MIDDLE EAST ANTICIPATORY CLIMATE ACTION MODEL (MEACAM): CONCEPTUAL AND TECHNICAL OVERVIEW

November 2024

MERCY CORPS

Table of Contents

List of Tables

List of Figures

Executive Summary

Anticipatory action (AA), i.e. acting ahead of predicted hazardous events to prevent or reduce acute humanitarian impacts, is gaining traction in the Middle East and North Africa region (MENA). Early Warning System(s) (EWS), which use forecasts for different hazards (including floods and drought) to identify areas of specific vulnerability and trigger predefined communication and preparedness actions, are the cornerstone of AA programs. Seasonal forecasting and real-time observation of meteorological conditions and hazards are used across the MENA region, particularly in the Gulf states,[i] but no EWS has been officially adopted by governments or ruling authorities in regional conflict-affected countries, particularly Iraq, Syria, and Yemen. In these countries, meteorological services have been interrupted and are slow to recover, and weather and climate records and meteorological infrastructure have been lost and discontinued, which has resulted in a growing reliance on the use of remotely sensed information (i.e., satellite imagery) to map hazard vulnerability and inform EWSs.

Communication of early warning information – such as weather forecasts, flood and drought advisories, and storm warnings – to communities and among humanitarian stakeholders is more widespread in Federal Iraq and Yemen, with gaps in Syria. The information is often geography- or sector-specific, for example, winter storms and flood vulnerability maps to support camp management or regional drought analyses that assess food security impacts. In addition, dissemination is limited to ad-hoc or periodically published documents or descriptive online dashboards. At present, there does not appear to be a single public platform that provides tailored near real-time hazard predictions and estimates on the number of people exposed to a given hazard.

To address this information delivery gap, Mercy Corps has developed the Middle East Anticipatory Climate Action Model (MEACAM), a publicly available online platform that uses satellite imagery to provide near real-time flash flooding and agricultural drought predictions at pixel level. MEACAM also provides estimates on human exposure to predicted flooding or drought, including the number of affected internally displaced persons (IDPs) and IDP camps. The platform's initial design emphasizes interpretability for a general audience while not omitting key exposure information, though user feedback from other actors will be welcomed and incorporated. Furthermore, the platform's back-end infrastructure facilitates the incorporation of additional attribute layers from Mercy Corps' Crisis Analysis Teams (CAT) and other humanitarian, development, or government agencies.

This report focuses on opportunities for enhancing data-driven EWS in Iraq, Syria, and Yemen, and explores the following key questions:

1. What are the humanitarian consequences of floods and drought?[ii] And who are the most vulnerable groups?
2. What existing early warning tools and platforms support AA?
3. What are the opportunities and challenges associated with developing early warning tools and platforms for Mercy Corps, communities, and the wider humanitarian and development community?
4. How could the MEACAM platform support early warning in Iraq, Syria, and Yemen?

[i] Early warning systems for Saudi Arabia, UAE, Kuwait, Bahrain.

[ii] Flooding and drought are the two most significant hazards across the three countries in terms of safety and economic and humanitarian impact.

Key Findings and Recommendations

Communities in Iraq, Syria, and Yemen are highly exposed to floods and/or drought and the wider effects of climate change, specifically displacement. There is currently limited access to timely[iii] weather and climate information that allows people and institutions to better prepare for, and respond to, the effects of weather events and long-term climate change. Furthermore, data on the specific needs of different groups (e.g. women and girls, small-scale farmers, displaced persons, the elderly, those with chronic health conditions) is scarce in most contexts, and where data is available, it is consistently outdated or lacks comprehensive sub-national geographic coverage.[iv]

There are definite opportunities for the use of data-driven early warning tools and platforms:

- Remote sensing data can be used to fill persistent gaps in environmental monitoring due to conflict-related damage to weather and climate monitoring stations, and to fragmented governance structures.
- Layering weather, population, and displacement data could help deliver more holistic early warning information, and as a result, support timelier and more relevant responses relevant to multiple organizational mandates.
- Humanitarian and hazard event datasets have persistent gaps in terms of coverage, geographic granularity, and timeliness. To encourage data sharing and improve accuracy, a platform blending multiple data sources could be tested in a high hazard exposure area.
- Artificial Intelligence (AI)-assisted early warning tools to support AA are being developed in both the humanitarian/development and private sectors. Given sufficient data input, these tools could support impact-based forecasting.
- Coordination of EWS/AA initiatives, including among donors, could foster greater scale-up of AA programming in Iraq, Syria, and Yemen by supporting the development of a multi-hazard EWS.

Nevertheless, key challenges persist:

- Differing governance structures between and within Iraq, Syria, and Yemen pose challenges when disseminating early warning information and affect the acceptance of such information.
- Forecasting the humanitarian impacts of drought, particularly drought-related displacement, remains challenging due to the complex factors that influence households' decision making.
- Despite the development of tools to support AA, organizations may struggle to take early action because many organizations will likely be reluctant to deliver "no regrets" humanitarian action while operating in a tighter funding environment.
- Local populations may be unable to access early warning platforms that rely on relatively fast internet connections and may be unable to understand the information presented by the platform if it has not been designed for general audiences.
- Sustained funding for early warning tools and platforms is required to ensure uptake within the humanitarian sector and by relevant authorities – which may prove difficult in countries with reduced aid budgets.

[iii] The interpretation of "timely" varies by hazard onset and the format in which people require weather and climate information. For example, drought risk may be foreseen more than three months in advance if using seasonal climate outlooks. This information, along with potential appropriate mitigation measures, would help farmers take action.

[iv] The initial MEACAM platform does not forecast displacement levels or economic losses caused by flooding or drought. However, this type of modelling is a logical next step.

Introduction

The Middle East Anticipatory Climate Action Model (MEACAM), which was developed by Mercy Corps and funded by the European Commission's Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO), is intended to be the first step toward implementing a geography-specific trigger mechanism as part of EWS in Iraq, Syria, and Yemen that will provide publicly available flood and drought forecasts and estimates of how many people will be affected. Although the primary audience is humanitarian implementers and governing authorities, the platform has been designed to be easily understood by the public in a bid to maximize MEACAM's user base. The platform offers flood and drought predictions at a granular spatial scale,[v] along with human impact estimates using the latest and most relevant available data. The platform's modular back-end structure can incorporate additional geospatial attribute datasets[vi] from other information management organizations and Mercy Corps' Crisis Analysis regional teams to ensure that the most informative location attributes are widely available and accessible, such as current levels of local agricultural production and basic service infrastructure.

The MEACAM project is aligned with the objectives of the United Nations Secretary-General's Action Agenda on Internal Displacement by facilitating prevention and earlier preparedness through the integration of human mobility monitoring data with information on hazard vulnerability and risk. By providing publicly available flood and drought forecasts, MEACAM also falls under Pillars 2[vii] and 3[viii] of the Early Warning for All initiative.[1] MEACAM emphasizes working with national governments, humanitarian and development actors, and local communities to assist local officials in fulfilling their social contract to displaced populations and other local community members, and to empower households by providing information on the severity and likelihood of impending hazards. Though internal displacement is often the result of intersecting vulnerabilities and threats, such as conflict, MEACAM will initially address the threat of natural hazards on displaced populations and take conflict into account in later iterations.

The MEACAM project is designed to be easily understood to ensure that the location, likelihood, and human impact of forecasted flooding and drought is appropriately and inclusively disseminated. The project adopts a "do no harm" approach based on a dissemination plan adapted to the local context, accounting for wireless information accessibility, language barriers and bandwidth limitations, disabilities, and gender (based on a forthcoming community consultation). Areas with high concentrations of migrants, refugees, and IDPs will be prioritized in the platform rollout. Though the most accurate hazard forecasts are featured on MEACAM, the platform adheres to a "no regrets" ethos regarding AA programming, meaning the intervention can reduce the burden on the community, even in the case of a false alarm or if the hazard is less severe than predicted.

There is increasing interest among humanitarian actors and donors in EWS across the MENA region. While some have developed projects that measure geographic vulnerability, no one has delivered flash flood and drought predictions as part of a platform designed around a modular attribute information catalog. The MEACAM platform is thus differentiated by two distinct offerings: 1) a platform that can integrate additional attribute information collected by aid actors and government agencies; and 2) flash flood and drought predictions at pixel level using satellite imagery data and spatial machine learning. Though the technical

---

[v] Flood predictions for 10 m2 pixels; Drought predictions for 5 km2 pixels.

[vi] For example, demographic or socio-economic attributes collected from locations in the field or geospatial infrastructure data (e.g., canals; water wells; electricity generators).

[vii] Detection, observation, monitoring, analysis, and forecasting.

[viii] Warning dissemination and communication.

success of an EWS is mostly based on the accuracy of hazard predictions, equal emphasis is placed on providing the most informative set of spatial attribute data through sharing agreements with other agencies and novel humanitarian indicators developed using the spatial analysis capacity of Mercy Corps' CAT teams. Admittedly, the technical achievements are only relevant if the platform is accepted by aid agencies and governing authorities – a significant challenge that is addressed in Part 3.

This report provides an overview of flood and drought hazards in the context of climate change, including impacts on specific vulnerable groups. It identifies existing platforms that collate humanitarian impact data alongside early warning and forecasting, summarizing opportunities and challenges for tools supporting both EWS and AA measures within Iraq, Syria, and Yemen. The report is structured follows:

- Part 1 introduces flood and drought hazards in the context of climate change in Iraq, Syria, and Yemen, as well as a brief overview of EWS and AA.
- Part 2 provides additional information on the impact of flooding and drought in Iraq, Syria, and Yemen, including information on the number of IDPs exposed to hazards.
- Part 3 summarizes existing data-driven early warning platforms and considers opportunities and challenges for tools to support AA.
- Part 4 provides an overview of MEACAM's drought and flooding prediction modules.

Methodology

- For all countries and the wider MENA region, secondary literature on natural hazards, vulnerable populations, and AA in the context of climate change was identified via Google, Google Scholar, PreventionWeb and relevant institutional websites (e.g. UNDRR, UNDP, World Bank, Reliefweb, IFRC, ODI) in addition to relevant ministries and institutions.
- Secondary literature was complemented by key informant interviews (KIIs) conducted between February and May 2024 with staff involved in climate and weather information and/or on AA programs at international and national organizations and relevant ministries identified by Mercy Corps personnel.
- Selected news media reports were included to illustrate information highlighted through other secondary literature or interviews and to provide insight on the potential for AA in Iraq, Syria, and Yemen.
- Tools and platforms to support AA were identified using Google search, Anticipation Hub, and the Center for Humanitarian Data. Only tools with relevant coverage and regular updates were included. Commercial tools were considered out of scope.

Key Terms and Concepts

Key Hazard Terms

Floods

- **Fluvial flood:** When water levels in rivers rise and overflow their banks.
- **Pluvial flood:** When heavy rainfall events saturate the ground and excess water cannot be absorbed, also termed surface water or flash flooding. Flash floods are a type of fluvial flood with a short duration; the time between the forecast and the event is less than six hours.

Drought

Drought is highly complex, but typically refers to a period of abnormally dry weather long enough to cause a hydrological imbalance. Drought is generally classified four ways:

- **Meteorological drought:** The absence or reduction of precipitation over an area compared to historic norms for the time period in question.
- **Agricultural drought:** Insufficient precipitation and soil moisture to support crop growth or other farming activities such as irrigation.
- **Hydrological drought:** Depletion of water supplies including streams, lakes, reservoirs, and groundwater resources.
- **Socioeconomic drought:** A water imbalance impacts the economy (e.g. crop losses) and society (e.g. contributes to adverse health outcomes).

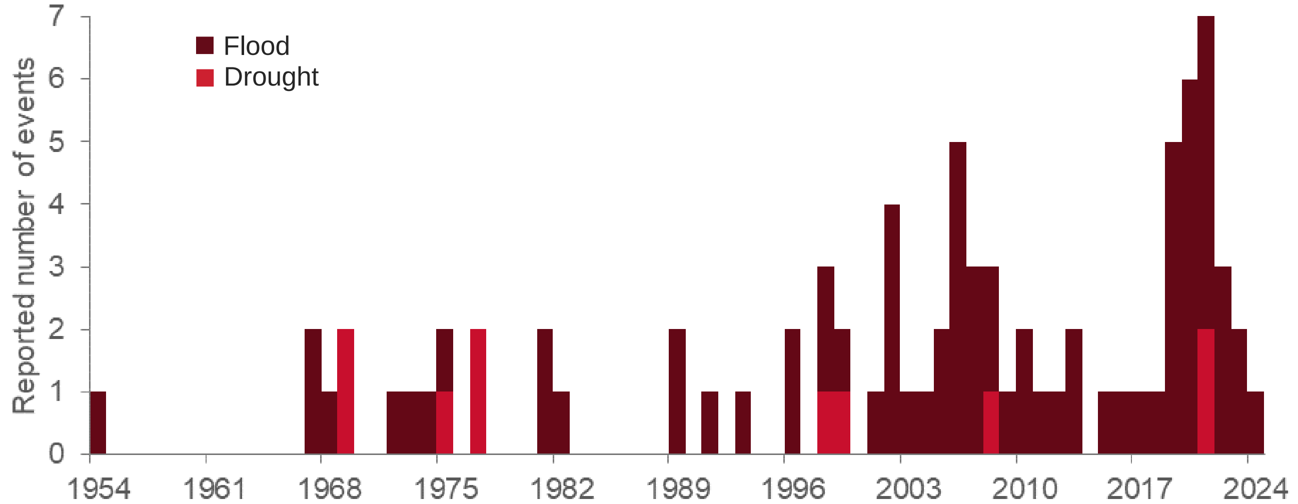
  These four drought types are linked, with agricultural, hydrological, and socioeconomic drought occurring after the onset of meteorological drought.

Sources: WMO, 2006 and WMO, 2023.

Floods, drought, and climate change in the Middle East

The MENA region is highly exposed to natural hazards, including floods and drought, which are exacerbated by climate variability. Since the 1950s, Iraq, Syria, and Yemen have seen an increase in the number of reported flood and drought events with subsequent social, economic, and environmental impacts (Figure 1). War damage to critical infrastructure, lack of governance, and displacement increases the vulnerability of communities to natural hazard events.

Figure 1. Reported number of flood and drought events in Iraq, Syria, and Yemen from 1954 to 2024.



Source: EM-DAT. Pre-2000 is subject to reporting biases. Small and medium-impact events may not be reported.

KEY CONCEPT: DROUGHT AND FLOOD EVENTS ARE CLOSELY LINKED

Floods and drought are two extremes of the same hydrological cycle, with myriad examples of interactions between major flood and drought episodes.[2] Reduced precipitation and prolonged periods of dry and/or hot weather cause soil compaction and vegetation reduction. When rain falls in large quantities, the compacted soil cannot absorb the water, leading to water pooling and flooding, or flash flooding if rainfall occurs in sloped areas. Areas that experience frequent droughts are shown to be more prone to flooding, and other regions historically vulnerable to flooding are now experiencing more droughts.[3]

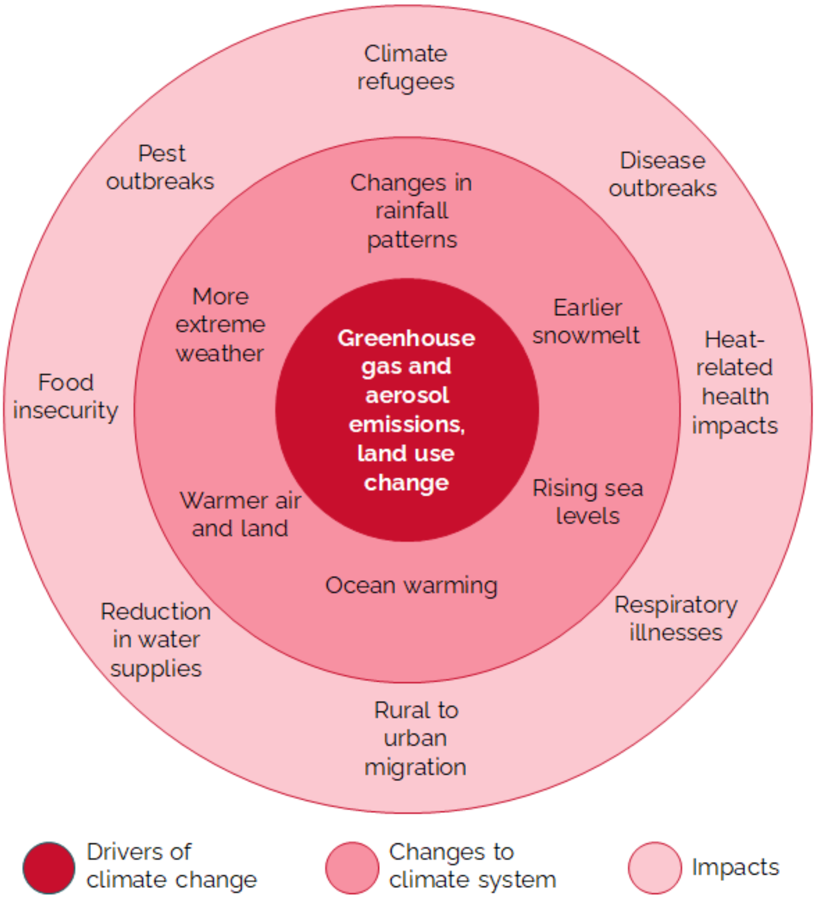
The MENA region is characterized by ever lower water availability and high temperatures that could potentially exceed the limits of human habitation.[4] Changes in precipitation and temperature affecting the patterns of flood and drought hazards due to climate change have already been observed (Table 1, Figure 2). As the number of warm days and the frequency, duration, and intensity of heatwaves have increased, particularly in urban centers, annual mean temperatures have risen 0.3-0.5°C per decade between 1980 and 2015. Climate models agree that the number of extremely hot days will rise, exacerbating water loss that can contribute to drought. Precipitation forecasting models predict with sizable levels of uncertainty, with some projecting that a decrease in precipitation is possible in Iraq and Syria, whereas an increase is possible in Yemen,[5] alongside increased frequency of extreme rainfall events in all three countries.[6]

Table 1. Summary table of observed changes to hazards since the mid-20th century and projected hazard risk to the 2050s under current emissions scenarios

Observed hazard	Projected hazard risk
Iraq	
Drought: Increases in maximum temperatures[7] exceeding 50°C in the summer. Droughts are reportedly occurring over longer periods.[8]	**Drought** is expected to increase in scale and severity across the MENA region.[10] Rising temperatures will likely result in higher rates of evaporation, soil salinity, and water scarcity. A continued decline in the water flowing in the Tigris and Euphrates rivers is likely.
Flooding: Regular flash and river flooding annually.[9] There is no clear signal for variations in precipitation patterns since global warming accelerated.[6]	**Flooding:** Heavy downpours are expected to increase in intensity, increasing flash flood risk. Models are uncertain as to whether precipitation will increase or decrease overall, with some indications the MENA region will become drier on average. Rising sea levels and drier soil in southern Iraq could increase the risk of coastal flooding.[11]
Syria	
Drought: Increases in agricultural drought severity.[12] Trend toward warmer and drier conditions in the Eastern Mediterranean possibly influenced intensity of the 2006-11 drought.[13]	**Drought:** A decline in the water levels in the Tigris and Euphrates rivers is likely. Higher temperatures will result in snowfall precipitation decreases, increasing water scarcity.[10] Warming and drying trend near the Mediterranean is likely to continue.[14]
Flooding is common and reported most years, particularly across the northwest and in the northeast during high rainfall years (e.g. 2019). Snowmelt can cause flooding in Spring.	**Flooding:** Precipitation models vary considerably, with some projecting little change. Storm severity is projected to increase. Sea level rise could see increased risks of coastal flooding.

