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Climate Change Risks and Opportunities In Yemen

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Question

- *What is the most up-to-date evidence on the key current and future impacts of climate change in Yemen?*
- *What does the evidence say about the priorities, challenges and opportunities in relation to these impacts?*

Contents

1. Summary

This rapid review provides insight into the effects of climate change in the Republic of Yemen (*Yemen*), with particular attention on key sectors of concern, including food security, water, energy and health. It highlights some of the government of Yemen's priorities in responding to climate change, although it does not provide detailed information on their policies and commitments. The current and expected climate change effects and related impacts differ locally, nationally and regionally. However, effects at the local level (and country level) are often hard to model accurately. Furthermore, it is important to recognise that the impacts on livelihoods, food and water security, infrastructure etc. differ within countries as well as within communities and at the individual level, with gender a particularly important vulnerability factor. Given the breadth of climate change impacts and the complex, interconnected nature of effects interacting with other factors, this paper can only provide a snapshot of information; more detailed information is found in the references. Many contextual and background factors are relevant when discussing climate-related impacts and potential priorities in Yemen; key issues are hence first briefly discussed in the background section. This is followed by a section on the current and projected climate change patterns, with a focus on temperature and precipitation. The final section explores some of the key sectors of concern in relation to these climate-related impacts. There is cross-over between sections but headings have been used for ease of navigation.

Limited studies and tools that provide climate data for Yemen exist, and there is a clear lack of recent and reliable climate data and statistics for past and future climates in Yemen, both at the national and more local levels (downscaled). Country-level information in this report is drawn mostly from information reported in Yemen's UNFCCC reporting (Republic of Yemen, 2013, 2015) and other sources, which tend to be donor climate change country profiles, such as a USAID (2017) climate change risk profile for Yemen and a Climate Service Center Germany (GERICS) (2015) climate fact sheet on Yemen. Many of these are based on projections from older sources. Studies more commonly tend to look at water scarcity or food insecurity issues in relation to Yemen, with climate change mentioned as a factor (one of many) but not the main focus. Regional information is taken from the latest Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) report in relation to the Arabian Peninsula (and hence Yemen). Academic sources as well as donor, research institutes and intergovernmental organisations sources are also included.

It was outside the scope of this report to review literature in the Arabic language.

Key findings:

- Many contextual factors need to be considered when discussing the climate-related impacts and potential priorities for Yemen. These include (but are not limited to) long-term mismanagement of water (and natural) resources, socio-economic factors, vulnerability and displacement, and prolonged political instability and conflict. These factors seriously hinder Yemen's ability to address the current and future impact of climate change (MFAN, 2018, p.3).
- A long-term warming trend in annual mean surface temperature has been observed across Asia during 1960–2015, and the warming accelerated after the 1970s (high confidence) (Ranasinghe et al., 2021). More frequent heat extremes in recent decades was also observed. Projections show continued warming over Asia in the future, with

extreme heat events likely to become more intense and/or more frequent by the end of the 21st century (Ranasinghe et al., 2021, p.1799). It is also likely that relative sea level rise will continue around Asia, contributing to increased coastal flooding in low-lying areas and shoreline retreat (Ranasinghe et al., 2021).

- Modelling of precipitation trends and changes over Yemen remains particularly difficult and contested. This is partly due to the lack of in-situ data in Yemen, which limits the ability to calibrate and verify satellite precipitation data over this region (Barciela, et al., 2021, p.41). There is some suggestion that the proportion of total rain falling in heavy precipitation events will likely increase in the late summer and autumn seasons in September–November in Yemen (USAID, 2017, p.2). And more extreme weather, with stronger and more intense flooding (USAID, 2017).
- The potential effects of climate change in Yemen include: increased water scarcity and reduced water quality; increased drought frequency, increased temperatures, and changes in precipitation patterns leading to degradation of agricultural lands, soils and terraces; reduced agricultural productivity impacting already at-risk food insecurity issues; damage to infrastructure; deteriorated coastal zones and fisheries; and associated growth of vector-borne and water-borne diseases (MFAN, 2018; USAID, 2017). Yemen's existing challenges such as water scarcity, food insecurity, land degradation, economic under-development, both intersect with and will likely be intensified by climate change impacts (USAID, 2017; Lewis, Monem & Impiglia, 2018).
- Uncertainty remains a key theme with climate change projections and potential impacts on sectors in Yemen, as many of the effects are not fully known or understood. Such as the effect of higher temperatures and more intense rainfall events on the growing seasons of crops or the likelihood of an increase in aridity and drought. Uncertainty and context are both key for planning for climate change impacts.
- Floods and heavy rains in Yemen most often affect poor people the hardest, especially internally displaced persons (IDPs), and small-scale farmers.

2. Background

Many contextual and background factors are relevant when discussing climate-related impacts and the potential priorities, challenges and opportunities from these; a few key issues are highlighted here.

Demographics and climate

Yemen faces acute human development and security issues, including the ongoing conflict. Yemen is classified a Least Developed Country (LDC) and is often considered the poorest country in the Arab region. Yemen's population, as of mid-2020, is estimated to be just under 30 million, with the vast majority under 20 years of age, and although urbanising with a few large cities, around 62% of the population live in rural areas[1]. Yemen has a high population growth rate

[1] See https://www.macrotrends.net/countries/YEM/yemen/rural-population [accessed 27/05/2022]

of around 2.3% annually (Gleick, 2020, p.97). Although over half of Yemen's work-force depends upon agriculture, less than 3% of the land is considered suitable for agriculture.[2]

Yemen has a semi-arid to arid tropical climate with significant geographic variability and three distinct ecological zones governed primarily by topography: the coastal plain, the western Sarawat mountains, and the eastern highlands. Although the land and seascapes are diverse and variable, desert covers a large proportion of Yemen. The overwhelming majority of the Yemeni population lives on the western and southwestern faces of the coastal plain and in the Sarawat mountains. The east of the country is very sparsely settled away from the coast, and is primarily scrubland and desert (United States Agency for International Development (USAID), 2017).

Barciela et al. (2021, p.17) describe the climate of Yemen "as a subtropical dry, hot desert climate with low annual rainfall, very high temperatures in summer and a big difference between maximum and minimum temperatures, especially in the inland area." Topography affects the regional distribution of rainfall in Yemen, particularly by the Sarawat mountain range, which means that much of the rainfall in Yemen occurs in the west. Yemen's seasonal precipitation is largely dictated by the locations of the Intertropical Convergence Zone (ITCZ) and the Red Sea Convergence Zone (RSCZ), producing a bimodal seasonal distribution of precipitation with one peak between March and May and the other between July and September, outside of this Yemen is largely dry (Barciela et al., 2021, p.17). Yemen is a disaster-prone country that faces natural hazards yearly, with floods as the most important and recurring form of disaster (MFAN, 2018).

