcrowding, healthcare overwhelmed, disruption of surveillance	Improve community based surveillance i.e. info on the case definition Health promotion activities Removal of vector-breeding sites Vector control activities		Access issues Unplanned scarcity of fuel Rumours circulating quickly
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Section 6: Next Steps and Recommendations

As anticipatory action is a new endeavour in Yemen for the YRCS and other partners, we chose to focus on the viability of pursuing further development of an FbA system for various hazards. All hazards were considered based on historical data, forecasting capacity, Red Cross Red Crescent priorities according to a broader strategic plan, whether it is technically feasible to develop an impact-based forecast to trigger action, and whether meaningful action could be taken in the lead time afforded by current forecast capacities.

As part of the validation workshop, YRCS expressed particular interest in pursuing anticipatory action approaches for flash floods and coastal flooding due to cyclonic activity. YRCS's level of interest and enthusiasm for anticipatory action approaches is high as they recognise that people living in conflict-affected countries are amongst those who most require support for climate-related impacts, and especially in anticipation of further shocks as the backdrop of need is so high.

In 2021, YRCS reached out to 510 regarding the potential development of a **tropical cyclone** EAP. 510 conducted a rapid risk analysis of tropical cyclone activity in Yemen from 1980-2020, identifying 10 tropical cyclone related heavy rainfall and subsequent flooding events that impacted Yemen, causing loss of life, damage, and displacement.

Anticipatory action for **flash floods** is slowly being developed within the Movement and some experience is being gained, but so far, no early action protocol addresses these due to a variety of complications related to their potential for forecast and short lead time. The seasonal nature of flooding in the wadis may require further analysis to understand the driver of these flash flood events. It would notably be interesting to examine coping strategies usually taken by local communities during this season. Internally displaced communities, if they have no previous experience with these floods, may be particularly exposed and vulnerable.

During the inception of the feasibility study, YRCS had also expressed interest in identifying aspects of conflict (i.e. the humanitarian consequences of conflict) that the YRCS may want to try and get ahead of, such as displacement. This would warrant a much deeper investigation, and direct interaction and discussion between ICRC and YRCS, interested PNS, with the support of the Climate Centre.

6.1 Next steps

YRCS requested the following next steps:

- Basic training on climate change projections and impacts in Yemen from the Climate Centre
- Guidance on simplified EAPs
- A presentation of the findings of the feasibility study to be jointly presented to YRCS with external partners (e.g. Civil Defense and Ministry of Water and Environment).

6.2 FbF/FbA Working Group Recommendations

A FbF/FbA Working Group does not yet exist to cover the north or the south of Yemen. WFP have expressed interest in co-leading such a WG. The YRCS has, since 2005, had an agreement on cooperation, cooperation and partnership with the Ministry of Water and Environment to reduce risks of disasters under the auspices of the International Federation of Red Cross and Red Crescent Societies and the World Bank. The following recommendations for the establishment of the FbF/A enabling environment were recommended during interviews:

- Leadership on AA should be cultivated with training on technical expertise. Improving EWS and forecasting could offer an entry point to developing the FbF community of practice or working group.
- Work with Sana'a University to see whether it is possible to strengthen weather forecasts for the whole country, develop bulletins and awareness raising from institutions jointly.
- YRCS, ICRC and others should jointly advocate to Humanitarian Country Level (HC) to help garner momentum for early action.
- Ensure there is community awareness raising to help change the mindset of community to be willing to act in anticipation of an event.

6.3 Overall Recommendations

First tier:

Offer technical support to the YRCS to access and use weather forecasts through trainings and workshops.

- Develop a robust hazard calendar for the YRCS and partners to follow throughout the year. Discuss basic actions that can be taken before each of the hazard seasons begin.
- Conduct hazard risk analyses which take into account changing conflict dynamics.
- Support the YRCS to prepare documentation for imminent DREF applications.
- Invite the YRCS to join current anticipatory action initiatives globally (e.g. Anticipation Hub) and in the region.
- Discuss climate change implications for Yemen with YRCS. Conduct climate trainings and other activities aiming to strengthen the resilience of current programming. Include anticipatory action training within these.