Yemen	
Drought: Since the 1950s, Yemen has experienced several increasingly severe droughts and decline in water availability.[15]	**Drought:** Increasing water scarcity and drought frequency are anticipated in part due to rising temperatures.[17]
Flooding, particularly flash flooding, is frequently reported, particularly in highland areas. Flooding from tropical storms is less common (e.g. Cyclone Tej in 2023)[16]	**Flooding:** Increasing numbers of people are expected to be exposed to tropical cyclones.[18] Sea level rise in the Gulf of Aden and the Red Sea will increase coastal flooding risks. Precipitation models are uncertain due to highly variable microclimates, but extreme precipitation events will likely increase.

Figure 2. Effects of climate change including observed and anticipated changes to the climate system and impacts in the MENA region.



***Source:** Met Office. "Effects of Climate Change" (2022).*

Unequal impacts of hazards and climate change

People are not equally affected by floods, drought, and climate change. Characteristics such as gender, age, disability, cultural group/ethnicity, and socioeconomic inequality intersect to shape vulnerability and coping capacities.[19] Those most at risk typically also face barriers within their everyday lives in accessing information and resources to help withstand hazards. Specific vulnerable groups include, but are not limited to:

- **Women and girls** who face higher levels of mortality and morbidity during disasters, reflecting structural inequalities in accessing adequate housing, information, healthcare, food, water, and sanitation.[20] They also face the risks of sexual violence and exploitation, particularly in the absence of social protection schemes or access to essential services.[21]

- **Persons with disabilities** and their carers face barriers in accessing early warning information, particularly in rural areas. For example, early warning messages may not be designed in consultation with people with vision, hearing, or cognitive disabilities, leaving them unable to access life-saving information. People with disabilities often face mobility challenges during disasters and risk being left behind in degraded environments without support networks, leading to increased mortality and morbidity.[22] The UN provides recommendations for increasing the availability of disaggregated data to support disability-inclusive disaster preparedness and response.[23]
- **Older persons** who may have higher pre-existing health vulnerabilities, including those that limit their mobility, which can affect their ability to respond to early warning information or take mitigation measures. Those who do not move from floods or drought with their support networks can remain isolated.[24]
- **Displaced persons,** whether refugees, asylum seekers or IDPs, who tend to be exposed to higher levels of disaster risk, including death, injury, and secondary displacement. They are more likely to reside in poorly constructed homes or camps with limited access to services, and they may be missing from institutional disaster risk reduction policies.[25] Refugees and IDPs often face legal restrictions on their freedom of movement, which can affect the mitigation measures they are able to adopt, for example, moving to higher ground during a flood.[26]

Torrential rains destroy camps for thousands of internally displaced people

"…More than 2,500 displaced families living in Marib, in eastern Yemen, lost their homes after several days of torrential rain and flooding… Social media users and Yemeni commentators often blame the authorities because they say that Al Jufainah camp is located in an area prone to flooding…These overpopulated camps are often damaged by flooding and fire. Families here have been 'forced to build their own accommodation, using blankets and plastic sheeting,' said a 2021 report by the United Nations agency for refugees."

France 24, July 15, 2022

- **Socio-economic inequality** is both a cause and a consequence of disasters, reflecting underlying structural inequalities that impact peoples' ability to access livelihoods, services, and adequate housing. A large body of research indicates that those living in poverty are statistically more likely to reside in hazard-prone areas and have less money to invest in risk mitigation.[27] Globally, there is a significant association between income inequality and flood mortality.[28]
- **Those subject to movement restrictions** often have increased vulnerability to natural hazard events. For example, prisons are commonly located in flood-prone areas and have limited emergency services, critical infrastructure, or access to social networks.[29]
- **Ethnic / religious minorities** who practice rituals tied to their environment may face additional challenges as hazard patterns change. For example, in Iraq, the number of places that the Sabean-Mandaeans in southern Iraq can conduct their water-based practices has reduced, threatening their ability to engage in rituals.[30]
- **Literacy (including computer literacy)** also exacerbates climate vulnerability by influencing access to information. Literacy is high in Iraq[31] and Syria,[32,33] but relatively low in Yemen,[34] which can constrain the benefit of early warning messaging. However, a lack of computer literacy, which is more prevalent in rural areas,[35] limits the effectiveness of digital EWS by requiring additional training.

Understanding the capacities and vulnerabilities of at-risk communities means having a strong, continuous understanding of a community, together with sensitively gathered data to support early warning. Disaggregated sex and age data can support understanding of the specific political, social, and economic barriers faced by women and girls to strengthen gender-responsive climate adaptation.[36] Understanding the location of IDP populations and their demographics can help identify at-risk populations ahead of disasters and support disaster risk reduction (DRR) activities.

Early Warning for Anticipatory Action

"The Middle East is the one region that is behind in defining anticipatory action protocols"

KII, EW/AA Specialist, March 2024

AA is essential for reducing or preventing humanitarian impacts, including displacement, of a forecasted climate-related hazard before its most acute impacts are realized. As part of the disaster risk management cycle (Figure 2), AA contributes to the objectives of DRR outlined in the Sendai Framework through "preventing new and reducing existing disaster risk and managing residual risk". It can help bridge the gap between longer-term DRR and durable solutions efforts and humanitarian response for populations facing climate-change induced risks. Effective AA also links to preparedness, through activities such as developing EWS, defining trigger-based systems (predetermined criteria for initiating actions), and capacity building activities with communities and organizations working to minimize impacts of climate related hazards.

KEY ANTICIPATORY ACTION TERMS

- **Anticipatory Action (AA):** Acting ahead of a predicted hazardous event to prevent or reduce acute humanitarian impacts before it unfolds. Commonly refers to mechanisms incorporating pre-agreed financing for pre-agreed plans, released on a "no regrets" basis once an agreed trigger point is reached. AA is often used synonymously with "early action" and "forecast-based financing".
- **Disaster Risk Reduction (DRR):** Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to sustainable development.
- **Early Action (EA):** A set of actions to prevent or reduce the impacts of a hazardous event or events before they fully unfold, predicated on a forecast or credible risk analysis of when and where a hazardous event will occur, e.g. shelter distribution before a forecasted hazardous event. Unlike AA, actions may not have been planned or allocated funding in advance. The timing of EA can vary – development and climate actors may allow EA along a longer timeline than AA as part of wider disaster risk management processes, whereas humanitarians may define EA as occurring after a hazardous event, but before its peak impacts.
- **Early Warning (EW):** Information provided in advance of a specific hazardous event or events, disaster, or conflict to enable stakeholders to take timely actions to reduce disaster risks, e.g. food security warnings that project where, when, and how severe acute food insecurity is likely to be.
- **Early Warning System (EWS):** An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication, and preparedness activities that enables individuals, communities, governments, businesses, and others to take timely action to reduce disaster risks in advance of hazardous events.
- **No regrets:** Actions taken in advance of a hazardous event that provide benefits to the recipient population irrespective of how or whether a disaster occurs.

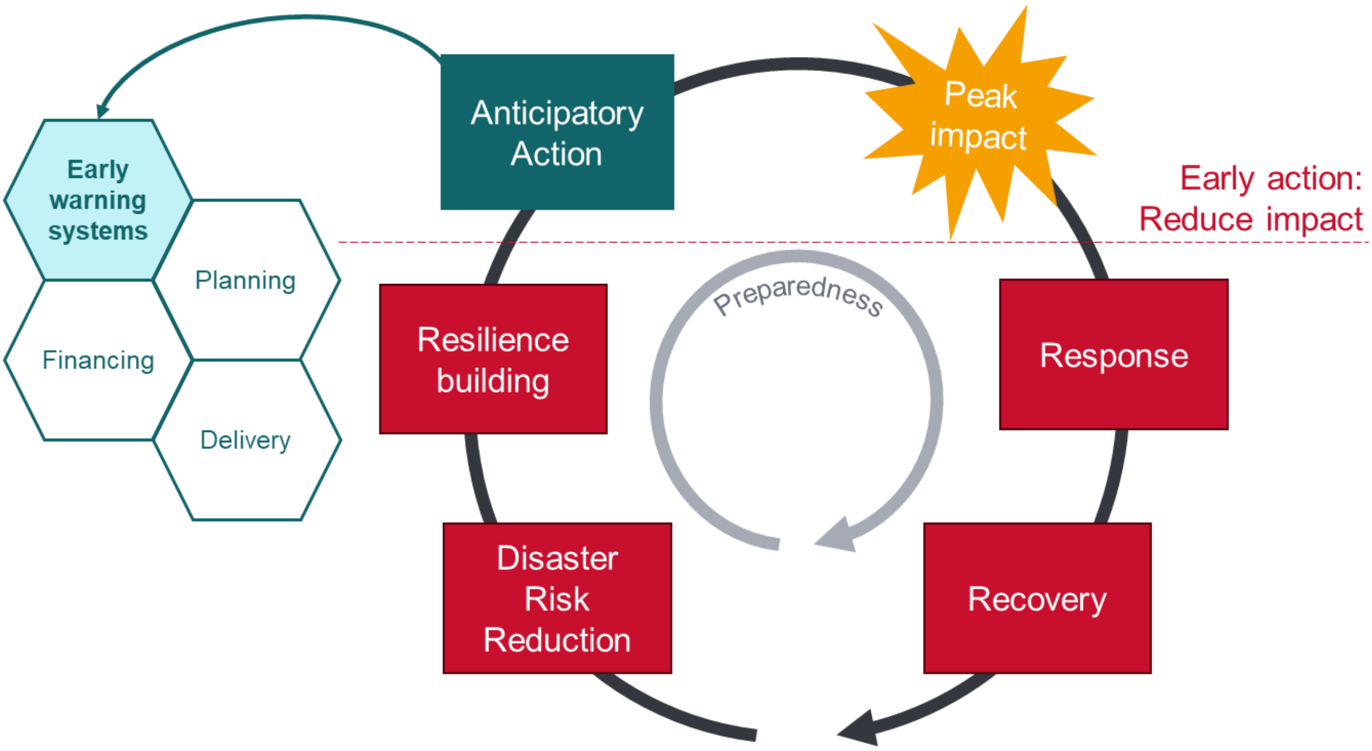
Source: *Glossary of Early Action Terms*, REAP (2022).

AA has four key components (Figure 3):[37]

1. **Forecasting, risk information, and EWSs**: includes real-time meteorological and hydrological observations and forecasts, and EWSs that incorporate humanitarian impact forecasting – including displacement – and early warning communications for various users.
2. **Planning:** includes regulatory frameworks for disaster risk management and sectoral and/or hazard-specific response strategies.
3. **Financing:** includes dedicated organizational or public funds, often on a "no regrets" basis, access to financial instruments, or public and private climate finance initiatives.
4. **Delivery:** includes the technical capacity to enact AA and the organizational mechanisms through which AA can be delivered (e.g. humanitarian / development organizations, social protection mechanisms, etc.).

This report focuses on the first component and explores current tools and platforms that could support forecasting, risk information, and EWS in Iraq, Syria, and Yemen. It focuses on drought and flood hazards, and explores the provision of humanitarian impact information using existing tools.

Figure 3. Anticipatory action as part of a response and resilience continuum



Source: After Scott, 2022, also showing the key components of anticipatory action.

Country Overview

Iraq

Floods: Many communities in Iraq face the risks of *fluvial flooding*, with almost 37% of the population exposed to 100-year floods.[38] Annual flooding in the Tigris (February-June) and Euphrates (March-July) river basins following the winter rainy season (October-March) can cause substantial damage and drive displacement, especially in the south. *Flash flooding* in northern mountainous and urban areas is frequently reported, particularly in winter, and is expected to increase as climate change makes rainfall more erratic.[10] All tributaries to the Euphrates River originate outside of Iraq, so alongside climatic factors, Iraq is also reliant on transboundary water management and negotiation to manage flood and drought risk.

The effectiveness of flood prevention infrastructure in Baghdad, constructed in the 1950s, has substantially reduced due to the Gulf War (1990–91) and Iraq War (2003–11). Infrastructure deterioration has left the city vulnerable to the impacts of extreme precipitation that often leads to flash flooding.[39]

Explainer: Flood return periods

Return periods describe how likely a flood event is to occur at, or above, a specific intensity within a timeframe defined by a probability.

For example, the term "100-year flood" is a flood of an intensity that will be equaled or exceeded on average once every 100 years (the "return period"). Therefore, there is a 1% chance of a 100-year flood every year.

A shorter return period suggests a higher probability that a flood will occur in a single year. There is a 10% chance of experiencing a 10-year or a 20% chance of experiencing a 5-year flood in a given year.

Source: GFDRR

Several killed as heavy rains cause floods in Iraq's Erbil

"At least eight people have died and several have been injured after torrential rains caused severe flooding in Erbil, the capital of the semi-autonomous Kurdish region of northern Iraq, according to officials...Hard ground, compounded by vegetation loss, means the earth does not absorb water as quickly, and when storms hit, they can become flash floods. Scientists say climate change amplifies extreme weather, including droughts as well as the potential for the increased intensity of rainstorms."

Al-Jazeera, December 17, 2021.

Drought: In addition to reducing agricultural production, droughts have historically contaminated drinking water due to an increased concentration of sewage and accelerated saline intrusion, the latter particularly occurring in southern Iraq. Large outbreaks of waterborne diseases, such as cholera, have been reported during drought events, most notably in the city of Basra, where a major outbreak was co-attributed to water management issues.[33] As drought has become more frequent, there are reports of climate-based migration as people move to find alternative livelihoods.[40] Drought increases the risk of dust and sandstorms due to low soil moisture, which has implications for health and the functionality of critical infrastructure. Impacts are well documented in Iraq, where dust storms have resulted in people being hospitalized with respiratory issues.[41]

Iraq: Specific vulnerable groups

- **IDPs and IDP returnees** are particularly vulnerable to hazards. Between October 2020 and November 2021, several formal IDP camps were closed, consolidated, or reclassified as informal camps under a Federal Government of Iraq initiative. Furthermore, the federal government had planned to close all IDP camps in the Kurdistan Region (KRI)[42] in July 2024 but delayed the decision. IDPs and IDP returnees are often housed in informal settlements with poor living conditions and limited access to public services. These are often located in flood-prone areas on the margins of major cities.[43]
- **Rural small-scale farmers and marshland populations** are highly vulnerable to acute food insecurity. Environmental degradation of the Mesopotamian marshes and wetland ecosystems in south and southwestern Iraq has resulted in the loss of fishing and agro-pastoralist livelihoods. In agricultural communities, prolonged drought has limited crop production and livestock herding activities. This has driven rural-urban displacement, particularly among those aged 15-24.[44] Individuals moving to urban areas often reside in informal settlements, which lack services and are commonly in flood-prone areas.
- Iraq is home to some 278,000 **Syrian refugees,** most of whom reside in the KRI,[45] in tents and poorly constructed homes that are vulnerable during heavy rainfall events.[46]

Humanitarian, Development, and Institutional Contexts

Information on the exposure of vulnerable populations, particularly displaced people, to natural hazards was formerly reported in Humanitarian Needs Overview documents. These have not been issued since 2023, and OCHA has stated that "diminishing humanitarian response and increased efforts to achieve durable solutions with and through development partners…" have removed Iraq from the list of the most severe humanitarian situations.[47] Other sources of hazard risk information include academic studies and country-level hazard maps produced by humanitarian organizations; however, the federal government of Iraq does not publish hazard maps that have been produced for them by academics or humanitarian organizations.[ix]

The capacity of key government agencies has suffered due to the conflict, with more projects being funded since the Covid-19 pandemic and the shift in focus from humanitarian to development.[x]Programme (UNEP) is working with the federal government of Iraq to develop and implement a National Adaptation Plan (NAP) to address climate change challenges.[48] The UN Development Programme (UNDP) is working with the Iraqi government and local communities to develop drought EWS, with stakeholder engagement and mapping of EWS needs completed.[49] In Iraq, responsibility for early warning and response is spread across government departments with different agencies tasked with collecting and managing weather and climate information, early warning for different sectors, and social protection.[50]

Syria

Floods: Winter storms and rapid spring snowmelt often result in *flash flooding,* with the most destructive events in urban settlements and IDP camps in northern Syria, primarily in the northwest. These events typically drive secondary displacement. During the 2019 winter floods, for example, severe flooding in the Areesha IDP camp in Al-Hasakeh Governorate displaced approximately 75% of the camp's inhabitants.[51] Over 13% of the population is exposed to 100-year *river flood events,*[52] particularly communities living near the Euphrates, Syria's largest river.

