DROUGHT IN FOCUS

MEACAM Research Report

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MERCY CORPS

Contents

About MEACAM research reports

The Middle East Anticipatory Climate Action Model (MEACAM) is an online platform featuring geographically disaggregated agricultural drought and flood predictions, and estimates of how many people, communities, and IDP camps will be affected. Currently, the Mercy Corps Crisis Analysis-developed platform provides national-level coverage of hazards flooding for Iraq, Syria, and Yemen.

Mercy Corps's MEACAM research report series covers drought and flooding risks and trends in Iraq, Syria, and Yemen, approaches to communicate early warning information in these countries, and the applicability of the information and predictions provided by MEACAM to applied early action and disaster risk reduction efforts. This report focuses on agricultural drought,[1] and presents case studies of affected communities, highlighting both the challenges they faced and their successful adaptation strategies. The report also contains technical information on MEACAM's statistical prediction model and the thresholds used to determine the likelihood of future agricultural drought in Iraq, Syria, and Yemen.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or DG ECHO. Neither the European Union nor the granting authority can be held responsible for them.

Funded by European Union Humanitarian Aid

1 Mannocchi, F. et al, Agricultural drought: indices, definition and analysis 2004

Introduction

Caused by both environmental and human-induced factors, drought events persist over extended periods and affect large areas with varying severity.[1] Drought monitoring typically involves observing precipitation levels, temperature, evapotranspiration, soil moisture, and surface water levels. These indicators can be monitored individually or used to calculate specialized drought severity indices, such as the Standardized Precipitation Index and Palmer Drought Severity Index.

MEACAM is designed to provide geographically disaggregated drought predictions that serve as an early warning to the public, aid actors, and government agencies. Specifically, it predicts the health of cropland, which is linked to agricultural drought, and the effect of meteorological drought on crop growth, soil moisture, and crop yield. Agricultural drought is typically considered the second stage in drought progression – after meteorological drought and before hydrological drought – which are defined in the following box. MEACAM produces one- to four-month projections of cropland health in geographically disaggregated areas[2] and estimates human and material exposure, namely to affected populations and across selected portions of farmland.

Definitions

Drought: A period of abnormally dry weather long enough to cause a serious hydrological imbalance, relative to a given timescale or activity.[3]

Droughts are divided into categories based on at what point in the water cycle the water deficit occurs. Most droughts begin with meteorological drought.[4]

Meteorological drought: Occurs when precipitation (rainfall or snowfall) is below the long-run average for an extended period of time.

Agricultural and/or ecological drought: Crop / plant and ecosystem stress arising from a combination of low soil moisture and evaporation.

Hydrological drought: Precipitation deficits due to low water levels in streams, reservoirs, and lakes.

Drought in Iraq, Syria, and Yemen

The Middle East is characterized by low water availability and high temperatures that could eventually exceed the limits of human habitation, and in some instances already have.[5] Historic drought records are incomplete due to conflict and challenges related to defining and declaring drought. Available data and literature indicates that in the climate change era, drought frequency, intensity, and duration are expected to increase as temperatures rise,

1 UNDRR, Global Assessment Report on Disaster Risk Reduction: Special Report on Drought 2021
2 The area of each hexagon is 38km2.
3 IPCC, "Glossary of terms" in Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation 555–564, Cambridge University Press, 2012
4 Douville, H. et al., "Water Cycle Changes" 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 1055–1210, Cambridge University Press, 2021
5 UN Climate Summit News (COP28), What the IPCC Synthesis Report means for Middle East countries 2023

driving increased water evaporation, soil moisture decline, and water scarcity.[6] Compared to several decades ago, agricultural drought is increasingly severe in Syria and Yemen,[7,8] and more prolonged in Iraq.[9]

The humanitarian impact of drought can be difficult to identify because affected communities often simultaneously face other natural hazards, economic challenges, and conflict. The cause(s) of displacement in particular can be difficult to attribute owing to the slow onset of drought and variety of socio-economic factors that lead to migration.[10] Notably, recent droughts in Iraq, Syria, and Yemen have had adverse impacts on social cohesion,[11] access to water and sanitation,[12] agricultural production and livelihoods,[13] acute food insecurity and malnutrition,[14] and disease outbreaks, including cholera.[15]