Second tier :

- Consider developing an interim EAP with the YRCS for a priority hazard. Use this exercise as a way to galvanise interest and discussions about the topic.
- Develop simulations of extreme weather events and test these out with YRCS headquarters and branches (“what would you do if...”)
- Connect YRCS with regional meteorological authorities.

Third tier :

- Consider supporting research projects on specific hazard forecasting and anticipatory action in Yemen to increase evidence base and ideas for programming.
- Connect with CREWS initiatives in the region to bolster the support given to local and regional hydrometeorological agencies, increase capacity and connect these with the YRCS Initiatives

Section 7: Synthesis of feasibility by hazard

Note that the Yemeni Red Crescent has experience responding to the impacts of each of these hazards.

The research detailed above can be synthesised based on four main criteria for feasibility:

1. Does this hazard have a high historical impact, and is there a high (current and future) risk of this hazard occurring in Yemen?
2. What is the current predictability of this hazard in Yemen?
3. Is it possible at this time to take meaningful early action to mitigate the impacts of the hazard?
4. What would be the conflict-implications?

Type of Hazard	Hazard (Section 2)	Relative impact (Section 2)	Current predictability (relative) (Section 3)	Possible meaningful anticipatory action (Section 5)	Notes
Hydro-met	Flooding (flash)	High	Low.	Possibly but limited by short lead-times.	Anticipatory action for flash floods is slowly being developed within the Movement and some experience is being gained but so far, no early action protocol addresses these due to a variety of complications in particular related to their forecastability. Note as well that impact-datasets rarely make the distinction between types of floods. Internally displaced communities, if they have no previous experience with these floods, may be particularly exposed and vulnerable.
	Flooding (Wadi)	Medium	Medium.	Yes.	The seasonal nature of these floods may require further analysis. It would notably be interesting to examine coping strategies usually taken by local communities during this season. Internally displaced communities, if they have no previous experience with these floods, may be particularly exposed and vulnerable.
	Cyclones	Medium	Medium	Yes.	YRCS have reached out to 510 about a cyclone EAP.

	Sand and Dust Storms	Medium	Medium	Possibly but limited by short lead times (3 days)	The health implications of dust and sand storms is still a developing area of research. Further analysis needs to be done on the severity of dust/sand storm impacts on agriculture and subsequent consequences on food insecurity. Considering the potential for sand/dust storms blocking road infrastructure could be a key consideration in early action planning for other hazards as well.
	Heatwave/ Extreme Heat	Unclear	High but definitions must be agreed upon.	Yes.	We were unable to access publicly available data on health impacts.
	Meteorological drought	Unclear	Medium - predicting meteorological drought from seasonal forecasts is possible but deeper types of droughts (and causation with impacts) require more technological capacity and analysis	Possibly.	More analysis needs to be done to understand how meteorological droughts lead to humanitarian impacts. For instance, food insecurity is chronic in Yemen, mainly driven by conflict-dynamics (food prices, supply chain disruptions etc.) - theoretically, any shock to the agricultural calendar could compound these situations but more research on this and more will certainly be needed before considering this.
	Landslide	High	No. Landslides are not forecastable hazards in Yemen despite their high impact.	Unlikely at this moment.	Supporting the development of landslide early warning systems could be considered.
Epidemic	Cholera	High	Medium. Cholera forecast models (for Yemen and	Yes.	Cholera may now be endemic in Yemen. A protocol for cholera AA exists within the IFRC and YRCS have experience of cholera response.

			globally) exist and are being improved.		
	Dengue	High	Medium-low. Global models exist and are being improved. Yemen specific dengue prediction models were not identified.	Possibly.	Potentially. Models would need to be tweaked to the Yemen context which would require investments and research.