[ix] KII, EW/AA Specialist

[x] KII, EW/AA Specialist

Drought: Syria is at high risk of drought as desertification, land degradation, high temperatures, poor and erratic rainfall, and transboundary water management issues have combined to create water scarcity. The over-abstraction of water for irrigation in the key wheat-producing areas of the northeast has exacerbated the drying up of the Khabur River[53] and contributed to rapid groundwater depletion and increased pollution.[54] Droughts in Syria have had large-scale humanitarian impacts. Droughts in 1998-2000 and in 2007-2010 reportedly displaced over 1 million people.[55] In 2021, the Euphrates reached record lows as poor precipitation combined with domestic and transboundary water management challenges. Access to water for over 5 million people was compromised and the prevalence of water-borne diseases increased. Wheat harvest losses caused widespread economic harm and increased food insecurity.[56]

Syria: Specific vulnerable groups

- **IDPs:** In northwest and northeast Syria, over 2.6 million IDPs[57] live in informal settlements and IDP camps with insufficient infrastructure including inadequate shelters, limited drainage, and poor access to services. Approximately 80% of people living in these sites are women and children.[58] IDPs have experienced repeated flooding along with water shortages due to drought, driving secondary displacement, often between IDP sites and informal settlements.
- **Transient populations, including herders,** are affected by the rising costs of animal feed, shrinking grazing land, and water shortages. Drought has forced pastoralists to travel further to find suitable grazing lands, which makes animals more susceptible to disease.[59] The 2022 drought precipitated large-scale livestock culling as livestock fodder prices became a barrier to maintaining herds.[60]
- **Small-scale farmers**, particularly across northeast Syria (the nation's "bread basket") have endured multiple climate-related shocks and disruptions to agricultural production. The 2007-2010 drought reportedly drove mass migration of rural farming families to urban centers in search of livelihoods, with various authors attributing the Syrian conflict to this period of drought, a link that is widely debated.[61]

Humanitarian, Development and Institutional

Syria remains mired in a protracted humanitarian crisis, with an estimated 16.7 million people in need of humanitarian assistance in 2024. Conflict continues in the north, with drought, floods, and the devastating 2023 earthquakes compounding humanitarian needs. Community and institutional preparedness are challenged by conflict across differing areas of control.[xi]

Publicly available countrywide hazard risk assessments appear absent, although there are suggestions these were conducted prior to the Syrian civil war.[62] The 2009 drought prompted calls for a national EWS and capacity building to implement the National Drought Strategy,[63] however, neither of these appear functional. Prior to the conflict, the government of Syria had worked to establish and improve national disaster risk management systems, including developing a national disaster risk strategy, but this has not materialized. National social protection and other similar mechanisms that could provide support in the event of droughts or floods were discontinued during the conflict and have not resumed. The focus since 2011 has been on humanitarian response.[xii]

Communities have deployed adaptive measures vis-à-vis flood and drought risks. Depending on their resources, communities have installed rainwater harvesting systems to support agricultural activities and

[xi] KII, EW Advisor

[xii] KII, EW Advisor

increase household water supplies. These have included techniques such as creating pits, bunds, and terraces to collect rain and surface water, and rooftop rainwater harvesting. Communities in flood-prone areas often construct their homes with flood mitigation measures including layers of stone at the base of walls and the use of lime-based plasters which are more resistant to flood waters.[64] Construction of dome-shaped homes is reported from IDP camps; these structures are more effective at directing water runoff during extreme rainfall events.[65] At the community level, access to weather, climate, and hazard information to aid decision making over adaptive measures is sporadic.[xiii]

Yemen

Floods are a recurring disaster in Yemen, driving displacement and associated damage to infrastructure and crops each year around the wadis that typically run east to west toward the Red Sea. Fluvial and flash floods are primarily caused by heavy rainfall events in July and August. An estimated 2.4 million people, nearly 8% of the population, are exposed to high (100-year) flood risks.[66] Flood risk also stems from tropical cyclones, which primarily affect eastern and central Yemen. Floods have historically caused major damage to infrastructure including roads, irrigation systems, and power grids. In rapidly urbanized areas damaged by years of conflict, poor drainage systems contribute to contamination of water networks during flood events.[67]

Drought is a recurrent environmental issue in Yemen that worsens the humanitarian situation. Less than an estimated 3% of Yemen's land is arable and together, drought and desertification impacts around 3-5% of this land each year in a context where two-thirds of the population is reliant on agricultural for their livelihoods[68,69] Drought intensity has already increased along the Tihama coastal plain, which is key to the national agriculture sector. Across 22 governorates, UN-OCHA in Yemen is planning for drought responses in six governorates throughout 2024, with an estimated 300,000 people likely to need humanitarian assistance.[70]

Agriculture contributes about 10% to Yemen's gross domestic product (GDP) and is an important livelihood source for millions of people. Water-intensive crops, such as *qat*, are widely grown, contributing to water scarcity issues. Extended periods of dryness are often followed by heavy rainfall and flash flooding, accelerating soil erosion, and environmental degradation. For example, January to June 2022 was one of the driest periods on record in nearly 40 years and was followed by flash flooding, which affected over 300,000 people.[71] Drought reportedly drove a 10% increase in displacement in 2023.[72]

Many *endemic and epidemic diseases* in Yemen are affected by flooding and drought events. Satellite-observed rainfall in combination with disease surveillance data have been successfully used to predict the risk of cholera outbreaks.[73] Periods of drought are also associated with increased rates of acute malnutrition.[74]

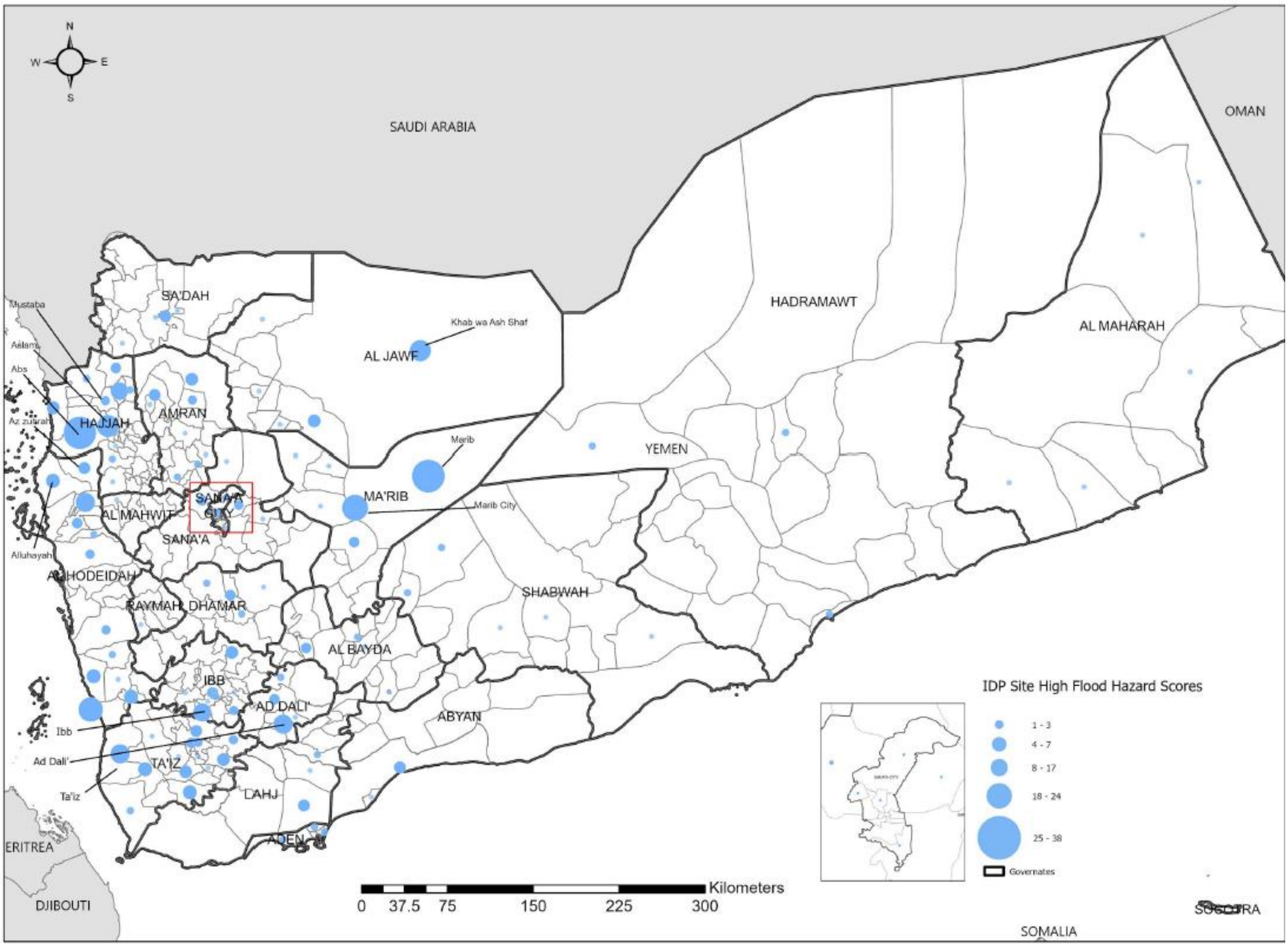
Yemen: Specific vulnerable communities

- **IDPs**, who number more than 4.5 million, reside in over 2,300 unplanned sites and camp-like settings and urban neighborhoods, and often face a greater risk of flooding. In 2024, 30% (672) of IDP sites were assessed as "high" or "critical" flood hazard, meaning over 747,000 IDPs live in areas susceptible to flooding.[75] Critical flood hazard sites are particularly concentrated in the flood plains and urban areas of Qatabah and Aslam districts (Figure 4). Many camps are in areas with limited humanitarian access, further restricting efforts to mitigate flood risks and effectively use early warning information.

[xiii] KII, Shelter Specialist

- **Muhamasheen:** The Muhamasheen, which translates as "the marginalized", have long faced discrimination. They lack access to essential services and often reside in poorly constructed shelters in flood-prone urban areas, primarily in Aden, Taiz, and Hodeida. Muhamasheen children face early marriage and forced recruitment into armed groups.[76] Their lack of documentation and access to traditional support networks can limit their ability to access humanitarian assistance during, and following, disasters.[77]
- **Small-scale farmers:** Yemen's heavy reliance on subsistence farming makes farming households, many of which are female-led, particularly vulnerable to flood and drought events. Agricultural drought and accompanying food and water insecurity prompts increased dependence on negative coping strategies such as selling assets and accessing informal credit at exorbitant lending rates. Rural-urban displacement of small-scale farmers is not more common among farming households searching for additional livelihood opportunities due to water scarcity and drought-related challenges.[78]

Figure 4. Map showing the number of IDP sites per district considered to have "high" or "critical" flood risk.



Source: REACH, 2024.

Humanitarian, Development, and Institutional context

Yemen continues to suffer from a protracted humanitarian crisis, with an estimated 11.2 million people in need of humanitarian assistance in 2024 due to a combination of conflict, climatic hazards, and economic challenges. The multi-dimensional nature of humanitarian challenges in Yemen, coupled with fractured governance structures, negatively affect community and institutional preparedness for floods and drought.[xiv] Prior to the conflict, several flood and drought mitigation initiatives were underway or in preparation. For example, there were plans for flood retention systems in Hadramout and Al-Mahara, including ongoing work to establish a national DRM fund for preparedness, response, and reconstruction and a multi-hazard and risk mapping unit. While mapping has been conducted by humanitarian organizations since the outbreak of conflict, wider government-led initiatives have stalled.[xv]

At the community level, deployed drought adaptation measures include rainwater harvesting, and the planting of alternative drought-resilient crops.[79] Farmer cooperatives have worked together to construct gabions and drainage channels as mitigation measures during both floods and drought. Access to hazard risk, weather, and climate information is constrained by a lack of trust in weather information across differing areas of control.[xvi]

Tools and platforms to support data-driven preparedness, early warning, and response

Governance of weather and climate information

The World Meteorological Organization (WMO) is the specialized UN agency that regulates and facilitates the exchange of weather and climate data and information, including within the MENA region. Within Iraq, Syria, and Yemen, all of which are WMO member states, national authorities are responsible for observing and forecasting the weather at various timescales, keeping historical records, and providing information. National authorities are commonly supported by global producing centers,[80] who provide weather and climate information free of charge, including on seasonal timeframes.

Regional Climate Outlook Forums

Regional Climate Outlook Forums (RCOFs) are multi-country platforms that unite national, regional, and international weather and climate information experts with key stakeholders such as representatives from authorities responsible for disaster risk management in a climatologically homogenous area. RCOFs aim to reach consensus on seasonal climate forecasts and consider the implications of forecasts on key sectors in the region. RCOFs covering MENA include:

- Arab Climate Outlook Forum (ArabCOF): Iraq, Yemen
- Mediterranean Climate Outlook Forum (MedCOF): Syria

Syria and Yemen have national weather and climate forecasting capacity, though it is limited by challenges arising from conflict. In Iraq, these systems are more robust and there are stronger links between national authorities responsible for weather services and humanitarian and development actors. Delivery of weather and climate information by national authorities in Syria and Yemen remains limited, particularly in Syria.[81]

[xiv] KII, EW/AA Specialist
[xv] KII, EW/AA Specialist
[xvi] KII, EW/AA Specialist

Iraq

The Iraqi Meteorological Organization and Seismology (IMO)[82] was established by British forces in 1923 and is part of the Ministry of Transportation. The IMO provides publicly available 24-hour forecasts, two- to five-day forecasts and monthly climate information. Its observational network uses information from several automatic weather stations managed by the Iraqi Agrometeorological Center,[83] which reports to the Ministry of Agriculture. These stations gather information such as air temperature, wind speed, soil moisture, and evaporation in irrigated and rain-fed agricultural areas. In addition, there are over 100 remote gauging stations managed by the Iraqi Ministry of Water Resources, which were installed by the United States Geological Survey (USGS)[84] and that collect rainfall statistics and support water management along the Tigris and Euphrates rivers.

Syria

The Syrian Meteorological Department (SMD),[85] supervised by the Ministry of Defense, is responsible for the provision of weather services in Syrian government-controlled areas. Daily weather forecasts are communicated via the Syrian Arab News Agency and social media.[86] The SMD reportedly has 20 surface stations gathering weather and climate information. As of 2024, no stations appear functional, as they are not reporting and there is no systematic provision of early warning information.[87] The Ministry of Water Resources, formerly the Ministry of Irrigation (MOI),[88] is tasked with water management activities, including drilling new wells, water law enforcement, dam management, and implementing water infrastructure projects. The ministry receives support from academic partners (e.g. ACSAD),[89] who provide groundwater models and training. The extent of the ministry's water monitoring capacity is unclear.

There is limited information on areas of Syria outside of government control. Most humanitarian organizations obtain weather and climate information from outside of Syria.[xvii]

Yemen

Governance of weather and climate services have shifted since the Department of Meteorology was established in the 1940s. Currently, there are two sources of weather and climate information, the Yemen Meteorological Service (YMS) and the General Authority for Civil Aviation and Meteorology (CAMA), who merged in the 1990s. YMS/CAMA[90] have several observation stations, a number of which have undergone rehabilitation in recent years[xviii], providing weather information to support forecasting services. CAMA/YMS provides daily weather forecasts and special weather bulletins and early warning information through various media, tailored to specific users.

The Ministry of Agriculture and Irrigation (MAI)[91] manages the agrometeorological network, but information on the status of the observation stations for monitoring rainfall is unclear. The National Water Resources Authority (NWRA)[92] is responsible for water resource management and enforcement of water laws. NWRA collects information on rainfall, river levels, and surface water flooding, but it is unclear how many of their stations are fully functional. There is limited information on the provision of early warning information and links with disaster management authorities and humanitarian agencies.