Annual average temperature and rainfall is variable across the different ecological zones. The coastal plain is arid, with a warm winter (16°C to 27°C and 38 to 58% humidity in Aden) and a hot, humid summer (27°C to 38°C, with temperatures in excess of 50°C not uncommon, and 76 to 82% humidity in Aden), and low average annual rainfall of between 10 to 100 mm per year (USAID, 2017, p.2). The western Sarawat mountains provide a more hospitable climate; in Sana'a, the diurnal winter temperature ranges from 8°C to 17°C, while the summer range is from 22°C to 28°C and humidity is lower in the mountains than on the coast. There is also more rainfall compared to the coast, averaging 100 to 600 mm/year. The eastern highlands are climatically similar to the coast, with very low rainfall (50 to 100 mm/year), warm, dry winters (11°C to 26°C and 9 to 25% humidity), and hot, humid summers (29°C to 41°C, with temperatures in excess of 50°C not uncommon, and 52 to 77% humidity) (USAID, 2017, p.2).

Conflict, food insecurity and displacement

The humanitarian crisis in Yemen remains one of the most acute in the world; with an estimated 20.7 million people in need of humanitarian assistance in 2022. The World Food Programme Yemen's (WFP Yemen, 2022) situation report from April 2022 for Yemen estimates that: 17.4 million people are currently food insecure (as of April 2022), estimated to increase to 19 million by the end of 2022; 31,000 people are in famine-like conditions; and 3.5 million people are acutely malnourished. Seven years of conflict has left an estimated 4.3 million people internally

[2] Taken from https://usaidgems.org/Documents/FAA&Regs/FAA118119ME/Yemen/Yemen2013.pdf [accessed 26/05/2022]

displaced across the country.[3] Many internally displaced persons (IDPs) continue to suffer from repeated displacement, often due to a combination of conflict and natural disasters (IDMC, 2022).

Vulnerability to climate change and policies

Yemen is highly vulnerable to climate change-related impacts because of its fragile socio-economic development and inadequate adaptive capacity as one of the least developed countries in the Arab region (Republic of Yemen, 2013). These vulnerabilities are heightened by the conflict-induced humanitarian crisis. Yemen's rural communities are highly vulnerable to climate change impacts as they rely upon sustainable access to natural resources and associated ecosystem services for production and subsistence (such as for drinking water, fuelwood and medicinal plants) (Republic of Yemen, 2013). Much of the natural resources in Yemen are already under strain and generally degraded, meaning they have limited resilience to climate change impacts.

Yemen ranks 172 out of 182 countries in the ND-GAIN index (2019), which ranks vulnerability to climate change and other global challenges in combination with its readiness to improve resilience. It is ranked as the 22nd most vulnerable country in the index (161 out of 182 countries) and the 13th least ready country (179 out of 192 countries) – meaning that it is extremely vulnerable to, yet very unready to address climate change effects.[4] *Vulnerability* measures the country's exposure, sensitivity, and ability to cope with the negative effects of climate change by considering vulnerability in six life-supporting sectors: food, water, ecosystem service, health, human habitat and infrastructure. *Readiness* measures a country's ability to leverage investments and convert them to adaptation actions by considering the country's economic, governance and social readiness.

It is important to note that indices (the combination of multiple indicators into a single score) such as ND-GAIN, although widely used, have large weaknesses and limitations that limit their value for global measurements. These include discrepancies between different country rankings, being highly influenced by their composition (e.g. data, indicator selection, weighting) and that the aggregated index score hides the underlying factors which caused the change year on year (New et al., 2022: 3032; Leiter et al., 2019: 10).

Despite its vulnerability to climate change impacts, it is estimated that Yemen currently (2020) accounts for only about 0.03% of global CO_2 emissions.[5] A USAID (2016) greenhouse gas inventory for Yemen pus its total greenhouse gas emissions in 2012 (the most recent year with complete data) at 29.84 MtCO2e, totalling 0.07% of global greenhouse gas emissions. With the

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[3] According to the World Food Programme (WFP) – https://www.wfp.org/countries/yemen [accessed 23/05/2022]]

[4] Information taken from https://gain.nd.edu/our-work/country-index/rankings/ [accessed 23/05/2022]

[5] Estimate taken from Our World in Data based on the Global Carbon Project ()https://ourworldindata.org/co2/country/yemen#total-greenhouse-gas-emissions-how-much-does-the-average-person-emit-where-do-emissions-come-from – accessed 23/05/2022). Note: This is measured as each country's emissions divided by the sum of all countries' emissions in a given year plus international aviation and shipping (known as 'bunkers') and 'statistical differences' in carbon accounts.

predominant source of greenhouse gas emissions coming from its energy sector (about 70% of emissions), and then its agriculture sector (at about 24% of emissions) (USAID, 2016).

Yemen signed the Paris Agreement in 2016, though it has not ratified the agreement to date (RCCC, 2021, p.7). In 2015 Yemen submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC. This document outlines the country's climate change mitigation and adaptation commitments (Republic of Yemen, 2015). In its INDC, Yemen pledged to reduce emissions by 1% by 2030 and outlined an additional 13% reduction that could be achieved with international support (Republic of Yemen, 2015). Yemen also developed a mitigation scenario to reduce greenhouse gas emissions in the energy sector in its Second National Communication to the UNFCCC (Republic of Yemen, 2013). The three key points of the mitigation scenario include: energy efficiency; fuel switching; and renewable energy. Yemen's INDC also emphasises the importance of implementing adaptation priorities under the guidance of key national policies and frameworks (Republic of Yemen 2015). It also commits Yemen to further detailing priorities in a National Adaptation Plan. Although Yemen developed and submitted a draft National Adaptation Programme of Action (NAPA) in 2009 to lay the groundwork for a NAP (GFDRR, 2011), the NAPA has not been finalised.[6] The Yemen NAPA identifies three main sectors most vulnerable to climate change: water resources, agriculture and livestock production, and coastal zones/fisheries (Republic of Yemen, 2009). These critical sectors pose potentially severe implications to the citizens at large and are considered to be in need of immediate and urgent adaptation attention.

3. Climate-related impacts and risks

This section synthesises information on regional and national climate-related impacts and risks in Yemen. Regional information is taken from the latest Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) report in relation to the Arabian Peninsula (and hence Yemen). Country-level information is drawn from information reported in Yemen's UNFCCC reporting (Republic of Yemen, 2013, 2015) and other sources, which tend to be donor-led climate change country profiles, such as a USAID (2017) climate change risk profile for Yemen and a Climate Service Center Germany (GERICS) (2015) climate fact sheet on Yemen. Generally, there is a lack of recent information and downscaled projections for climate change in Yemen.