Annex 1. Conflict Sensitive challenges in FbF delivery and potential solutions

Conflict Sensitive Challenges in FbF Delivery	Potential Solutions
Gaps in data can contribute challenges to the development of predictive models and triggers	• Open source data • Reanalysis rather than observational data • Global level forecasting
Complex and rapidly shifting conflict (scale, spatial distribution, severity etc.) means EAPs may become obsolete more rapidly	• Increased frequency/agile update schedule • The use of expertise to guide a conflict-informed EAP • Working on a governorate or even district level rather than nationally • Potentially include escalation levels that are activated as certain criteria are met (tiered approach with a menu of options)
Volatile political and social situation may dis-incentivise or constrain donors from investing.	• Adequately communicate risk (and measures being taken to mitigate risk) to donors. • Focus on long-term partnerships for disaster risk financing instruments.
Navigating access in regions/areas controlled by conflict actors (e.g. militias, armed forces)	• Pre-negotiation of access to expedite access approvals, pre-position supplies or pre-approve supplier agreements. • Consequently, more discussion and decision-making must be made around how to build in these steps into an EAP. • Engaging with local organisations already present with established networks.
Security of volunteers and staff	• Specific and robust security protocols to maintain safety • Careful choice of operation location (for example, choosing a more secure and “reliable” location in which to carry out FbF operations. However, it is important to note that this is not often the place that would most benefit from FbF).
Inability to conduct FbF at the household level (due to temporary, transient settlements etc.)	• Drop-in centres, restocking repair or cleaning of water sources etc. • Remote actions such as communications (information provision, safety guidance), utilising existing safety net programmes in the area, remote banking. • Institutional Level Actions, such as expedited distribution of non-food items

Annex 2. EM-DAT historical analysis of previous disaster events and their impacts⁸

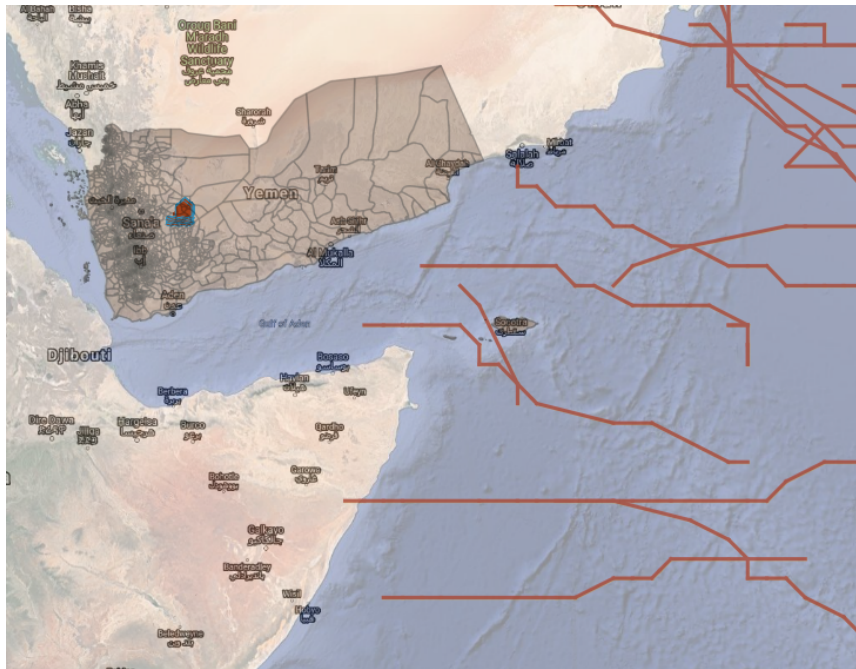
Year	Type	Sub-type	Location	Duration (days)	Injuries	Deaths	Total No. of People Affected
2012	Complex	Complex (Food Shortage)	Sana'a, Hajjah, Al Baida	30 days	n/a	n/a	1437214
2013	Hydrological	Flood (Riverine)	Taizz, Dhamar, Al Mahwit, Sana'a, Ibb, Hajjah, Al Hudaydah, Shabwah, Abyan provinces	2	10	40	49082
2015	Meteorological	Storm (Tropical Cyclone)	Hidaybu, Qulensya Wa Abd Al Kuri districts (Hadramaut province), Aden province	3		18	15000
2015	Meteorological	Storm (Tropical Cyclone)	Abyan, Hadramaut, Shabwah provinces	2	65	8	110000
2015	Biological	Epidemic (Viral Disease)	Hodeidah, Lahj, Hadramout, Aden, Taiz, Shabwa	70		3	3026
2016	Hydrological	Flood (Flash)	Al Hudaydah, Amran, Hajjah, Sana'a, Hajjah, Al Mahwit, Aden, Marib provinces	2		20	29750
2016	Hydrological	Landslide	Al-Lassbah village (Al-Shamayteen mountain region, Taz province)	2	20	20	
2016	Biological	Epidemic (Cholera)	Al Bayda, Al Hudaydah, Al Dhale's, Hajjah, Lahj, Taiz, Ibb, Amamat Al Asimah, Aden, Amran, Sanaa	98	180	11	
2017	Hydrological	Flood	Taëz, Lahj provinces, Portions of Jibla (south of Ibb), Taizz city, Ibb city	2	8	50	
2017	Biological	Epidemic (Cholera)	Sana'a	38			
2017	Biological	Epidemic (Diphtheria)	Sana'a	54	298		