[xvii] KII, Meteorologist
[xviii] KII, EW/AA Specialist

Platforms to support Early Warning and Anticipatory Action

Advances in weather and climate forecasting over the past decades have been rapid, as improved observations and enhanced data processing have combined with advances in technology and supercomputing.[93] The World Meteorological Organization identified societal and policymaker demand for highly localized weather and climate forecast information to support decision-making and protect lives for the next decade as both a challenge and an opportunity.[94] Humanitarian organizations themselves have developed several tools and platforms to support understanding of the potential impacts of disaster events, aiding decision making and AA.

Private companies have developed commercial weather and climate forecasting services, including Graph Cast (Google DeepMind) and Pangu-Weather (Huawei). Commercial tools are beyond the scope of this report. At the time of writing, many do not provide humanitarian impact information, although advances in AI-assisted applications may see this change.

Platforms with global or significant coverage in humanitarian contexts

Several platforms (Table 2) provide flood and drought disaster information to support AA and response activities with varying temporality and geographic scope. The tools often rely on a combination of weather and climate information sources, including observations to satellite data, coupled with historic information, sometimes including humanitarian impacts. Several tools listed in Table 2 provide examples of impact-based forecasting, for example, providing information on the potential number of people exposed to a hazardous event or number of people projected to be experiencing acute food insecurity.

Country-specific platforms to support AA are included in section 3.2.2.

Intended purpose

Some of the tools provided in Table 2 explicitly mention their intended utility or use by organizations for anticipatory/early action, including IPC[95] and IFRC GO.[96] Several tools may not explicitly mention use for AA, but contain some reference to "preparedness",[97] "humanitarian planning",[98] and/or use forecasting or monitoring indicators linked to adverse humanitarian outcomes. While preparedness, the broad set of actions to prepare for potential disasters, differs from AA, the set of actions taken in response to an imminent threat, the tools may provide alerts or updates prior to the peak of a given hazard (e.g. cyclone and flood extent forecasts), which can potentially support anticipatory actions.

Use in existing Anticipatory Action Programs

Several of the tools listed are currently used in AA plans developed by the Red Cross Red Crescent (RCRC) movement, UN agencies, and INGOs. For example, GloFAS is widely used by the RCRC movement, with example trigger statements for AA utilizing probabilities, lead-times, and GloFAS thresholds.[99] For example, IPC projections are incorporated into UN-OCHA AA Plans in Somalia.[100] Seasonal monitoring indicators included within the UN-FAO GIEWS and FEWS Net tools such as precipitation deficit forecasts[101] and water availability for crop growth[102] are used in AA frameworks by organizations in sub-Saharan Africa. Finally, the Google Flood Hub model has been trialed for flood AA in Nigeria by IRC and Give Directly.[103]

Further details on the advantages and limitations of the tools shown in Table 2 are provided in Annex 1.

Table 1. Summary table of widely used climate and weather tools with global or significant coverage in humanitarian contexts

Name	Owner(s)	Coverage	Hazards included	Event (Near real-time)	Imminent (3-10 days)	Seasonal (1-6 months)	Humanitarian impact information	Vulnerable group information
Advanced Disaster Analysis and Mapping (ADAM)[104]	UN-WFP	Global	Cyclones, Earthquakes, Floods.	Yes	Yes	No	**Event:** People affected (#); Flooded cropland (ha), WFP offices and warehousing locations. **Forecast:** People affected (#).	**Event:** Children (#), Elderly (#)
Famine Early Warning Systems Network (FEWS Net)[105]	Multi-partner initiative funded by USAID	43 countries, including Yemen, not Iraq or Syria	Abnormal dryness, Cyclones, Drought, Extreme cold, Extreme heat, Floods	Yes[a]	Yes[a]	Yes[a]	**Event / imminent:** Qualitative impact information is included in the weekly Global Weather Hazards product. **Seasonal:** Acute food security outcome distribution maps for the near-term (1-2 month) and medium-term (3-6 months) alongside qualitative impact information typically covering food security and livelihoods.	Yes – context specific, qualitative only
Foresight[106]	DRC	40 countries	Drought, Earthquake, Epidemic, Flood[b]	Annual estimates[b]			Internal and international displacement (# with upper and lower estimates)[2]	n/a
Global Disaster Alerting and Coordination System (GDACS)[107]	UN-OCHA, European Commission	Global	Cyclones, Earthquakes, Floods, Volcanic eruptions	Yes	Yes	No	**Event:** Fatalities (#), Injuries (#), People displaced (#), Houses damaged / destroyed (#), GDACS score (different parameters per hazard, taking into account vulnerability and coping capacities using the INFORM Risk index). **Imminent** (cyclones): People exposed (#)	Country INFORM Risk vulnerability category
Global Flood Awareness System[108] (GloFAS)[c]	European Commission	Global	River (pluvial) floods	Yes	Yes	Yes	*Impact information on GloFAS is experimental,[109] extends over 30 days and includes: People affected (#), Health, education, airport, powerplant facilities affected (#), agricultural land, forest affected (ha)*	n/a
Global Information and Early Warning System on Food and Agriculture[110] (GIEWS)[d]	UN-FAO	Global	Drought	Yes	Partial	Yes	**Event, imminent, seasonal:** Shows agricultural indices (e.g. ASI, NDVI) monitoring the conditions of major food crops rather than humanitarian impact information such as acute food insecurity.	n/a
Hunger Map[111]	UN-WFP	85 countries	Biomedical, Cyclone, Earthquake, Extreme temperature, Flood, Landslide, Storm, Tsunami, Wildfire, Volcanic eruption[4]	Yes[e]	Yes[e]	No	Hazard information does not include impact information. The map shows a nowcast of people with insufficient food consumption (#), acute and chronic malnutrition prevalence (%)	Children under 5 (% acute malnutrition)
Integrated Food Security Phase Classification (IPC)[112]	Multi-partner initiative	>40 countries including Yemen but not Iraq or Syria	Drought, Floods[5]	Yes	No	Yes[f]	Number of people (# and as % of population) experiencing acute food insecurity outcomes or acute malnutrition – both current and projected figures.	Context specific[6]

Name	Owner(s)	Coverage	Hazards included	Event (Near real-time)	Imminent (3-10 days)	Seasonal (1-6 months)	Humanitarian impact information	Vulnerable group information
Internal Displacement Monitoring Centre (IDMC)[113]	Norwegian Refugee Council	Global	Drought, floods, and other disaster typologies using the IRDR Peril Classification and Hazard Glossary[114]	Yes	TBC[g]	TBC[g]	**Event:** Internally displaced people (#).	Depends on source data[h]
IFRC GO – RiskWatch[115]	IFRC	Global	Cyclone, drought, earthquakes, floods, wildfires	Yes[i]	Yes[i]	No[i]	People exposed (#), value of exposed buildings (USD), schools and hospitals exposed (#), people in vulnerable groups exposed (#). Additional information dependent on national society reporting.	Varies depending on event
Pacific Disaster Center (PDC)'s All Hazards Impact Model[116] (AIM 3.0)[j]	University of Hawaii	Global	Cyclone, Earthquake, Extreme temperatures, Flood, Tsunami, Wildfire, Winter storm, Volcanic eruption	Yes	Yes	No	**Event / imminent:** People exposed (#), capital exposure (USD), potential needs based on Sphere standards (e.g. liters of water, sq meters of shelter), schools and hospitals exposed (#).	Children (0-14, #), elderly (#)
Google Flood Hub[117]	Google	Global	Flooding	Yes	Yes	No	n/a	n/a

More information on each is provided in Annex A. Note that all have differing temporal coverage for early warning, broadly subdivided here into: event (real-time), imminent (3-10 days) and seasonal (1-6 months, possibly longer). Many provide humanitarian impact information, or plan to in the future.

a. FEWS Net uses a summary narrative product for event / imminent forecast information (the weekly Global Weather Hazards report). Seasonal information, including seasonal calendars, current and projected acute food insecurity is available through an interactive web platform and narrative reports at country level.

b. Foresight uses a machine learning model to predict annual forced displacement. Hazards are grouped into a 'Natural' category as a driver of forced displacement alongside conflict, economic and governance indicators. Projections are annual, at country-level and up to three years. Foresight does not forecast specific events or produce seasonal outlooks.

c. GloFAS requires registration, non-organizational email accounts can be used.

d. The Earth Observation for Crop Monitoring tool is the only GIEWS tool profiled in this table.

e. The Hungermap uses information from the Pacific Disaster Center (PDC), also in this table.

f. The IPC does not specifically focus on hazard forecasting but uses information on seasonal hazards and seasonal climate outlooks as part of the analytical framework when making assessments and projections of acute food insecurity and acute malnutrition. Information on vulnerable groups is context specific; where specific populations are more likely to be experiencing adverse acute food insecurity outcomes this is noted (see: IDPs in Somalia as an example).

g. IDMC's Disaster Risk Model is currently offline. This model previously used information about recorded and forecast hazards to model the risk of future displacement. The tool will be available again in mid- to late-2024.

h. IDMC collates data from several sources which have variable information on specific vulnerable groups.

i. The Go platform information on imminent hazards is drawn from ADAM, GDACS and PDC. Information on events also uses these sources, alongside information from Red Cross Red Crescent National Societies. The Go platform provides historical seasonal trend information for selected hazards but does not use seasonal forecasts, so this is marked as 'No' in this table.

j. Requires organizational or institutional login to access. Publicly available PDC information include events only (https://disasteralert.pdc.org/disasteralert/)

Platforms or EW/AA initiatives specific to Iraq, Syria, or Yemen

In addition to the global and high coverage platforms identified in Table 2, several projects, consortia, and clusters make use of hazard exposure and early warning information to support AA (Table 3). There are also several initiatives underway aiming to strengthen the monitoring and provision of weather and climate information that could support EWS across the three countries; these are detailed below. Other than the FAO FSNIS and the Cholera Prediction Hub in Yemen, no identified platforms are providing impact-based forecasts that could support AA.

Table 2. Summary table of climate and weather monitoring and observation tools available online specific to Iraq, Syria and Yemen

Name	Owner(s)	Coverage	Hazard(s)	Event (Near real-time)	Imminent (3-10 days)	Seasonal (1-6 months)	Project status
Iraq							
Iraq Flood and Drought Monitor[118]	University of Southampton, University of Princetown	Countrywide	Floods, drought	Yes	Yes	No	A UNESCO-funded dashboard that uses ground, satellite, and modeled datasets to provide countrywide real-time and forecast information for floods and drought. The system does not provide humanitarian impact information, and it is not clear whether the system is actively being updated or used by humanitarian and/or government actors.
Iraq Climate-Induced Displacement tracking[119]	UN-IOM (DTM)	Central and Southern Iraq	Drought	Yes	No	No	IOM's Displacement Tracking Matric (DTM) in Iraq issues specific updates on climate-induced displacement, which it has tracked as part of their regular displacement monitoring since 2018.
Iraq Climate Monitoring Dashboard[120]	IMPACT, ACF, University of Mosul	Countrywide	Floods, drought (implied – specific risk not mentioned).	Yes	No	No	An online dashboard summarizing six climate observation indicators: Precipitation deficits, standardized precipitation index (monitoring meteorological drought), NDVI anomaly, NDWI anomaly, surface temperature anomalies, evaporation anomalies. Indicators are presented to support identification of "hot spots", similar to FAO GIEWS. No impact information or forecasts are provided.
Syria							
No online tools identified. Note that the text below details hazard analysis that can be used to support development of early warning systems for at risk areas.							
Yemen							
Cholera Prediction Hub[121]	University of Florida	Countrywide	Cholera	Yes	Yes	No	An FCDO-funded initiative established in 2018 that uses precipitation, socioeconomic, and cholera epidemiology information to forecast the number of cholera cases in the upcoming four weeks. Demonstrated to have a 92% forecasting accuracy rate with the information used to take action in high-risk areas to prevent spread of the disease.
Food Security Nutrition Information Systems (FSNIS)	FAO	Countrywide	Floods, drought, pests, dust	Yes	Yes	Yes	Established in 2019, the FSNIS issues early warning bulletins covering a range of hazards and upcoming risks. Impact information specific to the hazard (e.g. health impacts of dust) is communicated as part of the bulletins. This well-established system supports the IPC process.

All have differing temporal coverage for early warning, broadly subdivided here into the following: event (real-time), imminent (3-10 days), and seasonal (1-6 months or above). Note that few issue imminent or seasonal forecasts that would enable AA.

Syria

"The anticipatory action space in Syria is wide open…"

KII, AA Specialist, April 2024

In **Northwest Syria**, there are no identified EW/AA protocols in place. However, humanitarian actors provide preparedness activities, such as winterization programs,[122] to help IDPs mitigate some of the impacts of hazard events. The Start Network, a pooled fund for NGOs, has awarded one AA project for Syria in the past decade. This 2022 project saw an estimated 41,000 IDPs in camps in northern Syria being given support prior to a winter storm.[123]

Humanitarian actors have conducted projects supporting the identification of hazards and vulnerable groups. The challenges associated with winter weather conditions are well known, with the Shelter Cluster publishing winter plans annually, preparing vulnerable populations, particularly IDPs, for harsh winter conditions.[124] Annually produced humanitarian response plans continue to emphasize the high exposure of conflict-affected populations to drought and floods, laying out the preparedness measures that can be taken to reduce impacts of climatic shocks.[125] However, there does not appear to be one specific platform that the humanitarian community uses to access information on hazards, vulnerable groups, and potential impacts.

Yemen

"Yemen is a crowded space with projects…"

KII, EW/AA Specialist, April 2024

In Yemen, a growing number of projects focus on EW/AA, all within government-controlled areas. Yemen is one of the UN Central Emergency Response Fund's (CERF) AA pilot countries, with AA protocols being developed for flooding.[126] As part of these pilots, OCHA facilitates coordinated AA frameworks using forecast-based triggers, though it is unclear what sources are being used. The Yemen Red Crescent Society has increasingly focused on scaling up AA, with early action protocols defined for floods in 2023.[127]

The FAO's Food Security and Nutrition Information Systems (FSNIS) project aims to strengthen food security and nutrition early warning information systems through capacity building, assessments, data analyses, and reporting on hazards (events and forecasts),[128] including use of remotely sensed data. Since the project was launched in 2019, information and data on natural hazard risks, agricultural seasons and crops, alongside market information and household level vulnerability data have been collated[xix], and the UN-coordinated appeals process shares information with government and humanitarian partners.[129]

Iraq

A UNESCO-funded Flood and Drought Monitor[130] by the University of Southampton and Princeton University uses ground, satellite, and modeled datasets to provide countrywide real-time and forecast information for floods and drought. The system does not provide humanitarian impact information, and it is not clear whether the system is being updated or used by humanitarian and/or government actors.

FAO,[131] UNESCO, and the Green Climate Fund have worked to strengthen institutional, technical, and financial capacities for projects developing drought and flood risk management systems in Iraq. The

[xix] KII, EW/AA Specialist

UNESCO-funded project report, initially aimed at facilitating the development of a national framework for drought in 2014, included the need to enhance the availability of data and scientific information.

The World Food Programme (WFP)[132] launched a project in 2023 to strengthen early warning mechanisms as part of a wider aim to enhance climate action in Iraq. Working with the Ministry of Agriculture, Mosul University, and local authorities, meteorological stations were repaired and new stations installed under the project. Data from the stations are not connected to a web-based platform but constitute a consolidated source of meteorological information that could be beneficial for EWS.

Several climate and weather information platforms are reportedly under discussion and/or development in Iraq. The Federal Government of Iraq is planning to hold a meeting to unite efforts and avoid duplications.

Weather and Climate Information Services (WISER) for MENA

The WISER[133] programs are set to expand in the Middle East. Led by the UK Met Office, the aim is to generate and roll out use of co-developed weather and climate services to support decision making from local to regional levels. To date, projects across Africa have enabled enhanced information to be delivered to an estimated 3.3 million people. The program is set to expand in the MENA region in 2026, following an initial scoping phase. One of the goals is to enhance the development of in-region and in-country networks to support early warning. The first MENA Regional Dialogue Platform to support coordination and scaling of AA initiatives in MENA took place in July 2024.

Opportunities for data-driven tools and platforms

From the KIIs and literature review, five key opportunities for EWS in Iraq, Syria, and Yemen emerged. These are summarized below, with further detail provided on the following pages.

1. Real-time observation, and imminent and seasonal forecasts are available for Iraq, Syria, and Yemen. Provided these can be communicated in an accessible way, they can help people protect themselves and their assets.
2. Use of remote sensing data can help fill gaps in understanding created by conflict-related damage to weather and climate monitoring stations and fragmented governance structures.
3. Blending different sources of weather, climate, and population data to account for different organizational focus areas (e.g. food security, WASH, shelter) could help deliver more holistic early warning information.
4. There are persistent gaps in humanitarian and event datasets. To encourage data sharing, a platform blending multiple sources could be tested in a high hazard exposure area.
5. AI-assisted early warning tools to support AA are being developed rapidly in both the humanitarian/development and private sectors. Given sufficient data input, these tools could support impact-based forecasting.