IPCC AR6 Working Group I – Regional projections

Climate change projections are generated for a number of attributes using global climate models (or general circulation models (GCMs)), which combine physical processes to simulate the response of the global climate system to increasing greenhouse gas concentrations in the atmosphere (UN-ESCWA et al., 2017, p.67). A number of factors such as calibration, computing capacity, model resolution etc, influence the results of different GCMs. Coupled model intercomparison projects (CMIPs) have produced vast ensembles of GCM results that can be used to assess possible future climate changes, e.g. CMIP6 data underpins the IPCC AR6. GCMs are continuously being improved as scientific understanding and computational power develops and advances. "[GCMs], in conjunction with nested regional climate models, represent

[6] See https://unfccc.int/resource/docs/napa/yem01.pdf [accessed 26/05/2022]

the most advanced tools available to provide geographically and physically consistent estimates of regional climate change" (UN-ESCWA et al., 2017, p.67).

The IPCC AR6 Working Group I – The Physical Science Basis (WGI) includes a chapter on 'Climate Change Information for Regional Impact and for Risk Assessment' (Ranasinghe et al., 2021) and regional fact sheets focused on the relevant regional climatic information (downscaled country-level projection information is not available). The fact sheet content is not exhaustive but represents most of the high-level key messages assessed in the WGI Report region by region (IPCC AR6 WGI, n.d.). Yemen is included in the regional information on Asia in the AR6 WGI report,[7] specifically the Southwest Asia sub-region (this includes the Arabian Peninsula (ARP) and Western Central Asia (WCA) regions).

For the Southwest Asia sub-region, the AR6 WGI Asia regional fact sheet highlights that:

- Anthropogenic warming has amplified droughts since the 1980s (high confidence) (IPCC AR6 WGI, n.d., p.2).
- An increase in extreme precipitation has been observed, mostly in elevated areas (IPCC AR6 WGI, n.d., p.2).
- Annual precipitation totals, intensity, and frequency of heavy precipitation are projected to increase with increasing warming levels. Strong spatiotemporal differences with overall decreasing precipitation are projected in summer with the opposite tendency in winter (IPCC AR6 WGI, n.d., p.2).

Other key regional findings from the main chapter (Ranasinghe et al., 2021) include the below (Table 1 also shows a summary of confidence in the direction of projected change in climatic impact-drivers (CIDs) in Asian sub-regions):

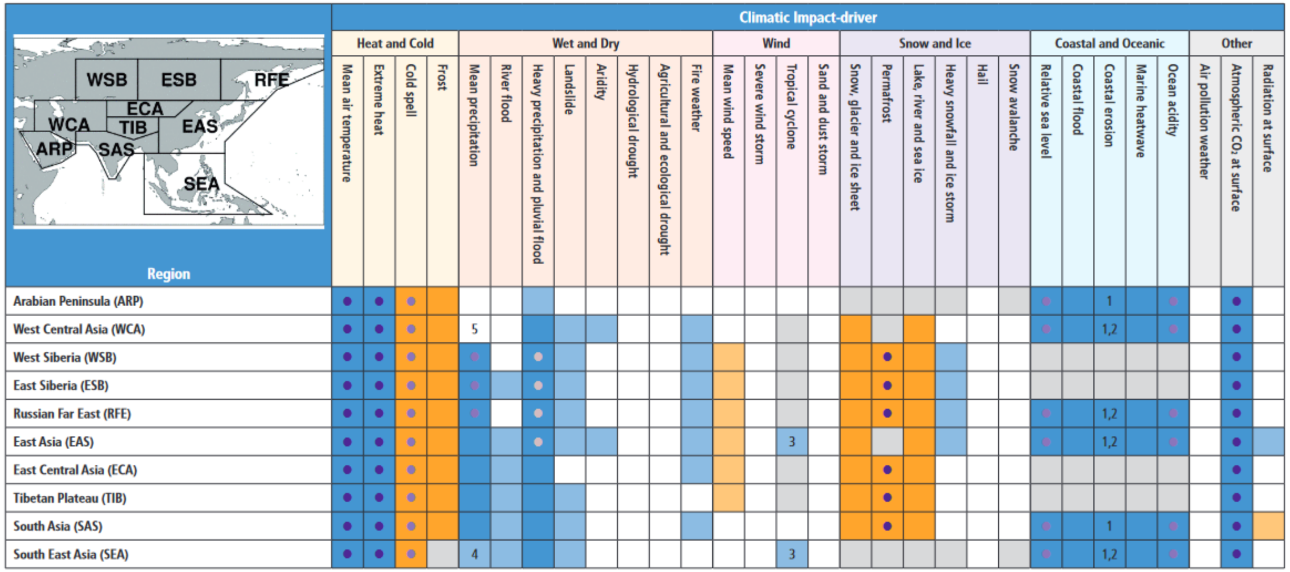
- *Heat and Cold current:* A long-term warming trend in annual mean surface temperature has been observed across Asia during 1960–2015, and the warming accelerated after the 1970s (high confidence). Records also indicate a higher rate of warming in minimum temperatures than maximum temperatures in Asia, leading to more frequent warm nights and warm days, and less frequent cold days and cold nights (high confidence) (Ranasinghe et al., 2021, p.1799).
- *Heat and Cold future:* Projections show continued warming over Asia in the future with contrasted regional patterns across the continent (high confidence). For Representative Concentration Pathway (RCP)8.5/Shared Socio-economic Pathway (SSP) 5-8.5 at the end of the century, the mean estimated warming exceeds 5°C in most areas of ARP and WCA. Under SSP1-2.6, the warming remains limited to 2°C in most areas (Ranasinghe et al., 2021, p.1799).
- *Extreme heat current:* There is increased evidence and high confidence of more frequent heat extremes in the recent decades than in previous ones in most of Asia due to the

[7] According to the region definitions given in AR6 WGI, Asia is divided into 11 regions: the Arabian Peninsula (ARP), Western Central Asia (WCA), West Siberia (WSB), East Siberia (ESB), the Russian Far East (RFE), East Asia (EAS), East Central Asia (ECA), the Tibetan Plateau (TIB), South Asia (SAS), South East Asia (SEA) and the Russian Arctic Region (RAR).

effects of anthropogenic global warming, El Niño and urbanisation (Ranasinghe et al., 2021, p.1799).