⁸ [EM-DAT Data Extraction Table](#)

2018	Meteorological	Storm (Tropical Cyclone)	Socotra Isl.	1		24	750
2018	Meteorological	Storm (Tropical Cyclone)	Al Maharah governorate	2	124	25	15000
2019	Biological	Epidemic (Cholera)	Ibb, Amanat (Sana'a city) and Hodeidah governorate	186	461542	713	
2019	Hydrological	Flood	Al Mahwit Governorate, Ibb Governorate	7		12	500
2019	Hydrological	Flood (Flash)	Marib, Sa'ada, Aden, Shabwa, Lahj, Taizz, Hadramaut, Ibb, Al Bayda, Al Jawf, Hajjah, Dhamar, Rayma, Hajjah governorates.	4		8	80000
2019	Hydrological	Flood	Sanaa	11		6	
2019	Biological	Epidemic (Dengue)	Hodeidah, Taiz, Aden, Hajja, Lahj, Hudaidah, Aden, Hajja, Lahj, Shabwa, Marib, Rayma	365	59486	219	
2020	Hydrological	Flood (Flash)	Lahj, Aden, Abyan, Taizz, Al Dale'e, Al Mahrah and Hadramaut governorates	2	4	2	23125
2020	Hydrological	Flood (Flash)	Aden, Lahj, Taiz, Ad Dali', Abyan, Hadramawt governorates	16	30	10	150000
2020	Hydrological	Flood (Cyclone Nisarga)	Hadhramaut, Shabwa, Al Mahrah	2	85	16	130
2020	Hydrological	Flood	Marib, Dhale, Abyan, Hadhramaut, Ibb, Hodeidah, Hajjah Governorates	5	6	20	9000
2020	Hydrological	Flood	Lahij, Ibb, Shabwah, Abyan and Sana'a governorates	4		17	
2021	Hydrological	Flood (Flash)	Sanaa, Ibb, Shabwa, Hodeida, Aden, Abyan, Al Dhale'e, Lahj, Hadramaut, Ma'rib and Ta'iz governorates	17		13	22380
2021	Hydrological	Flood	Dhamar, Amran, Al Mahwit, Marib, Ibb, Sana'a, Hajjah, Al Hodeidah, Al Jawf, Al Bayda, Al Dhale, Al Mahra, Raymah, Hadramout governorates	22		11	67980