Real-time event observation, and imminent and seasonal forecasts are available for Iraq, Syria and Yemen. Provided these can be communicated in an accessible way, they can help people protect themselves and their assets.

All the tools in Table 2 provide information on already occurring events, i.e. near real-time or "nowcasted" event information. For floods, many use remote sensing information from sources with global coverage, including from NASA's Flood Model and the Global Flood Awareness System (GloFAS). Many drought identification tools are primarily highlighting agricultural drought using precipitation and soil sources and indicators such as Climate Hazards Group InfraRed Precipitation with Station data (CHIRPs), the Normalized Difference Vegetation Index (NDVI), and the Standardized Precipitation Index (SPI). Wider use of data from these sources among humanitarian organizations could help support AA, particularly in high-exposure areas.

The main tools using seasonal (one- to six-month) climate forecasts are focused on mitigating adverse acute food security outcomes (e.g. FEWS Net, IPC). There could be a need for a tool that consolidates seasonal outlook information, collects information from global agriculture production centers, and considers potential implications for internal migration relating to livelihoods (e.g.), or identifies whether seasonal flood or dry seasons could be wetter or drier than normal.

INFORM Warning

The European Commission's INFORM Warning,[134] which is under development with a launch date of mid-2025, is intended to provide open-source multi-hazard early warning information, including information on risk trends, forecasts, scenarios, and events that could project humanitarian impacts within the coming 1 to 12 months. INFORM Warning is part of a series including INFORM Risk (global index measuring structural crisis risk) and the INFORM Severity Index (measures the severity of crises once they occur).

The outputs from INFORM Warning remain under development, but the platform is intended to provide global coverage and thus will include Iraq, Syria, and Yemen. The output format has not yet been finalized, nor is the platform's ability to forecast displacement and other humanitarian impacts.

Use of remote sensing data can help to fill gaps in understanding that persist due to conflict-related damage to weather and climate monitoring stations and fragmented governance structures.

Gaps in national capacity hamper weather and climate forecasting, particularly in Yemen and Syria, where weather stations have been destroyed or damaged by conflict, and there are limited funds or incentives to repair monitoring systems.[xx] The loss of historical records also curtails the development of models to support sub-national forecasting and understanding of hazard impacts on different groups of people.[31] Remote sensing approaches can help to fill in the gaps left by a lack of ground observations, though ground-truthing information derived from satellites is an essential step in ensuring that data is accurate and trustworthy. For example, in Northwest Syria, analysis of previous flooding events demonstrates that forecasts could predict rainfall with a 70% probability at a three-day lead time, and 50% with a seven-day lead time,[135] sufficient for delivery of early warning messaging and action to be taken by humanitarian organizations. Given the constraints of the context due to ongoing conflict and limited governance there is enough information available on historic flood extent and shelters at risk[136] to work on AA and DRR initiatives. KIIs revealed that there is adequate information – provided it can be communicated in an accessible way – to support delivery of timely warnings to people to help them protect themselves and their assets.

Authorities, particularly in Syria, do not appear to be using earth observation data at scale to support the provision of early warning information for AA. This presents additional remote sensing training and capacity strengthening opportunities to support a scale up of access to information. Use of remote sensing data also presents an opportunity for enhancing information exchange between authorities, communities, and

[xx] KII, Meteorologist

humanitarian and development partners, including working with communities to ground truth and build trust in satellite information.

Blending different sources of weather, climate, population, and vulnerability data (e.g. displacement information) to account for numerous organizational focus areas could help deliver more holistic early warning information.

"There is great opportunity within the Middle East to use multiple sources of data to provide early warning information..."

KII, EW/AA Specialist, March 2024

The expansion of publicly available datasets relating both to drivers of humanitarian need (e.g. vegetation health, conflict data, precipitation statistics) and humanitarian impacts (e.g. displacement, acute food insecurity, populations exposed to hazards) present an opportunity to provide holistic early warning information. Many of the tools identified are tailored to organizational mandates and thus focus on specific sources of data to track specific concerns (e.g. vegetation indices for agricultural production). Those which do provide more in-depth information (e.g., PDC) require an organizational login, which potentially limits the platform's reach.

Despite the high number of IDPs in the region and the public availability of data concerning their locations, there does not appear to be a single public platform that combines remotely sensed earth observation data (e.g. rainfall, drought intensity) with climate outlook information and IDP locations. Having the right vulnerability data available in the most accessible formats would be valuable to support early warning.[xxi]

There are persistent gaps in humanitarian and event datasets. To encourage data sharing, a platform blending multiple sources could be tested in a high hazard exposure area.

Finding data to support the understanding of plausible impacts from floods and drought presents challenges. While information on hazard extent or weather forecasts may be available at sub-national levels, data on displacement or food security might be disaggregated to the district level only.[xxii] Historic event data or community information may not be sex- and age-disaggregated, which prevents understanding of the unequal potential impacts on specific groups. These data may be available, but are not shared between organizations.

In the absence of quantitative data, AA has been undertaken in MENA using qualitative information, albeit for conflict- and instability-related risks. In Iraq, for example, a Start Fund AA allocation for a displacement spike from camp closures was informed by qualitative information such as conflict analysis and expert judgment, rather than displacement forecasts.[25]

Data gathered at different levels (i.e. households vs. community vs. region) according to different organizational focus areas, creates challenges when it comes to identifying specific exposed groups in a given area.[xxiii] There may be merit in testing a system in a highly exposed area with strong disaggregated data to show proof of concept.[xxiv]

[xxi] KII, GIS Specialist
[xxii] KII, EW/AA Specialist
[xxiii] KII, EW/AA Specialist
[xxiv] KII, GIS Specialist

HDX Signals

HDX Signals,[137] an initiative by OCHA's Center for Humanitarian Data, curates frequently updated datasets critical for identifying adverse humanitarian outcomes. The platform aims to notify users through email alerts and an automatic API when significant changes are detected in a dataset, adding an analytical layer to existing datasets contained on the Humanitarian Data Exchange (HDX).

The initial June 2024 release contains five datasets: Food insecurity (IPC), food prices (IPC), Agricultural hotspots (EC), Internal displacement (IDMC), Market monitoring (WFP), and Conflict events (ACLED).[138] This platform could represent a useful source of blended datasets to support AA.

AI-assisted early warning tools to support AA are in development. Given sufficient data input, these tools could support impact-based forecasting

The field of artificial intelligence (AI) is rapidly expanding, with significant advances in techniques and applications, and the humanitarian sector is expanding its use of data science to support EW and AA. Humanitarian/private sector partnerships have actively explored the use of AI-assisted tools for these same purposes (e.g. Google partnerships[139] focused on flood forecasting). Several organizations have expressed or demonstrated interest in AI-assisted flood forecasting, meaning a census of flood prediction efforts should be conducted on any new flood prediction initiative to avoid duplication.[140]

AI-assisted impact forecasting in the medium-term remains a challenging field, beset by issues around data gaps (including on specific vulnerable groups), transparency, and risks that models perpetuate biases, although opportunities remain to shape how this field evolves.[141] For example, platforms such as the PDC use AI-assisted approaches to enhance their delivery of early warning messages.

Challenges for data-driven tools and platforms

From the KIIs and literature review, five key challenges for EWS in Iraq, Syria, and Yemen emerged. These are summarized below, with further details provided on the following pages.

1. The governance structures in Iraq, Syria, and Yemen could pose challenges when working with, and communicating, early warning information.
2. Forecasting the humanitarian impacts of drought, particularly drought-related displacement, remains challenging due to the complex factors that influence individual households' decision-making.
3. Despite the development of tools to support AA, organizations may still struggle to take early action due to organizational approaches to no regrets action, lack of funding, or organizational/community inability to access and understand information.
4. Coordination of EW/AA initiatives, including among donors, could support greater scale-up of AA programming in the region, moving toward a multi-hazard EWS.
5. Sustained funding for early warning tools and platforms is required to ensure uptake within the humanitarian sector and by relevant authorities.

The varying governance structures in Iraq, Syria, and Yemen could pose challenges when working with, and communicating, early warning information.

EWS development needs to involve stakeholders drawn from authorities and communities, alongside humanitarian and development actors. Iraq, Syria, and Yemen all have "patchwork governance," with geographic areas under the control of official or de facto authorities. Different hazards may be the purview of different ministries, which can be challenging vis-à-vis communication of early warning information.[xxv] The foundations for risk management may not be in place, even if they had been prior to conflict. Communities may be affected by the same hazard, with varying access to information and capacity for AA response depending on the governance in their area.

Coordination challenges may persist between organizations and the authorities, particularly across differing areas of control. Yemen has the internally recognized Republic of Yemen government based in Aden and the de facto Houthi authorities based in Sana'a. The Republic of Yemen government has a Supreme Council for Civil Defense and associated committees for disaster management.[142] The de facto authorities in Sana'a have the Supreme Council for the Management and Coordination of Humanitarian Affairs and International Cooperation.[143] In Syria, there is the Autonomous Administration of North and East Syria, the Syrian Salvation Government (SSG) in Idlib, and the Syrian Interim Government that controls two non-contiguous strips of land along the northern border with Turkey, and the government of Syria in the rest of the country. As with Yemen and Syria, Iraq has multiple governance structures, with the Kurdistan Regional Government (KRG) serving as the official authorities of the autonomous Kurdistan Region in northern Iraq, while the federal government of Iraq governs the rest. Each has its own disaster management structures.

Despite the development of tools to support early warning and AA, communities and organizations may struggle to use EWS due constricted access to information and implementing organizations may struggle to secure buy-in for "no regrets" anticipatory action programing amid a constrained funding environment.

Flood and drought forecasts can contain high levels of technical language that prevent them from being used by non-technical experts, including communities, governments, and humanitarian organizations that support AA. For example, flood return periods and probabilities are frequently misunderstood, and people can wait for non-existent "definitive" information before taking action.[144]

Communities may mistrust weather stations and information that contradicts their indigenous knowledge[xxvi], which can lower the response capacities among the most vulnerable groups and limit the efficacy of hazard communications.[145] Blending information from communities with other sources is beneficial in terms of building trust and supporting decision-making. For example, GloFAS, the widely used river flood forecasting model, cannot account for small dams and dikes, or provide forecasts for small tributaries. Communities, however, may have their own approaches to monitoring rivers to complement flood models.

The challenges of financing AA in Syria and Yemen, in part due to sanctions, are likely to persist. Having pre-arranged financial instruments is challenging, particularly in areas outside of government control, and even when these are available, funding amounts are likely to be relatively small, which negate supporting AA at scale.[xxvii] Funding for institutional Disaster Risk Management plans, which could support a scale-up of EW/AA, remains limited, particularly in Syria.

In the context of ongoing humanitarian responses, organizational and donor appetite for AA may also be reduced. Organizations and donors may be unwilling to consider a no regrets approach, instead preferring

[xxv] KIIs, EW/AA Specialist and Meteorologist
[xxvi] KIIs, Meteorologist and EW/AA Specialist
[xxvii] KII, AA Specialist

to retain funding for humanitarian response.[xxviii] No regrets approaches are considered to reduce the burden of emergency response, particularly among communities with high baseline vulnerability, where even if a hazard does not materialize as expected, interventions will have a positive benefit regardless.[146] Embedding EWS/AA into organizational Standard Operating Procedures and encouraging an organizational shift in mindset regarding AA vs. response are essential for building wider support for AA, sustaining EWS, and supporting no regrets approaches.

Forecasting the humanitarian impacts of drought, particularly drought-related displacement, remains challenging due to the complex factors that influence individual households' decision-making.

According to the Internal Displacement Monitoring Centre (IDMC), better understanding of internal displacement volumes and flows are hampered by gaps in tracking forecasting displacement caused by drought. The Centre notes that forecasting drought displacement requires knowledge of when environmental drought stressors overcome other factors, such as socioeconomic factors.[147] Using historical data on displacement to inform future trends is problematic, as specific climate-related indicators may be missing and causality difficult to ascertain. Displacement can be cyclical and challenging to track and/or distinguish from internal migration, as individuals may repeatedly leave their original communities in search of livelihoods and then return.[148]

A 2022 study by the IOM of climate-induced displacement in southern Iraq considered four aspects: (1) environmental hazards and water access; (2) services and infrastructure; (3) livelihoods and mitigation measures; and (4) tensions and conflict.[149] Using data collected from 9,215 families across nine governorates, the authors found that multiple water-related indicators – including reduced rainfall and inefficient water infrastructure – were the strongest predictor of displacement. Correlations between displacement and the Normalized Difference Vegetation Index (NDVI), a remotely sensed observation of plants' chlorophyll content that is used as a proxy for crop health, were not conclusive. The authors note that, to fully understand displacement drivers, data such as the NDVI needs to be contextualized and viewed alongside socioeconomic information,[150] validating the need for a tool or platform that blends multiple indicators and data sources.

Coordination of EW/AA initiatives, including among donors, could support greater regional scale-up of AA programming, including hazard and multi-hazard EWS in conflict settings.

Such a blended tool can only be developed through data sharing and aggregation. Although this has improved over the past decade, questions over responsible data sharing, use, and analysis remains, particularly as a growing number of actors create and use humanitarian data.[151] Better early warning coordination across the Middle East through expanding existing communities of practice could support co-development of information platforms and address the challenges of supporting multiple organizations. With a growing number of AA projects, coordination that includes donors would also be beneficial to avoid duplication of effort.

Greater coordination could also collectively enhance how the sector moves toward multi-hazard EW and support the building of an evidence base for AA in conflict settings. This could include, but is not limited to, coordination on priority hazards, sharing of risk maps and impact data, co-development of AA triggers, and sharing of best practices and lessons learned.

[xxviii] KII, AA Specialist

Sustained funding for EW tools and platforms is required to ensure uptake, iterative development, and sustained use

Without sustained funding, it is highly likely that useful existing tools or platforms to support EW/AA cannot be maintained, regardless of how widely they are used. Ensuring access to high-quality data, an aim of the Early Warnings for All initiative,[152] requires ongoing support for data infrastructure and personnel. An EWS program in Asia emphasized the importance of novel informative attribute data and noted that developing and maintaining comprehensive attribute information on natural hazard risks, demographics, infrastructure, and accessibility involved significant, multi-year funding.[xxix] This investment enabled incremental development of the platform, with smaller-scale trials for selected areas and user testing and feedback prior to a wider rollout.

MEACAM' s potential to support early warning

Purpose

With a growing focus on AA across MENA, MEACAM's aim is to develop proprietary predictive models that provide early warning for flash floods and drought. Starting with a smaller-scale focus on flood and drought-prone areas in Iraq, Syria, and Yemen, MEACAM addresses two key gaps identified through literature review and KIIs:

- A technical design optimized for modularity with spatial data, which enables data shared by other organizations to be added to MEACAM as an interactive layer.
- Pixel-level hazard prediction using satellite imagery data and spatial machine learning.

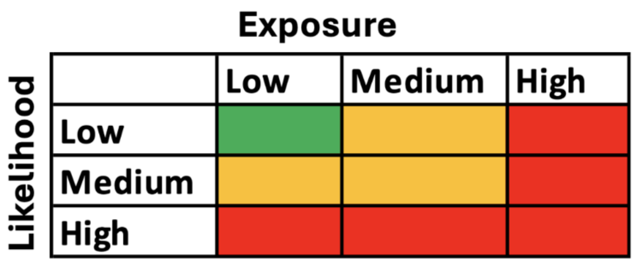
Apart from flood and drought predictions, informative attribute data is arguably the MEACAM platform's main added value, in particular its interoperability with secondary spatial data. This means that data collected and stored by other agencies and governments can be easily fed into the flooding and drought modules and used as additional attributes for one or more locations. For example, if another humanitarian or development information management organization collected detailed household vulnerability data in ten villages across three sub-districts in Iraq, this data could be added to MEACAM as attributes for those ten villages and appear if there is an early warning detected in any of those locations. Geospatial, vector, or raster data can also be incorporated in MEACAM. For example, after an area of interest is selected, MEACAM's interactive map features dynamic selectable layers. A raster layer of flood vulnerability for a single IDP camp would thus be selectable if the area of interest included that camp.

Existing and future novel spatial indicators produced by Mercy Corps' CAT teams in the region will also be gradually incorporated as visual and interactive layers on the MEACAM platform. For example, the environmental degradation indicator for Syria that was recently developed by Mercy Corps' CA-Syria team will be added to the drought module to provide information about crop type, activity, and water source for locations that are likely to be affected by drought. It is also important to note that the MEACAM platform is supported by a data engineer who helps other agencies upload their data.

[xxix] KII, GIS Specialist

Hazard predictions and vulnerability information will be updated in near real-time and presented in an online map that highlights areas where flooding or drought is likely to occur. Each hazard, flood, or drought will be presented in dedicated modules for each country. The areas where hazards are predicted to occur will be color-coded according to the severity and likelihood of the impact, as shown in Table 4. Exposure is defined as the total amount of farmland (drought) or population (flooding) affected by the predicted hazard. The specific categorization and exposure indicators are subject to change. Areas classified as "Low" (green) are assigned a value of 0.5 points, "Medium" sites (orange) are assigned a value of one point, and areas classified as "High" (red) are assigned a value of 1.5 points. These categories are weighted by population or hectares of farmland to identify areas where the human impact of the hazard is greatest.

Figure 5. MEACAM prediction risk categorization.