- *Extreme heat future:* Extreme heat events are very likely to become more intense and/or more frequent in ARP by the end of the 21st century, especially under RCP6.0 and RCP8.5. The exceedance of the dangerous heat stress 41°C threshold of the Heat Index is expected to increase by 50–150 days in ARP for SSP5-8.5 at the end of the century. Under SSP1-2.6, the increase would be restricted to less than 30 days. Such increases are already present in the middle of the century. The increase in the number of days with exceedance of 35°C of high heat stress is also expected to increase substantially for the mid-century under SSP5-8.5 (typically by 10–50 days), and a large difference is found between low- and high-end scenarios in the end of the century (high confidence) (Ranasinghe et al., 2021, p.1799).
- *Cold spell and frost current and future:* Cold spells intensity and frequency, as well as the number of frost days, in most Asian regions have been decreasing since the beginning of the 20th century (high confidence). It is very likely that cold spells will have a decreasing frequency in all future scenarios across Asian regions, as well as frost days (Ranasinghe et al., 2021, p.1799).
- *Precipitation future:* Higher uncertainty between CMIP5 and CMIP6 as well as spatial differences lend low confidence to model projections for mean precipitation changes in ARP and WCA, with large seasonal differences (Ranasinghe et al., 2021, p.1800). Heavy precipitation is very likely to become more intense and frequent in all areas of Asia except in ARP (medium confidence) for a 2°C global warming level or higher (Ranasinghe et al., 2021, p.1800).
- *Aridity and drought future:* There is low confidence for projected changes in aridity and drought given overall increases in precipitation, limited evidence and inconsistent regional trends, with medium increases for West Central Asia and East Asia especially beyond the middle of the century and global warming levels beyond 2°C (Ranasinghe et al., 2021, p.1801).
- *Wind future:* Surface wind speeds have been decreasing in Asia (high confidence), but there is a large uncertainty in future trends, for example across ARP. In ARP there is also low confidence in the direction of change of wind speeds, severe windstorms, tropical cyclones, and sand and dust storms in the coming years (Ranasinghe et al., 2021, p.1802).
- *Coastal and oceanic future:* In general, there is high confidence that most coastal/ocean-related climatic impact-drivers in Asia will increase over the 21st century. Relative sea level rise is very likely to continue around Asia, contributing to increased coastal flooding in low-lying areas (high confidence) and shoreline retreat along most sandy coasts (high confidence). Marine heatwaves are also expected to increase around the region over the 21st century (high confidence) (Ranasinghe et al., 2021, p.1805).

Table 1: Summary of confidence in direction of projected change in climatic impact-drivers (CIDs) in Asia, representing their aggregate characteristic changes for mid-century for scenarios RCP4.5, SSP2-4.5, SRES A1B or above within each AR6 region, approximately corresponding (for CIDs that are independent of sea level rise) to global warming levels between 2oC and 2.4oC. It also includes the assessment of observed or projected time-of-emergence of the CID change signal from the natural interannual variability if found with at least medium confidence



1. Along sandy coasts and in the absence of additional sediment sinks/sources or any physical barriers to shoreline retreat.
2. Substantial parts of the coasts in these regions are projected to prograde if present-day ambient shoreline change rates continue.
3. Tropical cyclones decrease in number but increase in intensity.
4. High confidence of decrease in Indonesia (Atlas.5.4.5).
5. Medium confidence of decreasing in summer and increasing in winter.

● Already emerged in the historical period (*medium* to *high confidence*)
● Emerging by 2050 at least in scenarios RCP8.5/SSP5-8.5 (*medium* to *high confidence*)
● Emerging after 2050 and by 2100 at least in scenarios RCP8.5/SSP5-8.5 (*medium* to *high confidence*)

High confidence of decrease	Medium confidence of decrease	Low confidence in direction of change	Medium confidence of increase	High confidence of increase	Not broadly relevant

Source: Ranasinghe et al., 2021, p.1804 reproduced under permission

Country-level projections

There is a lack of recent information and downscaled projections for climate change in Yemen.

Change in rainfall patterns and future projections is particularly difficult to assess for Yemen due to the paucity of data for most of the twentieth century. Although estimates for rainfall in Yemen during the twentieth century are difficult to verify, they provide a broad picture of intra-country differences and give a general range of annual rainfall falling between less than 50 mm along the Red Sea coast to more than 1000 mm in the southern highlands (Varisco, 2019, p.320). However, annual fluctuations can be steep. Another demonstration of this difficulty is in the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) (UN-ESCWA et al., 2017, p.67), which used an integrated assessment that combines regional climate modelling, regional hydrological modelling and vulnerability assessment tools at the Arab regional level to give a comprehensive picture of the impact that climate change is expected to have on freshwater resources in the Arab region until the end of the century and how this will affect the vulnerability (UN-ESCWA et al., 2017). The RICCAR reference period data (1986-2005) was compared with observed precipitation and temperature data in the Arabian Peninsula (1980-2008) to review the models. RICCAR simulations are overall in good agreement with the Arabian Peninsula observed station data regarding temperature variables. However, a noticeable underestimation of the annual precipitation was observed over the high-altitude stations such as Sana'a station in Yemen, demonstrating the difficulties in modelling some of these variables, especially precipitation (UN-ESCWA et al., 2017, p.79).

Table 2 is adapted from a Red Cross Red Crescent Climate Centre (RCCC) 2021 climate fact sheet on Yemen, which summarises findings on Yemen's historical and future climate.

Table 2: Summary of climate change in Yemen

This table has been removed for copyright reasons. The full table can be viewed at https://www.climatecentre.org/wp-content/uploads/RCCC-ICRC-Country-profiles-Yemen.pdf p.2.

Source: Adapted from RCCC, 2021

4. Key sectors of concern

The potential impact of climate change on the development of Yemen is expected to complicate current sustainability challenges further. Additionally, the impacts of climate change on different sectors intersect and can reinforce each other, further increasing vulnerability. For example, rural livelihoods are expected to decline due to decreasing water access and agriculture productivity, but are also at risk from the expected increase in severe natural disasters such as floods and associated asset destruction.

Agriculture and food security

Current trends

Before the outbreak of conflict in Yemen, agriculture and fisheries contributed 18 to 27% of Yemen's gross domestic product, 25 to 30% of the annual food requirement and employed more than 50% of the country's workforce (World Bank, 2015 cited in Lewis, Monem & Impiglia, 2018, p.56). This economic dependence on agriculture (and fisheries) has been growing due to a lack of viable alternative livelihoods. Much of Yemen's agricultural production is for subsistence. The three main agriculture-farming systems in Yemen are crop farming, livestock farming and highland mixed farming, with most agricultural households practising the latter type (Lewis, Monem & Impiglia, 2018, p.56). Yemen's agricultural sector is dominated by small, subsistence farms and derives from a terrace system with one planting season from July to August (USAID, 2017). Since precipitation events can be intense in the summer months of July and August, Yemen often experiences soil erosion and flooding at this time (MFAN, 2018). Rain-fed agriculture is the most common farming system in Yemen practised on more than half of all arable land (Crumpler et al., 2022, pp.14-15). Cereals (mainly wheat, sorghum, millet and barley), qat, coffee, fruit and fodder crops account for over 80% of crop production. However, Qat is a lucrative crop and a key pillar of many farmers' livelihoods, but it is highly water-intensive compared with other crops, using 40% of the country's water resources and 38% of the irrigated land (World Bank, 2016 cited in Lewis, Monem & Impiglia, 2018, p.58). Both qat and coffee grow best in the highlands zone, many farmers shifted from coffee to qat in response to the ongoing conflict as it is less labour intensive and has more harvests per year. The transition to qat has resulted in high levels of land degradation across the highlands that leaves rural poor highly vulnerable to climate change. Farmers are also finding it hard to escape the "qat cycle" (Lewis, Monem & Impiglia, 2018, p.58). Livestock has been affected by the erratic water balance as well. Both rising temperatures and erratic water availability affect many of the critical factors for livestock production – such as reproduction and health, forage, and water quantity and quality (RCCC, 2021, p.5).