Annex 3. 510 Study of Tropical Cyclone Risk in Yemen

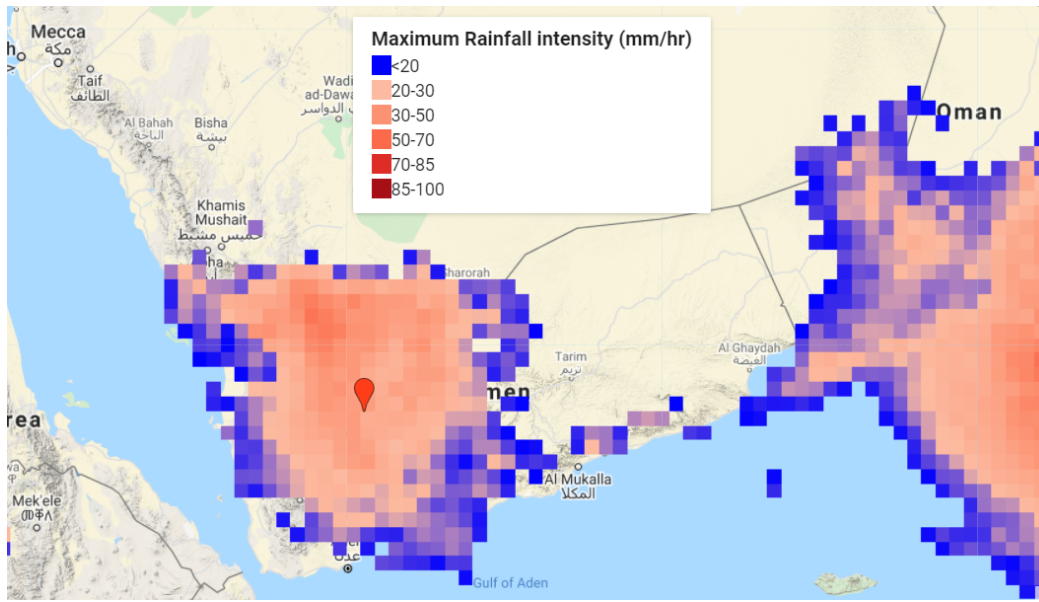
Historical impact of tropical cyclone in Yemen based on data on Tracks for tropical cyclone



These datasets contains information for few cyclones, which makes it difficult to do risk analysis. Therefore will be doing the risk analysis based on other datasets, reported impact data and metrological records. Main cyclone events in Yemen + rainfall outlook during cyclone events are listed below.

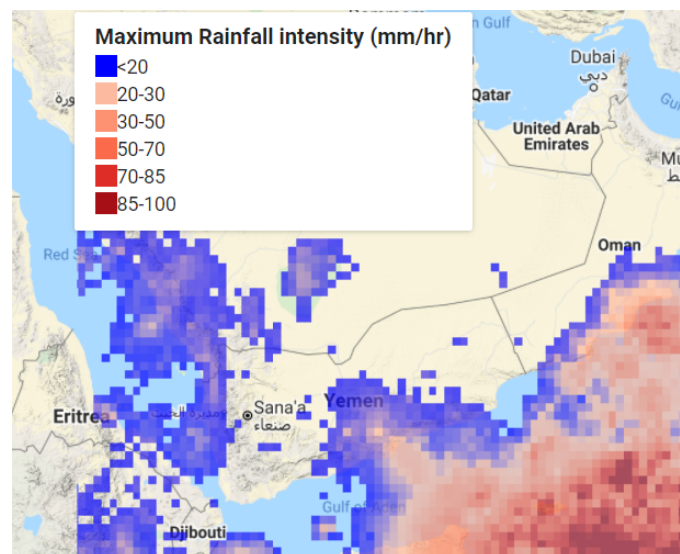
1980–1999

- June 11, 1996 – A tropical storm struck south-eastern Oman, The remnants entered the Empty Quarter of Saudi Arabia and later progressed into Yemen, where it produced the nation's worst flooding on record. The heaviest rainfall in 70 years, reaching 189 mm (7.4 in) in Ma'rib, washed away or damaged 1,068 km (664 mi) of roads and 21 bridges, some of them dating back 2,000 years.[3] At least 1,820 houses were destroyed, and there were 338 deaths in Yemen, with overall damage estimated at US\$1.2 billion. Stagnant floodwaters caused a locust outbreak in August 1996 that affected Saudi Arabia for the next three months.