Methodology

Flooding

Flooding is modeled by predicting changes in the Earth's surface using synthetic aperture radar (SAR) data collected by the Sentinel-1 satellite at a spatial resolution of 10m2 per pixel. The SAR instrument aboard the Sentinel-1 satellite bounces radar waves off the Earth's surface. Dramatic shifts in the intensity of SAR readings indicate changes on the Earth's surface – specifically, significantly lower SAR values, well outside the typical value for that week of the year, typically indicate the presence of floodwaters over dry land.[82]

Flood forecasts are based on the per-pixel predicted SAR reflectance value[xxx] and how that value compares to the typical pixel value and its proximity to the SAR values observed for surface water. SAR values are predicted using the following values:

- 1- to 5-day forecasted rainfall (mm)
- Aggregated rainfall for the previous 1 to 7 days (mm)
- Most recent Normalized Difference Vegetation Index (NDVI)
- Most recent Normalized Difference Moisture Index (NDMI)
- Upstream drainage [flow accumulation] area (km2)
- The previous SAR reflectance value
- Elevation above nearest drainage (HAND)

A pixel is labeled as flooded if the predicted change in SAR exceeds the estimated typical range of SAR values for that week and falls within at least the upper bounds of the SAR reflectance values observed for surface water.[xxxi] Pixels with high HAND values (>20 meters) were removed from the analysis as potential flooded areas since high HAND values generally indicate that the location is significantly higher than the nearest

[xxx] Sentinel-1 'VV' band values.

[xxxi] Following the methodology established by Bauer-Marschallinger et al. (2022).

drainage and therefore unlikely to flood. The initial areas of Iraq, Syria, and Yemen for which MEACAM flood predictions will be developed and tested are shown in Table 5 and were chosen because they are prone to pluvial and/or flash flooding.

Table 3. Summary of areas included in the MEACAM flood module with key characteristics

Sub-national area of interest (admin-3)	Characteristics
	Iraq
Basra	Urban, flood-prone environment built on a marsh with rapid expansion and informal settlements.
Kut	Agricultural land around the River Tigris is prone to river and flash flooding and subject to transboundary water management.
Soran	Hilly areas such as Taq Taq and Rawanduz have previously flooded (pluvial and flash floods), causing damage to agricultural land and homes. Snowmelt can also cause flood events.
	Syria
Afrin, Azaz Ad-Dana, Harim	Heavy winter rain can drive floods, particularly impacting IDP camps, compounding the impacts of ongoing conflict.
Al-Hasakeh	Heavy rain on drought-affected areas use flash floodsthat more adversely impact IDPs, especially those living in informal settlements, and can damage key agricultural land.
	Yemen
Abs (Hajjah)	Area of the coastal plain that is prone to flooding during the winter. IDP camps are located in flood-prone areas including on slopes and near drainage channels.
Aslam Al-Wasat, Aslam Al-Yemen	Hilly areas with minor tributaries to one of the main western wadis; prone to flash flooding with IDP camps in flood-prone areas.
Dhamar	Flood prone area along the Wadi Zabid, with recent flood events causing damage and displacement.
Hays	Hays town and surrounding areas along the Wadi Nakhlah are prone to flash flooding during the rainy season.
Ma'rib	Urban environment with high numbers of IDPs and informal settlements.

Drought

MEACAM provides predictions of agricultural drought, which is measured as the deviation from the long-run average Normalized Difference Vegetation Index (NDVI) of agriculture areas. Predictions are computed for hexagonal cells[xxxii] containing more than 50 hectares of cropland. Cropland was defined by the European Space Agency[xxxiii], and the NDVI was obtained from Landsat 8[xxxiv]. The first iteration of the model will predict 1- to 4-month NDVI deviations during the regional winter growing season, which is the most significant season in Iraq, Syria, and Yemen. The following explanatory variables were used to predict the deviation from average NDVI:

[xxxii] Using the H3 hierarchical geospatial index.
[xxxiii] ESA WorldCover 10m v200
[xxxiv] USGS Landsat 8 Level 2, Collection 2, Tier 1

- **Lagged deviations from average NDVI**: Previous deviations of NDVI from the monthly average were included in the model as past values likely contain predictive power. These indicators are calculated for the current and previous lags. For example, the 3-month prediction model for March includes the NDVI deviation from the average for February, January, and December.
- **Standardized Precipitation Evapotranspiration Index** (SPEI): A drought index that accounts for precipitation and potential evapotranspiration, i.e. the rate that water evaporates from the land. The variable is calculated over a period of months. The 1-, 6-, and 12-month SPEI are included in the model, and the index is calculated from the first lagged month. For example, a 3-month prediction model forecasting the NDVI deviation for May (when the current month is February) uses the 1-month SPEI is calculated using data from February and January, the 6-month SPEI calculated using data from February to that past August, and the 12-month SPEI calculated using data from February to January of the previous year.
- **Normalized Difference Moisture Index (NDMI) deviation**: The NDMI is a satellite imagery indicator that measures plant water content and is typically used as a proxy for soil moisture. The indicator is calculated by dividing the observed NDMI by the average NDMI of that month. For example, in a 3-month prediction model for May (when the current month is February), the observed NDMI for February is divided by the average February NDMI value. Furthermore, previous lags are also included; in this case, the observed NDMI for January divided by the average NDMI value.
- **Cumulative rainfall during the current rainy season, divided by the average cumulative rainfall at that point in the rainy season**: This measures the quantity of rainfall and how "on schedule" the rainy season has been. Rainfall data is obtained from the CHIRPS satellite. This statistic serves as one variable in the model and is calculated using past rainfall measurements. For example, in a 3-month prediction model for May (when the current month is February), the statistic is calculated by summing the total rainfall from October to February, divided by the average cumulative rainfall from October to February.
- **USD exchange rate of local currency dynamics (Syria & Yemen)**: The models for Syria and Yemen will also include the growth rate of the USD exchange rate for the local currency to account for significant currency depreciation in those countries. The variable is defined as the 1-month growth rate, calculated from the most recent and previous lags. For example, in a 3-month prediction model for May (when the current month is February) in northeast Syria, the February SYP/USD growth rate (January to February), and the January SYP/USD growth rate (December to January), are included in the model.

Platform applications

Local actor/government handover

Each country covered by MEACAM includes two or more distinct sets of local stakeholders and governance authorities. Syria is under the control of four authorities: the Autonomous Administration in the northeast, the Syrian Salvation Government in the northwest (mostly Idlib governorate), and the Syrian Interim Government that controls two non-contiguous strips of land along the northern border with Turkey. The Syrian government controls all the remaining territory south of the areas mentioned above – which is the largest land area among the ruling authorities. Governance in Yemen is split between the de-facto authority, which controls the northwest of the country, and the internationally recognized Yemeni government, but are fractured by several other stakeholders, most notably the Southern Transitional Council and Al-Qaeda in the Arabian Peninsula. Governance in Iraq is centralized compared to Syria and Yemen, though the northern third of the country, the semi-autonomous Kurdistan Region (KRI), is ruled by the Kurdish Regional Government (KRG), but is beholden to the federal government in Baghdad on matters related to national defense, foreign policy, and natural resource management (excluding oil production).

These distinct governance structures across zones of control, as well as the diverse existing aid architectures in Iraq, Syria, and Yemen create both complications and opportunities for the dissemination of an EWS. In terms of dissemination, each zone of control should be approached as an independent country, with the possible exception of the KRI and federal Iraq. In Syria, MEACAM can centralize information and relevant datasets and act as an EWS that accounts for communication challenges between intra-country aid agencies. The current lack of functional government institutions in IRG-controlled Yemen represent an opportunity for MEACAM to serve as an EWS in close collaboration with the ruling authority, in addition to related sector clusters, such as the Camp Coordination and Camp Management (CCCM) cluster, Rapid Response Mechanism (RRM) cluster, and, Food Security and Agriculture cluster (FSAC).

Creating opportunity for Anticipatory Action programming

Despite the challenges detailed in Part 3, AA opportunities in Iraq, Syria, and Yemen are expanding. The humanitarian response is shifting from humanitarian to recovery and development, with donors showing significant interest in climate-related projects and research. EWS are a prerequisite to proposing AA programming in these countries.

Current limitations and future work

Technical limitations and opportunities

The initial MEACAM flood and drought module designs and model specifications will not be the final versions. User testing and feedback from the wider humanitarian community will support iteration and improvements. Furthermore, the MEACAM platform will be continuously upgraded over the project lifecycle to ensure statistical accuracy and to incorporate any relevant technological innovations (e.g., advanced algorithms; new satellites) as they become available. Furthermore, novel indicators developed by Mercy Corps' MENA Crisis Analysis teams will be added to MEACAM as attribute data, where relevant.

Technical limitations currently include:

- **Accurate flood detection in mountainous terrain**: The SAR data collected by the Sentinel-1 satellite presents challenges because of the incidence angle from which images are taken, even after terrain correction is applied in the Google Earth Engine. The incidence angle causes three distortions:
    - **Foreshortening,** when the SAR sensor reaches the base of a tall hill or mountain before it reaches the peak.
    - **Layover,** when the front slope of a mountain is captured at the same time as the back.
    - **Radar shadow,** when the angle of the back slope is too steep for the sensor to record. No meaningful SAR information can be collected from mountainous areas with steep back slopes.
- **Contemporary cropland mask**: The cropland mask provided by the European Space Agency was created in 2021 and covers the globe, but there are limitations in the land cover classification. For example, orchards are grouped with wheat fields and other farmland in the "cropland" category but are often confused with the "forest" category. This causes errors when measuring agricultural drought because non-cropland may be included when measuring vegetation health; conversely, the vegetation heath measurements may omit some cropland. A recommended addition to MEACAM is contemporary crop and orchard classifications (separately) using training samples collected yearly in all three countries.

Despite the stated technical limitations, several opportunities exist:

- There is an abundance of relevant spatial data produced by aid and government actors that is published on public platforms, and other data that remains publicly unavailable. It is important to obtain a comprehensive view of this data landscape, particularly for non-public data. Equally, the MEACAM platform is well-positioned to incorporate these data as a layer interacting with flood and drought predictions. Mercy Corps needs to make a concerted effort to identify useful available data, coordinate with owners, and lead on the technical solution that connects this data to MEACAM.
- In Syria, MEACAM is well-positioned to provide early warning to multiple humanitarian clusters and working groups (AANES) and ruling authorities, since no comparable tools exist.
- Collaboration with other information management organizations is essential in Yemen and Syria because other organizations have conducted in-depth research on flood vulnerability (REACH; FAO). However, drought early warning remains novel in these countries.
- In Iraq, MEACAM dissemination efforts should focus on central government authorities as the country has functioning ministries whose mandates are related to early warning; specifically, the Ministry of Environment and Ministry of Water Resources.
- To maintain relevance, MEACAM must be represented in country-level, regional (MENA), and global working groups and initiatives centered on early warning.

Participatory approaches for future applications

The MEACAM platform is accessible: anyone can access[xxxv] timely flood and drought early warnings, in line with the UN's Early Warnings for All initiative. The MEACAM platform should feature an alert system that allows anyone with a mobile number or email address to subscribe. This feature is beyond the current scope of the project but will be given priority in a future version of MEACAM.[xxxvi] That said, public dissemination efforts will be inevitably constrained by technology and mobile network accessibility and affordability, particularly in active conflict zones.

Ideally, a MEACAM alert system would be complemented by efforts to build community resilience to the effects of climate hazards through training by government agencies or aid actors. For example, an outreach program to vulnerable communities that raises awareness of the MEACAM platform and provides practical training on practical approaches using everyday materials to mitigate the effects of flooding and/or drought.

[xxxv] A straightforward design does not insinuate that the MEACAM provides less relevant information. The goal of the MEACAM is to deliver the location, likelihood, and exposure of predicted flooding and drought.
[xxxvi] Alerts delivered in Arabic and English.

ANNEX 1: Information on Key Early Warning tools

Advanced Disaster Analysis and Mapping service (ADAM)

The World Food Programme's Advanced Disaster Analysis and Mapping (WFP ADAM)[153] service collects, analyzes, and maps global forecasts and impacts of earthquakes, floods, and tropical storms. Early warning and response reports are publicly available on a live map[154] as well as via email and social media posts. Information on flood risk exposure based on probabilistic hazard and vulnerability data is available on demand.

- **Flood early warning forecasts** are broadcast 3-5 days before a major event, identifying areas potentially at risk and when it might occur. The system uses GloFAS reporting points showing probabilities of exceeding 2-, 5- and 20-year flood periods and ECMWF forecasts to produce flood inundation forecasts for areas greater than 5,000 sq km. Early warning products detail population figures for "populated places of concern" alongside rivers at risk, likely date of peak flood extent, and WFP office locations (e.g. Iraq February 14, 2024).[155] Flood early warning products do not provide information on potentially affected cropland or infrastructure.
- **Flood event impact analysis:** Some 72 hours after floods, automated reports using satellite observation of flood extent are generated. Analysis may include total observed flooded areas, number of people living in flooded areas, total flooded cropland, and number of vulnerable people (elderly and children), summarized to Admin 02 level (e.g. Indonesia February 12, 2024).[156]

Famine Early Warning Systems Network (FEWSNet)

The Famine Early Warning Systems Network (FEWSNet) was set up in the 1980s by the United States Agency for International Development (USAID). The network monitors and provides early warning analysis of ongoing, imminent, or emerging threats to food security. It deploys a mixed approach, including scenario-building, to consider likely food security outcomes, which are often influenced by multiple factors, including climate. An agroclimatology team[157] uses remote sensing satellite imagery to monitor and forecast seasonal outcomes and provide a weekly Global Weather Hazards report,[158] highlighting areas at risk of, or experiencing, floods or drought. For monitored countries, which include Yemen, but not Syria or Iraq, regular updates are provided.

- **Food security outlooks** provide a summary map of the near- and medium-term acute food security outlook according to the Integrated Phase Classification (IPC) scale. Qualitative information covering contextual updates, specific population groups or geographic areas of concern and key drivers of acute food insecurity is provided, along with quantitative market information, where available.
- **Alerts / special reports** are early warning products designed to highlight an anticipated shock that may drive a significant change in the severity of acute food security outcomes and require immediate humanitarian assistance.

On individual country pages (e.g. Yemen),[159] FEWSNet provides contextual information. This includes seasonal calendars; covering rainy seasons, planting and harvest seasons, the lean season(s); maps of livelihood zones; and key crop production maps. Satellite-derived data including CHIRPS rainfall anomalies, ETA monthly data and NDVI pentadal data, sourced from the USGS.

Foresight

The Danish Refugee Council's Foresight model[160] uses Machine Learning (ML) to predict forced displacement (IDPs, refugees and asylum seekers) at the country-level from one to three years in advance, providing an upper and lower bound. The model uses several open-source quantitative indicators relating to conflict and violence, governance, economy, environment, and socio-demographics. Platform users can conduct "what-if" scenario analysis by adjusting improvements or deteriorations for clusters of variables (e.g. natural hazards). It is not currently possible to see the displacement forecast for individual hazards.

Environment indicators are sourced from EM-DAT,[161] the international disaster database, and include estimates of the number of people affected, injuries, homelessness, damage (in USD), and occurrences of "natural disasters" (including floods and drought). EM-DAT notes[162] that the database has several biases, including unequal reporting quality and coverage through time and accounting biases.

Global Disaster Alert and Coordination System (GDACS)

The Global Disaster Alert and Coordination System (GDCAS)[163] is a joint initiative of UN-OCHA and the Joint Research Centre (JRC) of the European Commission, established in 2004. GDACS is paired with the OCHA Virtual On-Site Operations Coordination Centre (VOSOCC), a real-time online coordination platform allowing for information exchange early in a rapid onset emergency. Many governments have adopted the use of GDACS and VOSOCC tools in national disaster response plans.

- **Flood event alerts** summarize information from officials, media, and scientific organizations, including on affected populations and affected and flooded areas (e.g. Yemen April 2023).[164] A GDACS flood alert is classified according to fatalities and displacement: (1) Red >1000 fatalities, >800,000 displaced; (2) Orange 100-1000 fatalities, 80,000-800,000 displaced; and (3) Green – all other floods. Early warning information is not available.
- **Drought event alerts** combine information from the Global Drought Observatory with information from authorities, media, and scientific organizations. The main indicator for the spatial delineation of a drought event is the Risk of Drought Impact in Agriculture (RDrl-Agri). The GDACS drought classification alert considers qualitative and quantitative impact information to assign a rating: (1) Red – Severe or life-threatening impacts including displacement, famine, violence relating to water resource conflict; (2) Orange – Drought impacting the economy or assets, non-life-threatening impacts on people; and (3) Green – A confirmed drought but no evidence of impacts, or only mild / intermediate impacts reports.

Likely since it involves information provided by national authorities, there are gaps in reporting on drought and floods in Syria, Yemen, and Iraq.