Agriculture is one of the largest greenhouse gas emitters in Yemen (USAID, 2016). Yemen still imports around 90% of its staple food. Furthermore, there has been a nearly 40% reduction in overall production since the outbreak of conflict due to the reduction of land under cultivation and increased cost of agricultural inputs (EFSNA, 2016 cited in Lewis, Monem & Impiglia, 2018, p.56). Currently, a large proportion of the population is food insecure (WFP, 2022).

Future trends

Yemen is highly vulnerable to food insecurity exacerbated by climate change and "faces decreasing financial and economic resilience as oil revenues dwindle, putting pressure on the exchange rate and on the treasury. As water resources shrink, food imports will rise and become costlier with increasing global prices" (World Bank, 2010). Climate change in Yemen is expected to increase temperatures, variability of rainfall and heavy precipitation events.

An FAO study (Lewis, Monem & Impiglia, 2018) draws out the major trends affecting agriculture in the Near East and North Africa (NENA) region and the general implications for small-scale farmers[8] before delving into an integrated analysis at the farming system level. The report uses temperature and precipitation data from the RICCAR (UN-ESCWA, 2017) report (discussed earlier in this report) and has developed Climate Impacted Farming System (CIFS) maps for the mid-century (2046–2060) in a moderate and worst-case scenario. It also identifies potential hot spot areas for agriculture under a changing climate. For Yemen, it finds strong changes in both temperature and precipitation are projected for the coastal highland mixed farming system, especially along the southwestern border of Yemen, in the mountainous lands. In the moderate scenario, this area is expected to observe a 1.6–2 ºC increase in temperature by the mid-century. In a worst-case scenario, it is projected to increase to 2.1–2.5 ºC (Lewis, Monem & Impiglia, 2018, p.56). Aside from some coastal areas that may experience increases in precipitation (especially under RCP 8.5), there is a general drying trend of between -4 and -7.9 mm/month reduction in both scenarios. Al Hudaydah, Dhamar, Ibb and Taiz governorates are seen to suffer the greatest changes in precipitation; this may be related to them receiving the largest amount of rainfall in the base scenario and so the impacts will, therefore, be even more pronounced (UN-ESCWA, 2017). Small-scale farms are currently growing cereal crops that are largely heat and drought tolerant, namely sorghum and barley; these will be important as these are largely subsistence farmers whose lands are likely to become more arid and experience a greater risk of drought in the context of climate change (World Bank, 2015 cited in Lewis, Monem & Impiglia, 2018, p.57). Millet – as a summer crop – is likely to incur yield losses due to rising temperatures (2.1-2.5ºC in RCP 8.5) that may be more pronounced in summer months. However, crops may benefit from longer growing periods overall because of rising temperatures in these mountainous areas; although the extent to which this may be the case is unknown. A 2010 World Bank assessment of regional climate change impacts on agriculture in Yemen also found a mixed pattern, with production increases in the highlands (from Sa'adah to Taiz) due to higher temperatures but significant yield reductions in some lower and hotter areas such as around Raymah in the west, Abyan in the south, and in the eastern half of the country (World Bank, 2010).

There is also likely to be an increase in extreme weather, including both droughts and floods that are likely to exacerbate runoff, erode soil and therefore contribute to yield losses (Lewis, Monem & Impiglia, 2018, p.57). Both floods and drought have contributed to diminishing crop yields (USAID, 2017, p.3). Regular flooding in Yemen has historically been beneficial for agriculture, however, high-magnitude flooding often leads to losses of cropland and fruit trees, death of livestock, and destruction of infrastructure, such as irrigation facilities and rural roads (MFAN, 2018, p.4). In recent years, Yemen's rainfall patterns have shown increasing extremes that have been attributed to climate change and variability. Frequent droughts and flash floods have already affected crop production, livelihoods and income generation for a large percentage of the population. Pests and diseases, sandstorms and land degradation also threaten crop production. The ability to manage post-harvest losses will become even more important for the subsistence of these farmers as such extremes become more likely (Lewis, Monem & Impiglia, 2018, p.58). Agricultural activities in the coastal plains and deserts are most vulnerable to floods (USAID, 2017, p.3). The impact of climate change on the most vulnerable groups (rural poor, women) include increased exposure to extreme weather events in combination with decreased financial resources available for reconstruction and preparedness due to lower (agricultural) incomes (MFAN, 2018, p.6). The rise in the sea level and, as a result, deterioration of the coastal

[8] See Lewis, Monem & Impiglia, 2018, p.5 for a discussion of their definition of small-scale farmers.

ecosystem, will lead to a diminished fisheries sector increasing the vulnerability of fishermen who are dependent on fish for their livelihoods (MFAN, 2018). Yemen's population growth is another factor that compounds Yemen's vulnerability to climate change impacts by raising the demand for food, water, and other natural resources.

Prior to the current conflict, over 90% of water consumption was used for irrigation. Water scarcity continues to be the largest hindrance to agricultural productivity in Yemen, and further depletion of water resources is expected to reduce agricultural productivity by up to 40 percent (USAID, 2016, p.3). The government of Yemen is concerned that climate change will decrease the frequency and amount of rainfall, thereby further affecting the country's agricultural production (MFAN, 2018, p.6). Furthermore, climate change is likely to increase the demand for irrigated crops, which may lead to competition for irrigated land between cash (e.g. qat – which is highly water intensive) and staple crops. This challenge will be compounded by the rapid population growth in Yemen that is triggering a transition towards cash crops and away from staple crops (Lewis, Monem & Impiglia, 2018, p.58). Given the reliance on imported crops in Yemen, there is also risk from the impacts of climate change in other regions as well as the geopolitical shifts that could alter food prices on the international market (Lewis, Monem & Impiglia, 2018, p.58). This demonstrates the interconnected nature of climate change impacts as climate change would not only affect water security, but also food security and the economy.

Lewis, Monem and Impiglia (2018, p.65) conclude that the "most direct impact of climate change on small-scale farmers in the region will likely be a reduction or increased variability in their food supply." For highland mixed farming in Yemen, impacts from climate change include (Lewis, Monem & Impiglia, 2018, p.65): Crop yield reduction and potential failure, including for barley and sorghum; Increased risk of pest and disease spread; Increased competition between cash (especially qat) and staple crops.