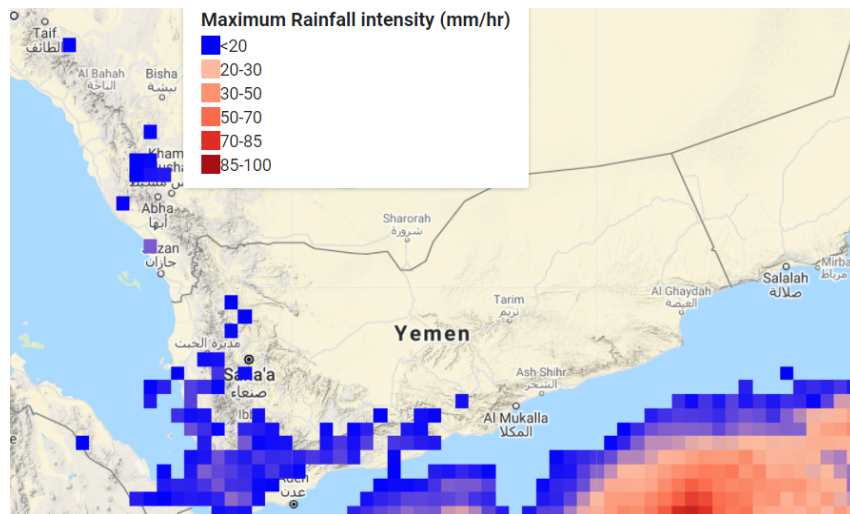
2000–2009

- October 24, 2008 – A weak depression moved over southern Yemen,[11] producing heavy rainfall that led to severe flooding.[82] Throughout the country, the floods destroyed 2,826 houses and damaged another 3,679, leaving about 25,000 people homeless. The effects of the flooding disrupted the livelihoods of about 700,000 residents. Overall damage was estimated at US\$874.8 million, although residual losses from damaged infrastructure were estimated to cost an additional US\$726.9 million. The overall economic impact of the storm was therefore estimated at \$1.638 billion, equating to roughly 6% of the country's gross domestic product.[33] The depression killed 180 people in the country.[11] It was the second worst natural disaster on record in Yemen, following the 1996 storm.

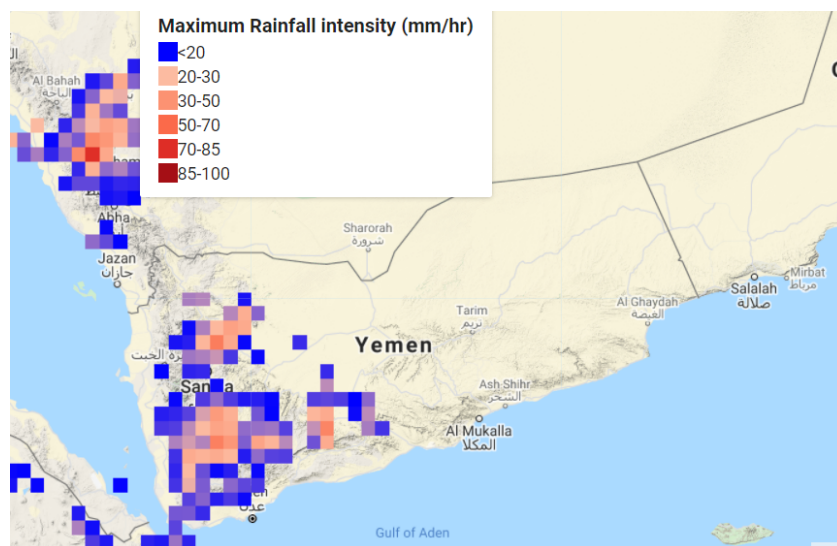


2010

- May 23, 2010 – Cyclonic Storm Bandu drifted in the Gulf of Aden, bringing heavy rainfall to Yemen. The storm destroyed several houses on the island of Abd al Kuri, killing one girl.