Global Flood Awareness System (GloFAS)

The Global Flood Awareness System (GloFAS),[165] jointly developed by the European Commission and the European Centre for Medium-Range Weather Forecasts (ECMWF) is part of the Copernicus Emergency Management Service. The system is designed to support flood preparedness activities worldwide, particularly in large trans-national river basins such as those transversing Syria and Iraq. GloFAS combines information from satellites, ECMWF models and in-situ measurements to produce a range of forecasting and monitoring information, including:

- **Flood forecasts** provide 1- to 3-day, 4- to 10-day and 11- to 30-day flood summaries, with decreasing certainty as time increases. Forecasts are updated daily and available in the online map viewer and through download. Summary maps show 2-, 5-, and 20-year return periods by probability (30-50%, 50-75%, and 75-100% likelihood). Additional information on the forecasts is available for reporting points, which summarize the likely peak flood extent and timing using hydrographs, a type of chart showing the rate of water flows over time.
- **Flood mapping and impact assessments** are produced only when the forecasted flood extent is greater than 5,000 km^2 and the peak flood is greater than a 1-in-10-year return period. Mapped areas show an estimate of potentially inundated areas and impact assessments consider exposure information including populations, landcover, and critical infrastructure. Impact ratings use an impact matrix taking into account the lead time to the event and total population potentially exposed.
- **Seasonal outlooks** indicate unusually high or low river flows over the next 16 weeks by combining meteorological forecasts with hydrological models. Outlooks are available by river basin or river network.

Global Information and Early Warning System on Food and Agriculture (GIEWS)

The Global Information and Early Warning System on Food and Agriculture (GIEWS) established by FAO in the 1970s continuously monitors food supply and key indicators impacting food security globally. The system uses FAO-developed early warning indicators such as the Agricultural Stress Index (ASI)[166] – a quick-look-indicator for the early identification of agricultural areas affected by dry spells or drought – and the Indicator of Food Price Anomalies (IFPA),[167] a statistical measure of food price volatility.

There are several tools and products[168] developed by GIEWS containing a mix of early warning information and data on extant conditions including:

- **Food price monitoring and analysis (FPMA) bulletin**: provides monthly warnings on countries facing abnormally high food prices based on the IFPA.
- **Country briefs:** summarizes climatic and economic factors influencing crop production, indicating where there are populations in need of humanitarian assistance or there could be a worsening of food security outcomes (e.g. Syria).[169]
- **Online earth observation data:** feeds into a dashboard[170] with global- to country-level maps covering up to 36 months of earth observation data on seasonal, vegetation and precipitation indicators.
- **Hand in Hand Geospatial Platform:**[171] contains data layers on food security indicators and agricultural statistics sources from FAO and external organizations

Hunger map

The World Food Programme's Hungermap[172] is a real-time map monitoring food security in around 90 countries, providing predictions of real-time food insecurity where data is limited. The interactive interface also shows metrics on conflict (ACLED), hazards (Pacific Disaster Center), the Normalized Difference Vegetation Index (MODIS NDVI), one-month precipitation anomaly (CHIRPS), and IPC/CH acute food security data.

Current food consumption information is shown as Food Consumption Scores (FCS), a core WFP collected indicator used as a proxy for quality of household food access. By navigating to an individual country, a user can find the FCS by Admin 01 level along with the FCS trend, and population experiencing insufficient food consumption and acute / chronic malnutrition.

Integrated Phase Classification (IPC)

The Integrated Phase Classification (IPC)[173] or Cadre Harmonise (CH) in Francophone Africa is a widely used five-phase scale providing common standards for classifying the severity of acute food insecurity. For countries assessed by IPC/CH, real-time and projected acute food insecurity is determined using a structured analytical process taking into account factors such as seasonal calendars, post-harvest surveys and weather and climate information. For example, in Yemen, FAO's Strengthening Food Security Information and Early Warning Systems Project (see report, under Yemen) supports delivery of IPC assessments.

On individual country pages,[174] IPC provides the number of people in Phase 1-5 acute food insecurity outcomes for the current, projected, and sometimes second projection time period. Data can be extracted in map or Excel formats or obtained via an API. Each report details the key drivers of acute food insecurity and identifies specific areas and / or vulnerable groups (e.g. IDPs). Special alerts are released in the event of a major change in previous analysis. IPC Phase 5 ("Catastrophe") is often considered "Risk of Famine", although Famine or "Risk of Famine" declaration is subject to additional analysis and review by a Famine Review Committee.

FEWS Net (see above) produces analysis according to the IPC scale and is considered an IPC compatible process.[175]

Internal Displacement Monitoring Centre: Disaster Displacement Risk Model

The Internal Displacement Monitoring Centre (IDMC)[176] maintains a database of global internal displacement data. Country-level data available includes displacement by year for hazards including floods and drought, alongside specific information on affected locations. At a country level (e.g. Yemen),[177] preliminary displacement figures, which require review, are found on the specific country page.

IDMC's **Global Disaster Displacement Risk Model** forecasts annual displacement by hazard type per country. It considers the likelihood of different hazards and their intensity, the number of people and assets exposed to hazards and the likelihood of exposed buildings being rendered uninhabitable as a proxy for displacement. The disaster displacement risk model tool is offline until approximately mid-2024, undergoing an update, including gap filling historical dataset and investigating ability to provide disaggregated data.

IFRC GO: Riskwatch

The International Federation of the Red Cross and Red Crescent (IFRC) societies Go platform contains an early warning module, termed Global Risk Watch.[178] The module provides curated data on disaster risks to support decision making and situational awareness. The Risk Watch module is divided into:

- **Forecast or recently detected events:** Provides information on forecast or recently detected hazards events, including floods and drought, sourced from WFP ADAM, GDACs and PDC. Clicking an event summarizes information from the source, which can include impact information such as number of fatalities and total number of people exposed.
- **Risks by month:** Visualizes information about the magnitude of risk, exposure and risk of displacement per country, per month or per return period:
  - Risk score from 1 (low) to 5 (very high), taken from INFORM Risk.
  - People exposed: The number of people exposed to each hazard per month using figures from the 2015 UNDRR Global Risk Model. Average annual exposure estimates were disaggregated by month based on recorded impacts of observed hazard events.

〉 People at risk of displacement: The number of people expected to be displaced per month on average by each hazard based on IDMC's disaster displacement risk model using estimates for average annual displacement risk. Values disaggregated by month based on historical displacement data associated with each hazard.

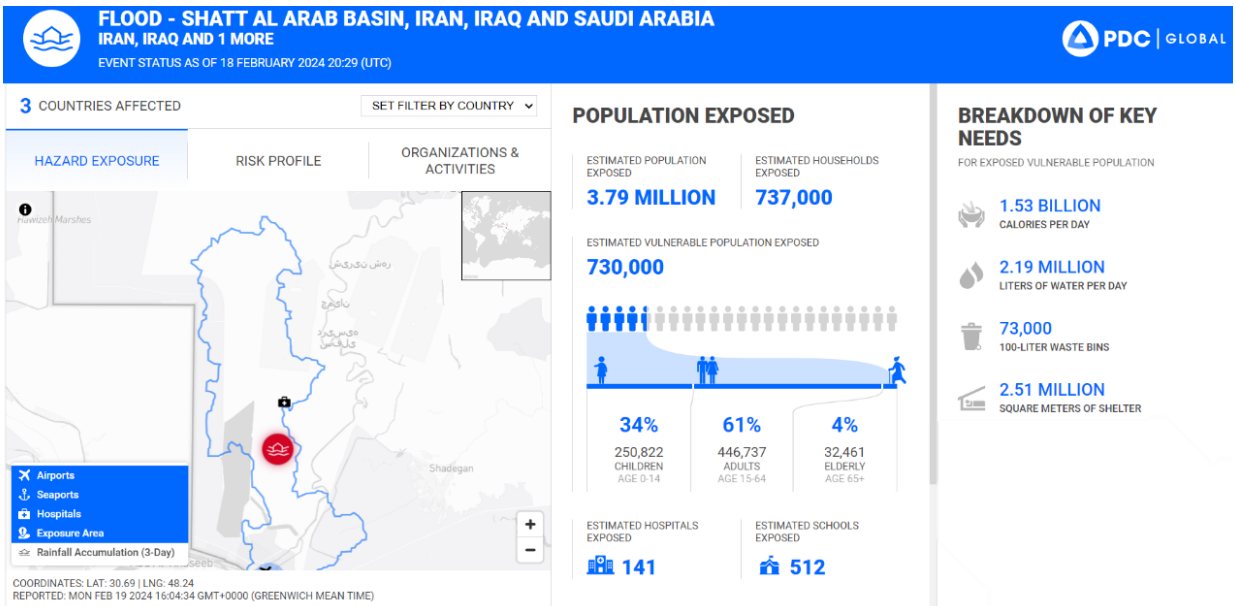
The Risk Watch system has not been linked to Early Action Protocols (EAPs) developed by the Red Cross and Red Crescent national societies; EAPs articulate a national plan to trigger early action in advance of a hazard. In addition to Risk Watch, country profile pages (e.g. Iraq)[179] contain static information including population maps, climate charts showing average temperature and precipitation across the year, and where available, seasonal calendars, summarized from ACAPS. The Previous Emergency module[180] contains impact information from national society reporting for events including floods and drought over the past decade.

Pacific Disaster Centre (PDC)

The Pacific Disaster Centre (PDC) is an applied research center managed by the University of Hawaii. Their DisasterAWARE[181] platform requires registration but can be used by governmental and nongovernmental organizations working on disaster preparedness, AA, and response programs. The platform is operational for floods and drought, providing early warning and event information. Within the dashboard, there are several different layers.

- **Flood alerts** are categorized as: (1) Information: A flood has occurred within 24 hours with severe impacts to people or infrastructure; (2) Watch: Conditions indicate a flood could occur with the potential to impact populations or infrastructure; and (3) Warning: Moderate or severe flooding is imminent or occurring. Flood alerts are automatically generated.
- **Drought alerts** are characterized as floods, but only "Watch" and "Warning" alerts are produced. Drought alerts are manually compiled from national authority and other information sources.

Impact estimates for both flood and drought aim to include population and infrastructure exposure alongside specific humanitarian needs according to Sphere standards at a 30 x 30m resolution. Population exposure estimates are broken down into in 5-year age increments and contain headline figures on the number of vulnerable people. The dashboard also curates a number datasets with variable timeframes and geospatial extent including INFORM Risk, historical flood information (Dartmouth Flood Observatory),[182] economic exposure to drought (CRU TS),[183] and water risk (WRI)[184] to provide contextual information alongside early warning alerts.



ANNEX 2: Anticipatory Action Stakeholder Mapping

The following lists include key stakeholders identified through literature review and KIIs as being critical to the development of EWS in Iraq, Syria and Yemen.

Iraq (Federal Government of Iraq)

Government ministries and bodies	Iraqi Meteorological Organization and Seismology Iraqi Ministry of Water Resources Iraqi Agrometeorological Network, Ministry of Agriculture Ministry of Health and Environment Ministry of Science and Technology National Centre for Water Resources Management National Disaster Management Council
Research Institutes	Al-Aghsan Foundation for Agricultural and Environmental Development Al-Nahrain Center for Strategic Studies
Humanitarian and Development organizations	UN-FAO UN- WFP UN-IOM Iraqi Red Crescent Norwegian Refugee Council *Note: There does not appear to be an anticipatory action working group at this time.*

Syria (Government of Syria – GOS) / Autonomous Administration of North and East Syria (AANES)

Government ministries and bodies	Syrian Meteorological Department (GoS) Ministry of Agriculture and Agrarian Reform (GoS) Ministry of Local Administration and Environment Ministry of Water Resources (GoS) Civil Defence Department, Ministry of the Interior (GoS) National Agriculture Policy Center (NAPC) National DRM Centre Syrian Environmental Protection Society Agricultural and Irrigation Committee (AANES)
Research Institutes	Higher Institute for Applied Sciences and Technology Higher Institute of Water Management, Al-Baath University International Centre for Agricultural Research in Dry Areas (ICARDA) Higher Institute for Environmental Research, Tishreen University Arab Centre for the studies of arid zones and dry lands (ACSAD)
Humanitarian and Development organizations	UN-FAO UN- WFP UN-IOM Camp Coordination and Camp Management Cluster WASH Cluster ICRC Syrian Red Crescent NES NGO Forum Syria Resilience Initiative partners *Note: There does not appear to be an anticipatory action working group at this time.*

Yemen: Government-controlled areas (GoY) and Northern Yemen (NY)

Government ministries and bodies	Ministry of Water and Environment (GoY) Ministry of Agriculture and Irrigation (GoY) Ministry of the Interior (including the Disaster Management Unit) (GoY) Yemen Meteorological Service and the General Authority for Civil Aviation and Meteorology (GoY) Ministry of Health (GoY) Disaster Management Committees (GoY) Supreme Council for the Management and Coordination of Humaniatrian Affairs and International Cooperations (NY)
Research Institutes	Yemeni Organization for Science and Technology Research Sana'a Cener for Strategic Studies Sana'a University (Meteorology Department?) University of Science and Technology Yemen The Yemeni Center for Strategic Studies and Research
Humanitarian and Development organizations	UN-FAO UN- WFP Camp Coordination and Camp Management Cluster WASH Cluster ICRC Yemeni Red Crescent Various INGOs iMMAP REACH Initiative *Note: There does not appear to be an anticipatory action working group at this time.*

References

[1] World Meteorological Organization, WMO and the Early Warnings for All Initiative (2024).
[2] Ward, PJ et al. The need to integrate flood and drought disaster risk reduction strategies *Water Security* 11 (2020).
[3] Cardiff University. Extreme fluctuations between drought and flooding are devastating communities at greatest risk of climate change impacts, new research reveals *Cardiff University Press Release* (2023).
[4] UN Climate Summit News (COP28). What the IPCC Synthesis Report means for Middle East countries *UN Climate Summit News - COP28* (2023).
[5] Gutiérrez, J. et al. Atlas In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by V. Masson-Delmotte et al. Cambridge: Cambridge University Press, 2021.
[6] Tabari, H., and P. Willems. Seasonally varying footprint of climate change on precipitation in the Middle East *Scientific Reports* 8 (2018): 4435.
[7] Naqi, N. M., M. H. Al-Jiboori, and A.-S. T. Al-Madhhachi. Statistical analysis of extreme weather events in the Diyala River basin, Iraq *Journal of Water and Climate Change* 12 (2021): 3770–3785.
[8] Red Cross Red Crescent Climate Centre. Climate Factsheet: Iraq (2021).
[9] Ahmed, A. et al. Flood susceptibility mapping utilizing the integration of geospatial and multivariate statistical analysis, Erbil area in Northern Iraq as a case study *Scientific Reports* 13 (2023): 11919.
[10] Tomaszkiewicz, M. Future Seasonal Drought Conditions over the CORDEX-MENA/Arab Domain *Atmosphere* 12 (2021).
[11] Richardson, K. et al. Climate Risk Report for the Middle East and North Africa (MENA) Region (2021).
[12] Mohammed, S., K. Alsafadi, S. M. N. Mousavi, and E. Harsányi. Rainfall Change and Spatial-Temporal Aspects of Agricultural Drought in Syria In *Water Resources in Arid Lands: Management and Sustainability*, edited by A. Al-Maktoumi et al., 215–221. Cham: Springer International Publishing, 2021.
[13] Kelley, C., S. Mohtadi, M. Cane, and Y. Kushnir. Climate change in the Fertile Crescent and implications of the recent Syrian drought *PNAS* 112 (2015): 3241–3246.
[14] Red Cross Red Crescent Climate Centre. Climate Factsheet: Syria (2021).
[15] Gadain, H., and B. Libanda. Agricultural Water Deficit Trends in Yemen *Atmosphere* 14 (2023).
[16] Davies, R. Thousands Displaced by Floods After Cyclone Tej Dumps 400mm of Rain *Floodlist* (2023).
[17] Odhiambo, G. O. Water scarcity in the Arabian Peninsula and socio-economic implications *Applied Water Science* 7 (2017): 2479–2492.
[18] Bloemendaal, N. et al. A globally consistent local-scale assessment of future tropical cyclone risk *Science Advances* 8 (2022).
[19] Chaplin, D., E. Lovell, and J. Twigg. Intersectional Approaches to Vulnerability Reduction and Resilience-Building (2019).
[20] Neumayer, E., and T. Plümper. The Gendered Nature of Natural Disasters: The Impact of Catastrophic Events on the Gender Gap in Life Expectancy, 1981–2002 *Annals of the Association of American Geographers* 97 (2007): 551–566.
[21] Committee on the Elimination of Discrimination against Women. General Recommendation No. 37 on the Gender-Related Dimensions of Disaster Risk Reduction in the Context of Climate Change (2018).
[22] Smith, F., M. Simard, J. Twigg, M. Kett, and E. Cole. Disability and Climate Resilience: A Literature Review (2017).
[23] Office of the United Nations High Commissioner for Human Rights (OHCHR). Analytical Study on the Promotion and Protection of the Rights of Persons with Disabilities in the Context of Climate Change (2020).