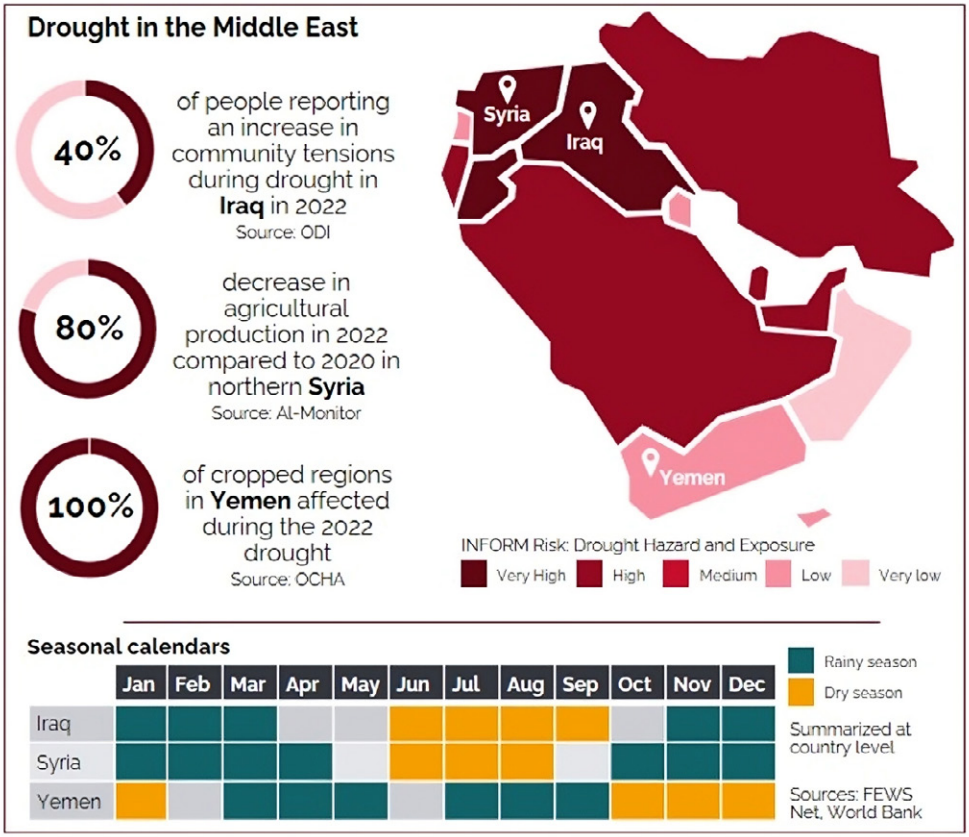


Figure 1. Drought in the Middle East.[16]

6 Richardson, K. et al., Climate Risk Report for the Middle East and North Africa (MENA) Region 2021
7 Mohammed, S. et al., "Rainfall Change and Spatial-Temporal Aspects of Agricultural Drought in Syria" in Water Resources in Arid Lands: Management and Sustainability 215–221, Springer International Publishing, 2021
8 Gadain, H. and Libanda, B., Agricultural Water Deficit Trends in Yemen. Atmosphere 14, 2023
9 Red Cross, Red Crescent Climate Centre. Climate Factsheet: Iraq 2021
10 Internal Displacement Monitoring Centre (IDMC), No Matter of Choice: Displacement in a Changing Climate. Research Agenda and Call for Partners 2018
11 Norwegian Refugee Council, Inadequate and Inequitable: Water Scarcity and Displacement in Iraq 2023
12 REACH, Three Years into the Water Crisis in Northeast Syria: Main Gaps and Adaptation Efforts Going Ahead 2023
13 Office for Coordination of Humanitarian Affairs (UN-OCHA), Yemen Humanitarian Update - Issue 8 - August 2022
14 Integrated Phase Classification, Yemen: Acute Food Insecurity Projection Update October - December 2022
15 Alhaffar, BA. et al., The cholera outbreak in Syria: a call for urgent actions IJID Reg 8, 2023
16 Al-Monitor, Double blow: Syria braces for historic drought after earthquake 2023; FEWS NET, Yemen 2023; European Commission, INFORM Risk 2023; ODI Humanitarian Practice Network, Extreme heat, drought and displacement in Iraq 2023; ReliefWeb, Yemen Humanitarian Update: Issue 8, August 2022 2022; World Bank, Yemen Climate Data: Historical 2023