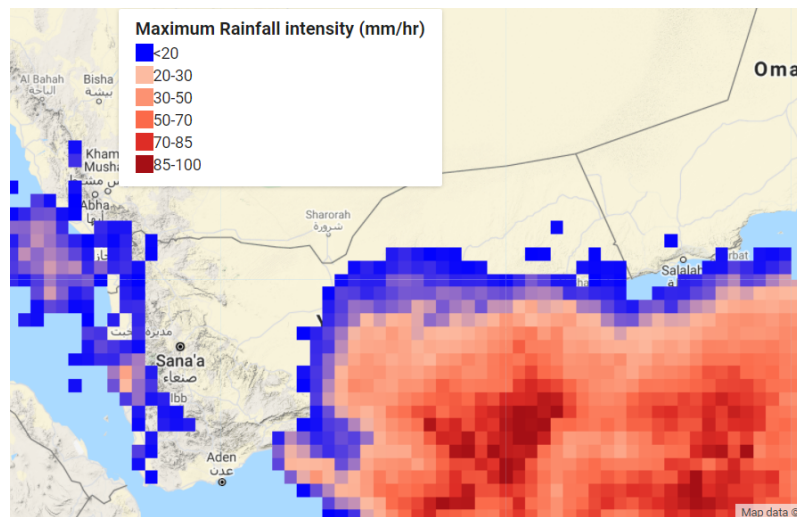
- November 10, 2011 – A depression dissipated off the coast of southern Oman, producing 40 mm (1.6 in) of rainfall.



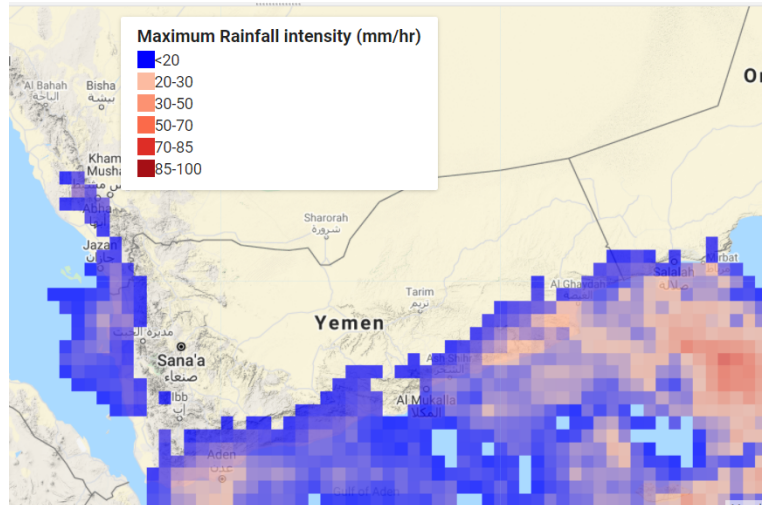
- November 3, 2015 – After peaking as the second-strongest storm on record in the Arabian Sea,[6] Cyclone Chapala became the first recorded storm to make landfall in Yemen as a very severe cyclonic storm – the equivalent of a hurricane – when it struck Ar Riyan with winds of 120 km/h (75 mph).[27][28] It moved offshore and made a second landfall west of Balhaf.[6] The storm earlier hit Socotra Island, killing 11 people while dropping the equivalent of 10 years of rainfall, estimated from 460 to 610 mm (18 to 24 in).[27] On the Yemen mainland, satellite imagery suggested Chapala dropped several years' worth of

rainfall, estimated at over 250 mm (9.8 in).[6] On the mainland, the storm severely damaged 444 houses and wrecked primary roads in Hadhramaut Governorate.[89] Nationwide, the storm displaced over 50,000 people, including 18,000 on Socotra.[28] Chapala struck in the midst of an ongoing civil war.