[24] van Boetzelaer, E. et al. "Elderly people in humanitarian crises, a forgotten population: A call for action". *PLOS Global Public Health* 3 (2023).
[25] Platform on Disaster Displacement. Internal Displacement in the Context of Disasters and the Adverse Effects of Climate Change (2020).
[26] Calabria, E., C. Jaime, and B. Shenouda. Anticipatory Action in Refugee and IDP Camps (2022).
[27] Prevention Web. Poverty and inequality as a risk driver of disaster (2021).
[28] Lindersson, S. et al. The wider the gap between rich and poor and the higher the flood mortality *Nature Sustainability* 6 (2023): 995-1005.
[29] Gaillard, J. C., and F. Navizet. Prisons, Prisoners and Disaster *International Journal of Disaster Risk Reduction* 1 (2012): 33–43.
[30] Dziadosz, A. The End of Eden: Climate Change Comes to the Cradle of Civilization *Harper's Magazine* (2018).
[31] World Bank. Gender Data: Iraq (2024).
[32] World Bank. Gender Data: Syrian Arab Republic (2024).
[33] Richardson, K. et al. Climate Risk Report for the Middle East and North Africa (MENA) Region (2021).
[34] World Bank. Gender Data: Syrian Arab Republic (2024).
[35] Arab Barometer. The MENA Digital Divide (2020).
[36] Cleveland, N. Gender Data Must Be the Bedrock of Climate Justice (2023).
[37] Peters, K., L. Weingärtner, P. Mall, C. Balcou, and Overseas Development Institute (ODI). Anticipatory Action in the MENA Region: State of Play and Accelerating Action (2022).
[38] Rentschler, J., M. Salhab, and B. A. Jafino. Flood Exposure and Poverty in 188 Countries *Nature Communications* 13 (2022): 3527.
[39] Red Cross Red Crescent Climate Centre. Climate Factsheet: Iraq (2021).
[40] International Organization for Migration (IOM). IOM Displacement Tracking Matrix: Iraq (2023).
[41] BBC News. Iraq Dust Storm Leaves 5,000 People Needing Treatment *BBC News* (2022).
[42] Rudaw. Kurdistan's Latest News (2024).
[43] European Commission. 2024 Humanitarian Implementation Plan: Iraq (2023).
[44] Barhoum, L., and E. Nalbandian. Unfarmed Now, Uninhabited When? Agriculture and Climate Change in Iraq (2022).
[45] United Nations Refugee Agency (UNHCR) and United Nations Development Program (UNDP). Iraq Country Chapter 2023-2024 In *3RP: Regional Refugee and Resilience Plan 2023-2024* (2023).
[46] World Food Programme (WFP). WFP Provides Immediate Food Assistance to Flood Victims in Iraq *WFP News Releases* (2021).
[47] Office for Coordination of Humanitarian Affairs (UN-OCHA). Global Humanitarian Overview 2023 (2022).
[48] United Nations Environment Programme (UNEP). Iraq Launches National Adaptation Plan Process for Climate Change Resilience (2020).
[49] United Nations Development Program (UNDP). Institutional Survey and Assessment Report on Drought Early Warning System in Iraq (2024).
[50] World Food Programme (WFP) and Overseas Development Institute (ODI). Appendix 2 - Anticipatory Action in the MENA Region: Country Findings Iraq (2022).
[51] Office for Coordination of Humanitarian Affairs (UN-OCHA). Syria Crisis: Northeast Syria Situation Report No. 31 (15 December 2018 – 31 March 2019) (2019).
[52] Rentschler, J., M. Salhab, and B. A. Jafino. Flood Exposure and Poverty in 188 Countries *Nature Communications* 13 (2022): 3527.

[53] Kelley, C., S. Mohtadi, M. Cane, and Y. Kushnir. Climate change in the Fertile Crescent and implications of the recent Syrian drought *PNAS* 112 (2015): 3241–3246.
[54] Bauer-Marschallinger, B., et al. Satellite-Based Flood Mapping Through Bayesian Inference from a Sentinel-1 SAR Datacube *Remote Sensing* 14, no. 15 (2022): 3673.
[55] RICCAR. Arab Climate Change Assessment Report (2017).
[56] Bauer-Marschallinger, B., et al. Satellite-Based Flood Mapping Through Bayesian Inference from a Sentinel-1 SAR Datacube *Remote Sensing* 14, no. 15 (2022): 3673.
[57] Office for Coordination of Humanitarian Affairs (UN-OCHA). Syrian Arab Republic: 2024 Humanitarian Needs Overview (2024).
[58] Shelter / NFI Cluster NW Syria - XB Hub. Shelter & Non-Food Items Cluster Strategy 2024: Northwest Syria Hub (2024).
[59] Al Hajj, T. Droughts Threaten Syrian Pastoral Communities *Carnegie Endowment for International Peace* (2023).
[60] REACH. Briefing Note: Humanitarian Impact of Water Shortages in Northeast Syria (April 2022) (2022).
[61] Kelley, C., S. Mohtadi, M. Cane, and Y. Kushnir. Climate change in the Fertile Crescent and implications of the recent Syrian drought *PNAS* 112 (2015): 3241–3246.
[62] The World Bank. Natural Disasters in the Middle East and North Africa: A Regional Overview (2014).
[63] Food and Agriculture Organization of the United Nations (FAO). FAO's Role in the Syria Drought Response Plan 2009 (2009).
[64] Global Shelter Cluster. Shelter Response Profile: Northwest Syria (2023).
[65] SY Plus (2021) قبب طينية تبنيها أم عبدو لتجعل منها ملاجئ أثناء طوفان المخيمات
[66] Rentschler, J., M. Salhab, and B. A. Jafino. Flood Exposure and Poverty in 188 Countries *Nature Communications* 13 (2022): 3527.
[67] Internal Displacement Monitoring Centre (IDMC). Internal Displacement: Yemen (2024).
[68] Lackner, H., & Al-Eryani, A. Yemen's Environmental Crisis Is the Biggest Risk for Its Future *The Century Foundation* (2020).
[69] World Bank. Arable land (% of land area) – Yemen, Rep (2021).
[70] Office for Coordination of Humanitarian Affairs (UN-OCHA). Yemen Humanitarian Needs Overview 2024 (2024).
[71] Kim, K., et al. Climate, Peace and Security Fact Sheet: Yemen (2023).
[72] Office for Coordination of Humanitarian Affairs (UN-OCHA). Yemen Humanitarian Needs Overview 2024 (2024).
[73] Usmani, M., et al. Combating Cholera by Building Predictive Capabilities for Pathogenic Vibrio cholerae in Yemen *Scientific Reports* 13, 2255 (2023).
[74] Office for Coordination of Humanitarian Affairs (UN-OCHA). Yemen Humanitarian Needs Overview 2024 (2024).
[75] REACH & CCCM Cluster Yemen. Flood Hazard Analysis of IDP Sites in Yemen (2024).
[76] UNHCR. Yemen's 'Marginalized Ones' Endure Hunger, Displacement (2021).
[77] ACAPS. Yemen: Challenges to Housing, Land and Property Rights (2023).
[78] International Organization for Migration (IOM). Desk Review: Report on Migration, Environment and Climate Change in Yemen (2021).
[79] Aklan, M. The Impact of Flooding on Agricultural Communities in Yemen (2024).
[80] World Meteorological Organization. Global Producing Centres of Long-Range Forecasts (2024).
[81] Bacon, J., et al. WISER MENA Scoping Report: Opportunities for Improved Weather and Climate Information in the Middle East and North Africa Region (2022).

[82] Iraq Meteorological Organization. Meteorological and Seismological Information (2024).
[83] Iraqi General Directorate for Meteorology and Seismic Monitoring. About Us (2024).
[84] United States Geological Survey. International Programs: Middle East and North Africa (2024).
[85] Meteo Syria. Facebook Page (2024).
[86] World Bank. Weather, Climate and Water Services in the Middle East and North Africa (2023).
[87] World Bank. Weather, Climate and Water Services in the Middle East and North Africa (2023).
[88] Ministry of Agriculture and Irrigation - Yemen. Official Website (2024).
[89] Arab Center for the Studies of Arid Zones and Dry Lands. Official Website (2024).
[90] Yemen Meteorological Service. Official Website (2024).
[91] Ministry of Agriculture and Irrigation - Yemen. Official Website (2024).
[92] National Water Resources Authority of Yemen. Official Website (2024).
[93] Alley, R. B., Emanuel, K. A., & Zhang, F. Advances in Weather Prediction *Science* 363, 342–344 (2019).
[94] World Meteorological Organization (WMO). WMO Open Consultative Platform White Paper #1 (2021).
[95] Integrated Food Security Phase Classification. IPC Global Strategic Programme 2023 – 2026 (2023)
[96] IFRC GO, Accelerating anticipatory action across the IFRC — a systems approach (2022)
[97] Universität Bonn Center for Remote Sensing of Land Surfaces (ZFL), Using GloFAS for Flood Monitoring: Website Overview (2024)
[98] Famine Early Warning Systems Network. About FEWS (2024)
[99] The International Federation of Red Cross and Red Crescent Societies. EARLY ACTION PROTOCOL ANNUAL REPORT Kenya | Hazard May 2024 (2024)
[100] United Nations Office for Coordination of Humanitarian Affairs (UN-OCHA). *Somalia Anticipatory Action Plan for Drought* (2020).
[101] Guimarães Nobre, G et al. *Ready, set, go! An anticipatory action system against droughts*. *EGUsphere* [preprint] (2024).
[102] Start Network and Welthungerhilfe. *Standard Operating Procedures – Madagascar FBF* (2021).
[103] International Rescue Committee. *With the support of Google.org, the International Rescue Committee and GiveDirectly scale Artificial Intelligence for Climate Resilience* (2024).
[104] World Food Programme. The Food Security and Nutrition Analysis and Mapping (2024).
[105] Famine Early Warning Systems Network. Official Website (2024).
[106] Danish Refugee Council. Predictive Analysis: Foresight Displacement Forecasts (2024).
[107] Global Disaster Alert and Coordination System. Official Website (2024).
[108] Copernicus Emergency Management Service. Global Flood Monitoring (2024).
[109] European Centre for Medium-Range Weather Forecasts. GloFAS Rapid Flood Mapping and Rapid Impact Assessment (2024).
[110] Food and Agriculture Organization of the United Nations. Global Information and Early Warning System (2024).
[111] World Food Programme. Hunger Map (2024).
[112] Integrated Food Security Phase Classification. IPC Information Support System (2024).
[113] Internal Displacement Monitoring Centre. Official Website (2024).
[114] International Science Council. "Peril Classification and Hazard Glossary." (2024).
[115] International Federation of Red Cross and Red Crescent Societies. Risk Watch: Seasonal (2024).
[116] Pacific Disaster Center. Impact Modeling (2024).
[117] Google Research. Flood Forecasting (2024).
[118] University of Southampton. Iraq Hydrology App (2024).
[119] International Organization for Migration. Climate Dashboard - Iraq (2024).

[120] Impact Initiatives. Climate Dashboard for Iraq (2024).
[121] Esri. Interactive Dashboard for Iraq (2024).
[122] Shelter / NFI Cluster NW Syria - XB Hub. Winterization Advocacy Paper 2023-24 (2023).
[123] Start Network. Alert 664 Syria (Anticipation of Storm) (2022).
[124] Shelter / NFI Cluster NW Syria - XB Hub. Winterization Advocacy Paper 2023-24 (2023).
[125] Office for Coordination of Humanitarian Affairs (UN-OCHA). Humanitarian Needs Overview: Syrian Arab Republic (2023).
[126] Office for Coordination of Humanitarian Affairs (UN-OCHA). Anticipatory Action (2024).
[127] International Federation of Red Cross and Red Crescent Societies (IFRC). Yemen: IFRC Network Mid-Year Report, January - June 2023 (2023).
[128] ReliefWeb. Agrometeorological Early Warning Bulletin - Yemen (2023).
[129] Food and Agriculture Organization of the United Nations (FAO). Food Security and Nutrition Information Systems to Enhance Resilience of Rural Households in Yemen (2021).
[130] University of Southampton. Iraq Hydrology App (2024).
[131] Food and Agriculture Organization of the United Nations. Development of National Framework for Integrated Drought Risk Management (DRM) in Iraq (2024).
[132] World Food Programme. Country Overview - Iraq (2024).
[133] UK Met Office. WISER Weather and Climate Information Services (2024).
[134] "INFORM" European Commission. INFORM Warning (2024)
[135] Calabria, E., C. Jaime, and B. Shenouda. Anticipatory Action in Refugee and IDP Camps (2022).
[136] REACH. Northwest Syria: Flooding Susceptibility and Preparedness Survey March 2021 (2021).
[137] Humanitarian Data Exchange. Data Signals (2024).
[138] Milano, L. Data and Models for Forecasting Humanitarian Crisis (2024).
[139] Hoyer Gosselink, B., & Royz, M. How AI Flood Forecasting Can Help Communities in Need *Google: Company News Blog* (2024).
[140] Humanitarian Innovation Hub. Charting the Roadmap for AI Uptake in Humanitarian Action (presentation and panel discussion) (2024).
[141] OCHA: Centre for Humanitarian Data. Briefing Note on Artificial Intelligence and the Humanitarian Sector (2024).
[142] The World Bank. Natural Disasters in the Middle East and North Africa: A Regional Overview (2014).
[143] World Food Programme (WFP). WFP Yemen Country Brief, November 2019 (2019).
[144] Chaves-Gonzalez, J., et al. Anticipatory Action: Lessons for the Future *Frontiers in Climate* 4 (2022).
[145] Baudoin, M-A, et al. From Top-Down to 'Community-Centric' Approaches to Early Warning Systems: Exploring Pathways to Improve Disaster Risk Reduction Through Community Participation *International Journal of Disaster Risk Reduction* 7, 163–174 (2016).
[146] Chaves-Gonzalez, J., et al. Anticipatory Action: Lessons for the Future *Frontiers in Climate* 4 (2022).
[147] Baudoin, M-A, et al. From Top-Down to 'Community-Centric' Approaches to Early Warning Systems: Exploring Pathways to Improve Disaster Risk Reduction Through Community Participation *International Journal of Disaster Risk Reduction* 7, 163–174 (2016).
[148] Habas, J., Sevillano Marco, E., & Miranda, M. The State-of-the-Art on Drought Displacement Modelling (2022).
[149] International Organization for Migration (IOM). DTM Iraq – Drivers of Climate Induced Displacement: Climate Vulnerability Assessment (2023).
[150] Internal Displacement Monitoring Centre (IDMC). No Matter of Choice: Displacement in a Changing Climate (2018).

[151] Diepeveen, S., Bryant, J., Mohamud, F., Wasuge, M., & Guled, H. Data Sharing and Third-Party Monitoring in Humanitarian Response (2022).
[152] United Nations. Early Warnings for All (2024).
[153] Joint Research Centre. JRC Dataset: C5D56E48-42A7-4FFB-AF7B-3F422B987603 (2024).
[154] World Food Programme. ADAM Live (2024).
[155] World Food Programme. Flood Forecast Report: IRQ_FL_Forecast_20240214 (2024).
[156] World Food Programme. Flood Report: ADAM_IDN_FloodReport_20240212 (2024).
[157] Famine Early Warning Systems Network. Topics: Agroclimatology (2024).
[158] Famine Early Warning Systems Network. Global Weather Hazards: March 2024 (2024).
[159] Famine Early Warning Systems Network. Yemen (2024).
[160] Danish Refugee Council. Predictive Analysis: Foresight Displacement Forecasts (2024).
[161] Emergency Events Database. EM-DAT (2024).
[162] Emergency Events Database. Known Issues and Limitations: Specific Biases (2024).
[163] Global Disaster Alert and Coordination System. Models for Disaster Risk (2024).
[164] Global Disaster Alert and Coordination System. Event Report: Event ID 1101927 (2024).
[165] European Commission. Global Floods (2024).
[166] Food and Agriculture Organization. FAO Dataset: 2afba815-0402-400a-bcf8-cf0959f19421 (2024).
[167] Food and Agriculture Organization. Food Prices Research: Detailed Report (2024).
[168] Food and Agriculture Organization. GIEWS Reports (2024).
[169] Food and Agriculture Organization. Country Brief: Syria (2024).
[170] Food and Agriculture Organization. Earth Observation: GIEWS (2024).
[171] Food and Agriculture Organization. FAO Data (2024).
[172] World Food Programme. Hunger Map (2024).
[173] Integrated Food Security Phase Classification. IPC (2024).
[174] Integrated Food Security Phase Classification. IPC Country Analysis: Yemen (2024).
[175] Famine Early Warning Systems Network. Integrated Phase Classification (2024).
[176] Internal Displacement Monitoring Centre. Internal Displacement: Yemen (2024).
[177] Internal Displacement Monitoring Centre. Internal Displacement: Yemen (2024).
[178] International Federation of Red Cross and Red Crescent Societies. Seasonal Risk Watch (2024).
[179] International Federation of Red Cross and Red Crescent Societies. Country Profile: Overview (2024).
[180] International Federation of Red Cross and Red Crescent Societies. Previous Events: Country Profile (2024).
[181] Pacific Disaster Center. Disaster Aware (2024).
[182] Colorado Flood Observatory. Flood Observatory Archives (2024).
[183] University of East Anglia. CRU Data: High-Resolution Gridded Data (2024).
[184] World Resources Institute. Aqueduct Water Risk Atlas (2024).

CONTACT

MICHAEL CHOHANEY
Regional Quantitative Analysis Specialist | Middle East, North Africa, & Europe
mchohaney@mercycorps.org

About Mercy Corps

Mercy Corps is a leading global organization powered by the belief that a better world is possible. In disaster, in hardship, in more than 40 countries around the world, we partner to put bold solutions into action — helping people triumph over adversity and build stronger communities from within.
Now, and for the future.

MERCY CORPS

45 SW Ankeny Street
Portland, Oregon 97204
888.842.0842

mercycorps.org