Water resources, use and security

Current stressors

Yemen does not have any perennial rivers, and the minimal seasonal rainfall is largely lost to evapotranspiration (al-Akwa & Zumbrägel, 2021, p.3). In Yemen's western mountains, higher rainfall levels of between 300 mm to around 1,000 mm/year provide most of the runoff that feeds seasonally flowing wadis in the coastal areas and provides much of the country's water (Gleick, 2020, p.96). Wadis are intermittent streams and one of the most common and important landscape elements of the Arabian Peninsula, draining wide catchment areas (UN-ESCWA et al., 2017, p.49). However, most of the country's area is hyper-arid desert receiving less than 100 mm/year of rain. The population is largely dependent on a mix of formal and informal water systems, such as local wells, private water providers, urban groundwater withdrawals, rainfall capture and use, seasonal irrigation, and small-scale local desalination systems. There has also been long-term unsustainable use of Yemen's groundwater, especially around major cities like Sana'a (Gleick, 2020, p.96). Groundwater resources are in heavy use in Yemen to supplement scarce surface water resources but remain largely unregulated, leading to rapid depletion of aquifers and deterioration of water quality**.** Aquifer exhaustion can be seen in Yemen, where water tables have decreased; where coastal aquifers are over-pumped, there is seawater intrusion and increasing salinisation of the aquifer, such as in Tehama (FAO, 2020f cited in Crumpler et al., 2022, p.14). Yemen over-extracts an estimated 0.9 billion cubic meters of water each year from its deep aquifers, meaning many of its groundwater aquifers are declining one to seven meters each year (MFAN, 2018, p.4).

For example, the water level in the Wajid Aquifer System (which extends across the border of Saudi Arabia and Yemen) has dropped at a rate of 3 m/yr for the past 20 to 30 years (as of 2013) and as much as 6 m/yr in some areas around Wadi Dawasir-Sulayyil (Saudi Arabia) and Sa'dah (Yemen). In 1983, the average depth of groundwater was 20-40 m below ground level, and by 2002 it had dropped to 100 m below ground level (UN-ESCWA & BGR, 2013, p.327). A decrease in the average well yield was observed during this period from 6.7 to 3.0 L/s. Abstraction almost doubled over the 20-year period between 1983 and 2002, mostly for agricultural development, which has led to the exhaustion of the aquifer system in some areas, while other areas are threatened by exhaustion in the coming 10 to 15 years (UN-ESCWA & BGR, 2013, p.328). There are also two main threats to groundwater quality: increased salinity and pollution.

Estimates of annual per capita water demand in Yemen are variable (Aljawzi et al., 2022). Measured on a per capita basis, the FAO (2016a cited in Gleick, 2020, p.96) AQUASTAT data indicate that average renewable water availability (including both surface and groundwater) in Yemen is on average less than 125 m3/p/yr—one of the lowest in the world and considered to be facing chronic water scarcity if using Falkenmark et al.'s (1989 cited in Gleick, 2020, p.96) simple metrics of scarcity. These data also only reflect current climatic conditions and do not account for anticipated climate changes. According to Aljawzi et al. (2022, p.2) and previous studies, the estimated renewable groundwater in Yemen is 1.5 Bm3, renewable surface water is 1.0 Bm3, and the water demand amounts to 3.4 Bm3 – a deficit of 0.9 Bm3 that is compensated by non-renewable groundwater. Water demand is estimated to have reached 3.9 Bm3 in 2020, increasing this deficit to about 1.4 Bm3, and future estimates see water demand increasing to 4.4 Bm3 by 2025.

A recent study by Aljawzi et al. (2022) assesses the current water situation in the Sana'a region in Yemen, which includes Sana'a city. Using a variety of data sources, the study used remote sensing (RS) and GIS techniques in combination with the Arc Hydro model to estimate water demand and supply for domestic and agricultural purposes. Although there were 56 rain gauge and meteorological stations in the study area, only 6 stations were found to be operating in 2020 – demonstrating the data and monitoring issues experienced in Yemen. Overall, the study found that "there is insufficient water to meet the needs of the region's yearly population growth rates of 3.2 and 4.5% in Sana'a governorate and Sana'a city, respectively" (Aljawzi et al., 2022, p.1). Further water estimates include (Aljawzi et al., 2022):

- It is estimated that in the Sana'a basin, groundwater abstraction increased significantly from about 25 million cubic meters (Mm^3) in 1970 to around 330 Mm^3 in 2020, while groundwater recharge was about 80 Mm^3 in 2020.
- Water demand for domestic use was in the range of approximately 106–128 and 199–241 Mm^3 in the Sana'a governorate, whereas in Sana'a city, it was in the range of about 249–302 and 607–737 Mm^3 for 2020 and 2040, respectively.
- Agriculture water demand was between 1.14 and 1.53 billion cubic meters (Bm^3) in 2007, and declined to 801 Mm^3 and 1.16 Bm^3 in 2018 due to the reduction in the cultivated area by about 33% from 2007 to 2018, which was attributed to a lack of water. The qat plant increased from 19% in 2007 to 33% in 2018 of the total cultivated areas, with an annual

water need of about 15–29% and 25–43% of the total water used for agriculture in 2007 and 2018, respectively.

Throughout Yemen, rain-fed and irrigated agricultural and animal farming use around 90% of water resources (al-Akwa & Zumbrägel, 2021, p.3). According to the Ministry of Planning & International Cooperation, groundwater depletion in Yemen poses a major threat to the water sector, as the bulk of rural economy depends heavily on it. There has been a 15 fold increase in the amount of water used for irrigation since 1970, while rain-fed agriculture (fed solely on rain) has shrunk by about 30% (Ministry of Planning & International Cooperation, 2021, p.4). The total cultivated area that relies on groundwater also grew from 37 thousand hectares in 1970 to 427 thousand hectares in 2019 (Ministry of Planning & International Cooperation, 2021, p.5). Investment in extraction technologies to exploit groundwater aquifers have increased since the 1970s, making obsolete the traditional irrigation systems, such as wadis in lower-lying areas or underground aqueducts (qanat) irrigation in the highlands (al-Akwa & Zumbrägel, 2021, p.3). This modern technology has also greatly changed Yemeni topography through soil erosion and the abandonment of traditional terrace farming.

Aklan and Lackner (2021, p.3) put forward three main reasons for water scarcity in Yemen:

1. Rapid population growth has increased demand, thus reducing per capita water over generations.
2. The introduction of diesel-operated pumps and tube well-drilling technology in the past century for irrigation has affected traditional rainwater harvesting systems and enabled groundwater extraction significantly above recharge levels. This has led to the expansion of agricultural areas and the depletion of aquifers.
3. Climate change is manifested through increasingly intense and irregular rainfall patterns and other phenomena affecting water availability. This has further reduced replenishment of aquifers, as the loss of top-soil prevents absorption of flows, particularly where terraces and traditional spate systems have deteriorated due to lack of maintenance.