Country-Level Drought Across Studied Areas

Iraq

Iraq's climate is rapidly changing. Groundwater and rainfall levels continue to decline as the frequency of short and long-term meteorological drought conditions has increased over the past 30 years.[17] This trend is illustrated by the change in vegetation health, measured using the Normalized Vegetation Index (NDVI), during seasons with low rainfall, which is visualized in Figure 2.[18] The map highlights a cluster of districts in northern and central Iraq with a high and very high sensitivity to lower rainfall levels,[19] which likely reflects the predominance of rainfed agriculture in these areas. Notably, NDVI values in districts in Basra were largely unaffected by low rainfall levels because most agriculture in the governorate is irrigated. Regardless, farmers in Basra contend with significant soil and groundwater salinity issues,[20] meaning MEACAM's agricultural drought prediction approach is less suitable for Basra and similar areas than areas where NDVI is more sensitive to rainfall dynamics.

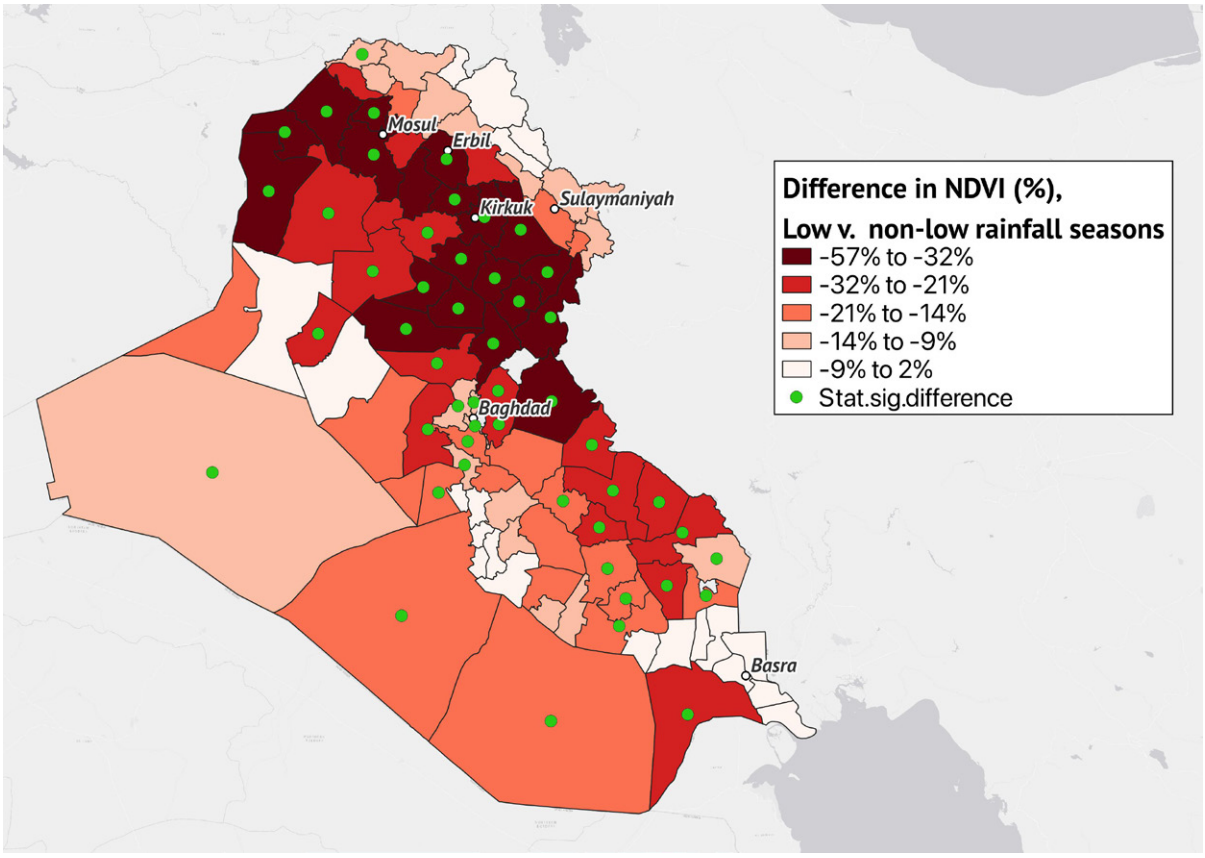


Figure 2. The percentage difference in the maximum NDVI value of winter growing seasons when seasonal rainfall was and was not in the bottom 20th percentile using seasonal rainfall from 2003 to 2024 (n=22). Green dots indicate that NDVI was statistically significantly different in low and non-low rainfall seasons. Areas with greater differences in NDVI are more suitable to the agricultural drought predictions provided by MEACAM. WFP NDVI and WFP rainfall data were used in the analysis, and only calculated for districts with 500 hectares or more of cropland according to the ESA.