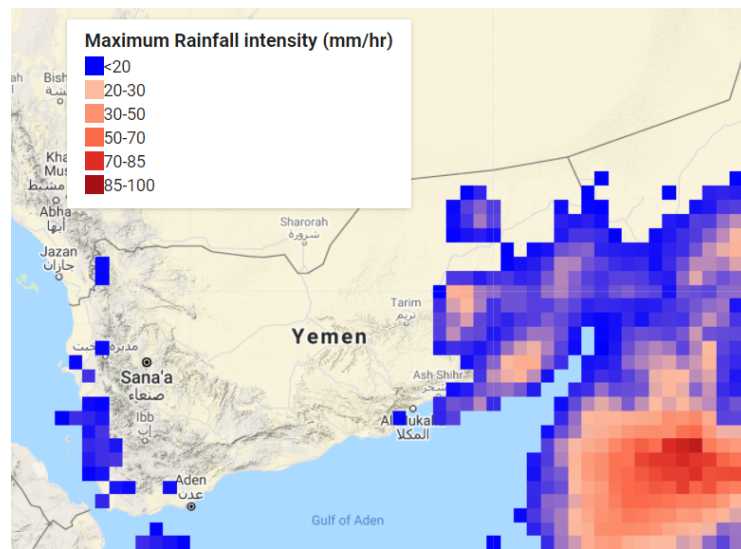
- November 8, 2015 – Just days after the previous cyclone, Cyclone Megh brought additional rainfall to the Yemenese island of Socotra, killing two people.[27] Two days later, Megh struck the Yemen mainland northeast of Zinjibar with winds of 55 km/h (35 mph).[91] Collectively, Megh and the earlier Chapala killed 26 people and injured 78 in Yemen.



- May 18, 2018 – Cyclone Sagar attained peak intensity in the Gulf of Aden, brushing Yemen's coast with damaging rainfall. The storm killed a woman when her house caught fire due to the storm.
- May 25, 2018 – Cyclone Mekunu made landfall in southwestern Oman, after brushing the Yemeni island of Socotra. The cyclone killed 31 people – 20 on Socotra, 4 on the Yemeni mainland, and 7 in Oman.[94][95] Damage was estimated at US\$1.5 billion. Heavy rainfall created the first lakes in 20 years in Rub' al Khali, or the Empty Quarter, creating favourable breeding conditions that led to a severe locust infestation that affected 10 countries.

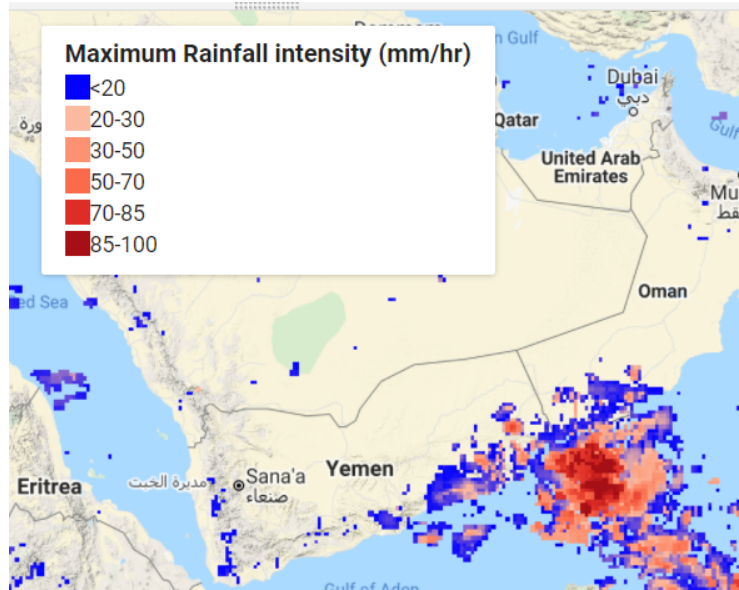


- October 14, 2018 - Cyclonic Storm Luban struck eastern Yemen, dropping 290 mm (11 in) of rainfall in Al Ghaydah.[101] The storm caused US\$1 billion in damage,[102] and killed 14 people in Yemen, with 124 people injured, and about 8,000 people left homeless.



2020

- May 29, 2020 - A depression formed near the border of Oman and Yemen, and stalled over that region until it degenerated into a low pressure area on June 1.[111] The highest precipitation total was measured in Mirbat, Oman, where 1,055 mm (41.5 in) of rain fell.[112] Two people drowned in a wadi due to flash floods,[113] while another person died and three were injured when a building collapsed.[114]



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