Future stressors

Yemen will likely face more intense water scarcity and stress along with a decrease in water quality, amplified by the impacts of climate change (MFAN, 2018). Greater rainfall variability in the future could lead to more drought occurrence or more floods based on the magnitude, duration and frequency of rainfall in the area, diminishing water supplies more rapidly (RCCC, 2021, p.3). Similarly, increased temperatures could lead to higher evapotranspiration rates, further slowing the replenishment of water sources. Furthermore, overexploitation of groundwater resources and rising sea levels due to climate change increase the likelihood of saltwater intrusion, making it unsuitable for human consumption unless treated (USAID, 2017, p.3). Yemen is also particularly susceptible to coastal damage due to increased storm surges and sea level rise, and the intensification of these has the potential to affect more than 50% of the country’s coastal land area, coastal population, and coastal GDP through the deterioration of Yemeni wetlands, coastal mangrove migration, land erosion, infrastructure damage, and seawater intrusion (USAID, 2017, p.4; Republic of Yemen, 2015).

Using an ensemble of climate models and socio-economic scenarios, WRI scored and ranked future water stress—a measure of competition and depletion of surface water—in 167 countries by 2020, 2030, and 2040 (Maddocks, Young & Reig, 2015). They found that 33 countries face extremely high water stress in 2040, with Yemen ranking 16th. Although, the article recognises the limitations of averaging future water stress across an entire country into a single score, which can mask local-level risks. As with any forward-looking modelling, uncertainty permeates these models as future climate conditions and development patterns are impossible to predict; these rankings illustrate one possible future of water supply and demand (Maddocks, Young & Reig, 2015).

Influences on infrastructure and energy supply

Flood events have had major impacts on infrastructure in Yemen, and the risk of heavy rainfall events and flooding is expected to increase with climate change (RCCC, 2021, p.3). In 2021, flash flood events caused impacts in several places across the country, which affected infrastructure that delivers power and water to the population (IFRC 2020 cited in RCCC, 2021, p.3). For example, RICCAR (UN-ESCWA et al., 2017, p. 54) using the methodology and tools developed by UNISDR's Global Disaster Loss Collection Initiative, supported the population of disaster loss databases in six Arab States, including Yemen, based on data for 1971-2013. Taking into account only disasters triggered by natural hazards (weather-related or of geological origin), in Yemen the vast majority of economic losses (87%) were caused by floods and flash floods. The highest human losses, by far, were reported in Yemen and Morocco compared to Jordan, Lebanon, the State of Palestine and Tunisia (even when comparing similar time periods); the highest combined economic losses culminated in Yemen with around US$ 3 billion of losses over this period (UN-ESCWA et al., 2017, p. 55). Additionally, concerns are being raised about the significant risk to Yemeni infrastructure posed by sea level rise and extreme weather events on the coasts (Al Safaani et al., 2015 cited in RCCC, 2021, p.4).

Increased temperature extremes, especially for extended periods, can result in increased morbidity and mortality and necessitates the promotion of passive (and sometimes active) cooling strategies in building design and construction – affecting energy demand (RCCC, 2021). Increased temperatures cause an increase in water evaporation, which can have implications for the availability of surface water and the operation of hydropower facilities (RCCC, 2021, p.4). Electricity access in Yemen has always been challenging; around two-thirds of the poor had access to electricity when it was last formally measured in 2014, the lowest rate in the Middle East. The current conflict has led to further deterioration, with the country's largest power plant in Marib going offline in March 2015 (ESMAP & World Bank, 2022). It is estimated that currently during the ongoing conflict, the public water network and electricity grid serve no more than 10% of families in Yemen (Aklan & Lackner, 2021, p.5). To cope with the collapse of the country's public utility, people relied on neighbours who had diesel-powered generators or turned to batteries, candles, kerosene, and firewood. In the absence of public utilities, a "solar revolution" has also taken place in Yemen with the number of solar importers multiplying, while many small electronic retailers have started selling solar home kits. "The increasing availability and financial accessibility of solar power – combined with the years of intermittent and only occasional electricity service in towns, and even less supply in rural areas – has led to solar energy's expanded use throughout the country during the war" (Aklan & Lackner, 2021, p.6). It is estimated that more than 70% of households now use solar energy as their primary energy source (Aklan, de Fraiture & Hayde, 2019 cited in Aklan & Lackner, 2021, p.6). In recent years, Yemen has considerably reduced its CO_2 emissions, mainly due to this “solar revolution” (al-Akwa & Zumbrägel, 2021). However, according to al-Akwa and Zumbrägel (2021, p.9), “this is a consequence of the destruction of the national electricity grid due to the ongoing war and internal conflict rather than any strategic planning.” Furthermore, costs have put the technology beyond the reach of some critical facilities, including hospitals and schools and the most vulnerable populations in rural areas (ESMAP & World Bank, 2022). Recent papers have also highlighted the potential risks that the increase of solar-powered irrigation systems pose to over-exploitation of groundwater resources (Aklan & Lackner, 2021).

Health & vulnerable populations

As climate change exacerbates the ongoing food and water insecurity (plus the ongoing conflict), Yemenis are at high risk of needing medical assistance (RCCC, 2021; USAID, 2017). Climate change may affect the prevalence and morbidity and mortality rates of vector-borne diseases, including malaria (USAID, 2017, p.4). The incidence of heat-related illnesses is likely to rise along with the frequency of waterborne diseases. Vulnerable populations, such as children, women and the elderly, are at a higher risk of the adverse impacts of climate change on health (RCCC, 2021, p.5).

Drought health consequences

A study by Bellizzi et al. (2020, p.1) maps hotspot countries over the Eastern Mediterranean Region (EMR) where drought episodes (here defined as a prolonged dry period in natural climate cycle) have become more widespread, prolonged and frequent over the past four decades. The paper reviewed scientific literature and WHO EMR documentation on trends and patterns of the drought health consequences from 1990 through 2019. An index score was developed to categorise countries according to vulnerability factors towards drought. As drought is a slow-onset, long duration, spatially diffuse emergency, rather than a sudden, high-impact event (such as a flash flood), it differs from other natural hazards and has many multiple “downstream” effects that might result in increased morbidity and mortality. The paper identifies complex health consequences due to drought in EMR, including malnutrition (through effects on ecosystems, agriculture, and food security), vector-borne diseases (increase in density of mosquitos due to the loss of competitors and predators, and proliferation of water storage tanks as a drought adaptation strategy), and water-borne diseases (due to reduced water availability which may lead to increased contamination and decreased dilution capacity). Yemen (along with Afghanistan and Somalia) was found to be a “hotspot” for health consequences due to drought due to poor population health status and access to basic sanitation, as well as other elements such as high food insecurity, displacement and conflicts/political instability that render these contexts further vulnerable (Bellizzi et al., 2020, p.6).