17 Ismael, Y. and Awchi, T., Meteorological Drought Analysis in Iraq using SPI and Theory of Runs for the Period 1980-2022 Earth Environ. Sci. 1374, 2023

18 Humanitarian Data Exchange, Iraq NDVI Subnational 2023;Humanitarian Data Exchange, Iraq Rainfall Subnational 2023; Google Earth Engine, ESA WorldCover v200 2023

19 Six districts with data in Ninewa and Salah Al-Din governorates, and all districts (5) with data in Baghdad, Diyala, and Maysan governorates

20 Jabbar, M.T. (2012). Assessment of soil salinity risk on the agricultural area in Basrah Province, Iraq: Using remote sensing and GIS techniques, Journal of Earth Science, 23, pp. 881-91.

Despite the 2023 harvest being comparatively better than previous years, in part due to higher rainfall, this did not result in gains for all farmers.[21] Women-led farming households are still recovering from previous droughts – particularly in southern governorates – prompting many to seek livelihoods outside the agricultural sector and migrate.[22] Figure 3 shows the location and scale of drought-induced displacement in 2023, with some 116,094 people affected across 11 governorates.

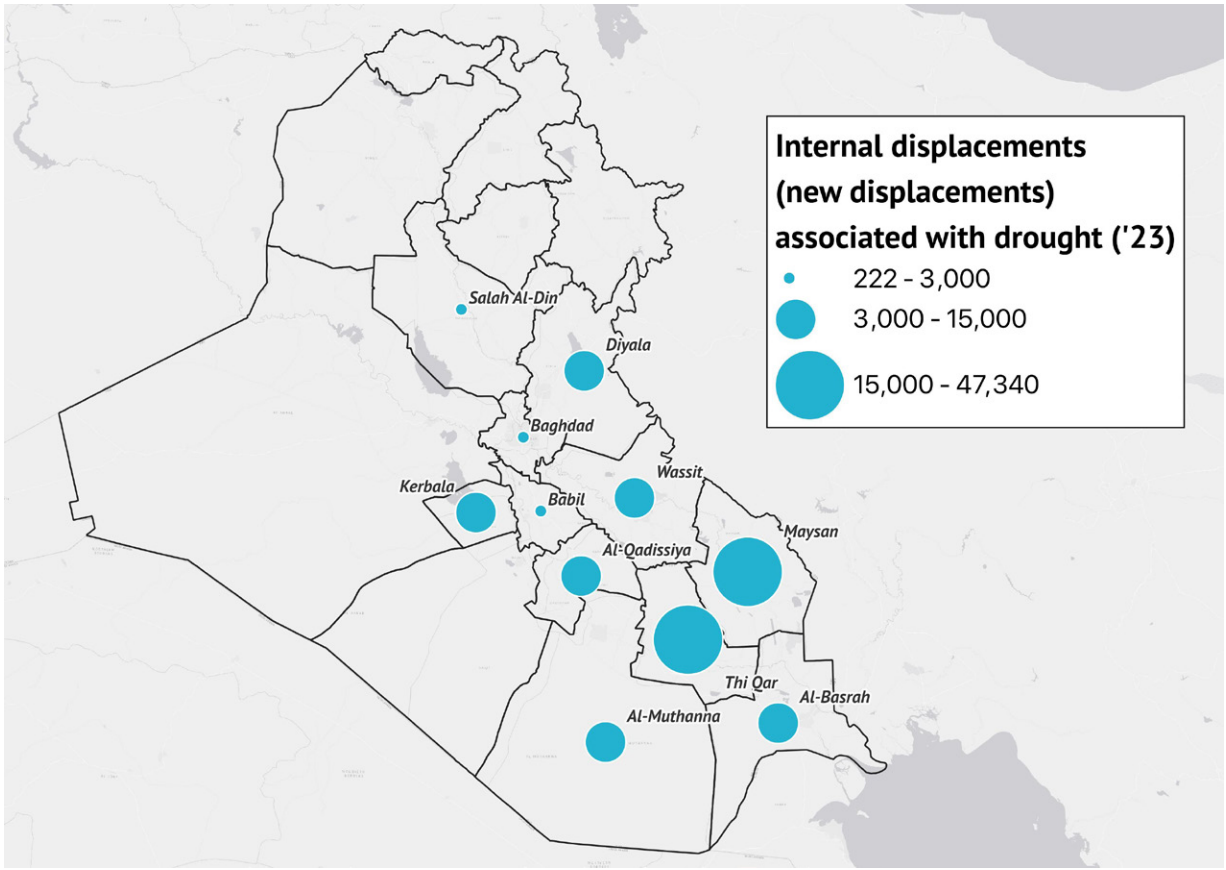


Figure 3. The number of Iraqis displaced in response to drought conditions in 2023. Data obtained from IDMC.[23]

Numerous adaptation approaches have been employed by Iraqi communities contending with agricultural drought, including improving irrigation systems to account for poor and inconsistent rainfall, adopting hydroponic farming methods, and using rainwater harvesting for domestic use and farming. The Federal Government of Iraq also has a 25-year plan for drought management,[24] entailing measures such as establishing desert oases, restoring grazing pastures, promoting the use of drought-tolerant plants, and water harvesting. The Ministry of Water Resources is constructing dams and reservoirs to support agricultural production during dry periods and the Ministry of Agriculture plans to upgrade and construct irrigation systems across 750,000 hectares of land, including deserts, to increase agricultural productivity.

21 Islam, I. and Wilson, T., Extreme heat, drought and displacement in Iraq Humanitarian Practice Network, 2024
22 International Organization for Migration, DTM Iraq – Drivers of Climate Induced Displacement: Climate Vulnerability Assessment 2023
23 Humanitarian Data Exchange, IDMC IDP Data: Iraq 2023
24 Republic of Iraq, Land Degradation Neutrality Target Setting National Report 2019

Climate-related challenges: Basra City

As part of the ACTIVATE program,[25] in 2023, Mercy Corps sought to gain an understanding of climate-related challenges and social cohesion in a selected neighborhood in Basra city. The study drew on a representative sample of the community, from a range of ages and ethno-religious affinities. Participants were asked how large an impact climate change has had or could have on them and their community in the next year to five years.

Which climate-related hazards were of concern?

Among the highlighted hazards were agricultural drought, storms and floods, heatwaves, dust storms, and air and water pollution. Sixty percent of participants said that agricultural drought would have a large (35%) or extremely large (25%) impact on them and their community in the next one to five years.

How do climate-related challenges shape social cohesion?

Concern about drought has a weak, negative relationship with both vertical and horizontal social cohesion. Vertical social cohesion is the relationship between communities and figures of authority whereas horizontal social cohesion is between individuals within a community. Broadly, as participants' concerns about drought increase, the degree to which they feel ties to government officials, and more broadly to members of their community, tend to decrease.

"Perhaps the roots of the problem are the ineffectiveness of laws and the weak role of the environmental police, as well as the weak role of the municipality and the failure to assist the Water Resources Department in maintaining and cleaning the place"

– (Al Manda[26] Peace Campaign Representative) Basra Peace Team

Syria

Syria has contended with several severe drought periods[27] over the past two decades, including the 2009-2010 drought that some assert contributed to the outbreak of civil conflict.[28,29] According to some estimates, over 1.5 million farmers migrated from their communities in search of new livelihoods due to the 2009-2010 drought. Directly linking displacement to drought remains challenging, as households respond to various push factors. However, agricultural drought in Syria has particularly impacted pastoralists, who are traveling further afield to find grazing land, including driving people into areas affected by conflict.[30]

Figure 4 illustrates the difference in NDVI during low-rainfall seasons, identifying northeast Syria as a region highly vulnerable to reduced precipitation. This vulnerability stems from the prevalence of rainfed agriculture in the

25 Under the ACTIVATE program, in March 2023, the study sample consisted of 110 people – both Sabean and non-Sabean – from this neighborhood including 79 men, 28 women, and two who report their gender as "Other". The average age of participants was 26 years, and the ethno-religious breakdown is as follows: 89 Shia Muslims, 10 Sunni Muslims, five Sabeans and one participant was identified as "not religious". ACTIVATE ran from September 2021 – August 2023 in Anbar, Baghdad, and Basra governorates, and was funded under DRL Funding Opportunity SFOP0007617, DRL Democracy, Human Rights, and Rule of Law in Iraq.

26 Al-Manda is the name of Sabean Mandaen Religion adherents in Iraq.

27 These droughts can all be classified as meteorological, agricultural, and to a lesser extent socio-economic, especially the 2009-2010 drought period, due the financial pressure agricultural drought placed on farmers and the unemployment it generated in agriculture-related sectors.