Cholera

Between October 2016 and January 2020, over 2.3 million cholera cases and nearly 4,000 cholera-related deaths were reported in Yemen (Barciela et al., 2021, p.6). A number of recent papers have explored the links between climate (and conflict) and cholera in Yemen, with Garrison et al. (2020, p.103) arguing that “Recent conditions in Yemen provide a perfect paradigm of how conflict and climate magnify public health system insecurities, generating infectious disease outbreaks, like [cholera].” The study uses c*holera outbreak data* derived from

ProMED Mail1 and WHO EMRO2 online databases, with data from WHO's Global Health Observatory Data Repository (WHO GHODR) from 1971–2011 to support the historical record of cholera in Yemen and analyse the ability of the Yemeni Ministry of Public Health and Population to control cholera outbreaks during various climatic and political circumstances. Rainfall data was obtained from the daily African Rainfall Climatology (ARC) dataset from the NOAA-Climate Prediction Center (CPC) archives, at 0.1° x 0.1° spatial resolution from 1983 to 2020. The ARC datasets are produced using a combination of rainfall gauge measurements and satellites to produce the gridded rainfall estimates. As conflict is poorly documented and vulnerable to bias, only airstrike data was collected from Relief Web Reports and the Armed Conflict Location and Event Data Project (ACLED) from 2015–2019. Population and migration data was also included. The study highlights that cholera is endemic to Yemen. The association between environmental factors and cholera has been established (Camacho et al., 2018, Eisenburg et al., 2013, Hashizume et al., 2008 all cited in Barciela et al., 2021, p.6). Rain and cholera have a positive relationship; where cholera is amplified during high rainfall periods. However, Yemen has low annual rainfall, which suggests endemic cholera is promoted by other stimulants. For example, the study finds that the 2009–2011 cholera outbreak in Yemen had below-average rainfall. However, western governates experienced above-average rainfall in 2016-2018, accompanied by cholera outbreaks. Yet this apparent connection was not observed countrywide, aside from western governorate (Garrison et al., 2020). Garrison et al. (2020, p.103) conclude that "The research findings implicate conflict-induced migration and the Civil war interfered with public health infrastructure; and extreme rainfall attributed to cholera amplification" in 2016-2019, further exposing vulnerabilities in the country's public health capacity.

A recent paper by Barciela et al. (2021) assesses the validity of their Cholera Risk Model (CRM) and rainfall forecasts in Yemen to understand whether the continued use of these tools in Yemen is appropriate, and to explore the scalability of the approach to other countries. The CRM was developed as part of the Early Action for Cholera Project in Yemen, a joint project between the Met Office, University of Florida and University of Maryland. The CRM provides an indication of cholera risk which is valid for 4 weeks (from issue date). The Met Office provides rainfall information to users in Yemen on a weekly basis (including a 7-day hindcast, a 7-day forecast, a 4-week forward outlook, and a summary highlighting high-impact weather. To assess the reliability of the CRM, its predictions in 2017, 2018 and 2019 were compared to recorded cases of cholera in Yemen. In the most populous governorates (comprising about 80% of the population), the CRM's predictions were accurate 60% of the time (Barciela et al., 2021, p.52). The paper concludes that "the number of new cholera cases is weakly correlated to forecast rainfall. The statistical modelling suggests that targeted interventions based on the weekly rainfall assessments may have reduced the number of cholera cases, however more data would be needed to validate this" (Barciela et al., 2021, p.7).

Barciela et al. (2021, p.49) used a number of methods to validate the precipitation from the Met Office forecast models used in the weekly rainfall assessments, namely validation against observation data. The assessment found the following, which also sheds some light on the difficulties of modelling and predicting precipitation in Yemen (Barciela et al., 2021, pp.49-50):

- As there was an absence of in-situ rainfall observations in Yemen, satellite-derived rainfall observations were used to investigate model accuracy.
- The rainfall forecasts over Yemen have better spatial accuracy for days with light rain, compared to days with heavy rain. The analysis showed that light rain was typically

forecast to be within 11 km of the observation, whereas for heavy rain, the location accuracy was at least 160 km.

- The very heavy rain observed over Yemen is typically due to small-scale, convective, processes embedded within the large-scale drivers. To be able to model these processes, forecast models require spatial resolutions of the order of these small-scale processes (~1.5 km). Light rain is driven by large-scale processes, which can be modelled by coarser-resolution models, hence is forecast more accurately.
- The precipitation is weakly correlated (a coefficient of between 0.4 and 0.5) with weekly number of new cholera cases. This is a similar result to Camacho et al. (2018).
- The statistical model suggests that the targeted interventions made, acting on the weekly rainfall assessments, have reduced the number of cholera cases, although more epidemiological data prior to 2017 (i.e. more before targeted interventions took place) is needed to validate this.
- The accuracy of the Met Office Global Model is higher, or similar, to models from other National Weather Centres (such as the European Centre for Medium-Range Weather Forecasts (ECMWF) or the NCEP (National Centers for Environmental Prediction)).

Internally displaced persons (IDPs)

Evidence collated by the Internal Displacement Monitoring Centre (IDMC) in their 2022 Global Report on Internal Displacement (IDMC, 2022) highlights the number of displaced people in Yemen. Putting this at 4,289,000 as of 31 December 2021 (this figure includes not only people displaced last year, but also those who fled their homes several years or even decades ago) (IDMC, 2022, p.18). The report emphasises that for Yemen there is no information available on when these people were displaced and there is a lack of mechanisms to monitor progress towards the process of returning or integrating locally of IDPs in Yemen, making it impossible to remove people from the statistics. The report also includes a section on displacement related to "disasters" and extreme weather events, such as flooding and drought. Overall the report finds that in 2021, in Yemen, 377,000 people were displaced by conflict and 84,000 by disasters. Specifically, the majority of these disaster-related displacements in 2021 came from heavy rains and floods, with an estimated 84,000 people displaced.[9] As of the end of 2021, 11,000 remained displaced, waiting for their houses and shelters to be rebuilt. "A combination of drought, desertification and heatwaves also triggered 30 displacements" in Yemen in 2021 (IDMC, 2022, p.46). However, the report notes that a lack of reliable monitoring systems makes capturing displacements associated with drought in the MENA region challenging.

A report from the International Federation of Red Cross and Red Crescent Societies (IFRC) (2021, p.13) looking at climate-related displacement, highlights a case study in Yemen that illustrates "how disasters have caused the secondary displacement of persons already internally displaced due to protracted conflict." In 2020 in Yemen, the protracted armed conflict intensified and this was further compounded by extreme flooding, which devastated entire communities and fuelled the spread of diseases such as cholera, dengue, malaria and diphtheria (IFRC, 2021, p.14). This affected more than 300,000 people, most of them IDPs who had previously fled

[9] This specific number is taken from IDMC's country profile on Yemen. See https://www.internal-displacement.org/countries/yemen [accessed 23/05/2022].

conflict areas, leading to secondary displacement. A similar situation was repeated in 2021 when storms and heavy rains caused devastating flooding in many parts of Yemen, with over 174,000 people affected and conflict-displaced persons living in IDP camps again hit particularly hard, causing secondary displacement (IFRC, 2021, p.33).

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