28 Kelley, C. et al., Climate change in the Fertile Crescent and implications of the recent Syrian drought PNAS 112, March 2015

29 Eklund, L. et al., Societal drought vulnerability and the Syrian climate-conflict nexus are better explained by agriculture than meteorology Commun Earth Environ 3, 2022

30 Schwartzstein, P. & Zwijnenburg, W., We Fear More War. We Fear More Drought. How Climate and Conflict Are Fragmenting Rural Syria 2022

area. The map also highlights several districts in Aleppo and Rural Damascus, indicating that agricultural drought risk due to lower rainfall extends beyond the northeast. Nevertheless, the MEACAM platform agricultural drought predictions are particularly valuable for the northeast because of the region's heightened sensitivity to rainfall fluctuations and its role as Syria's primary cereal grain producing region.

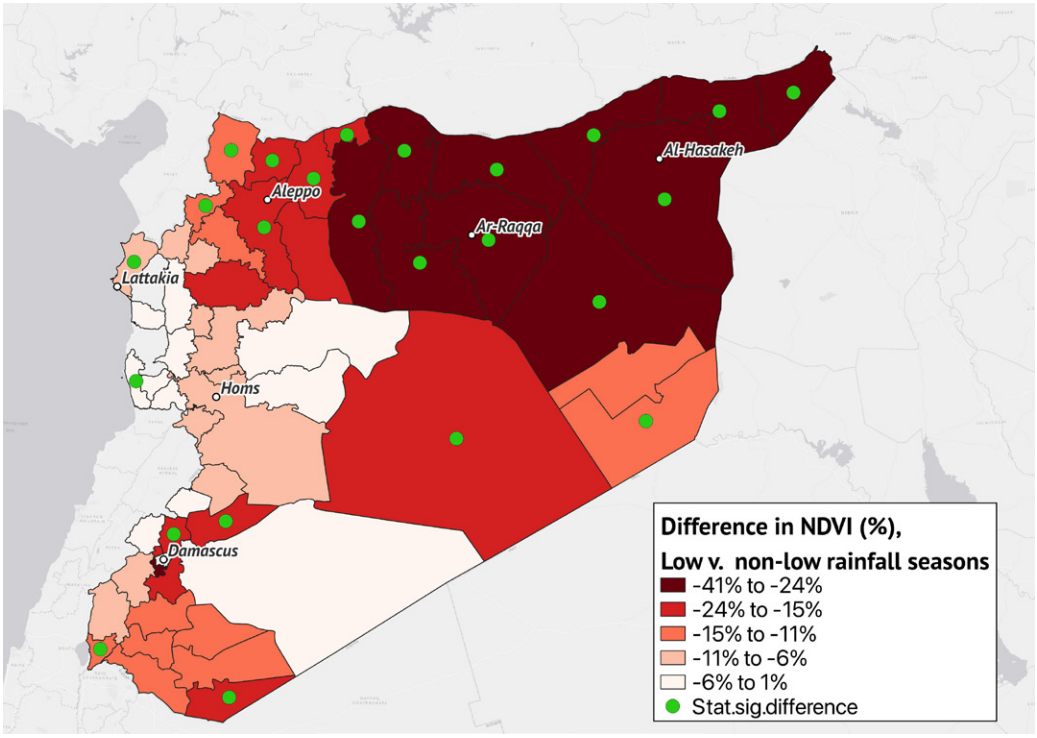


Figure 4. The percentage difference in the maximum NDVI value of winter growing seasons when seasonal rainfall was and was not in the bottom 20th percentile using seasonal rainfall from 2003 to 2024 (n=22). Green dots indicate that NDVI was statistically significantly different in low and non-low rainfall seasons. Areas with greater differences in NDVI are more suitable to the agricultural drought predictions provided by MEACAM. WFP NDVI and WFP rainfall data were used in the analysis from, and only calculated for districts with 500 hectares or more of cropland according to the ESA.[31]

Impacts of drought in northeast Syria, 2022

Mercy Corps measured agricultural production in northeast Syria during the 2018-2022 growing seasons to determine the impact of agricultural drought on agricultural production.[32] Agricultural production in 2022 decreased by 82% compared to the 2020 growing season and 84% compared to the 2019 growing season. Notably, cultivation expanded along the Euphrates, particularly in southern Deir-ez-Zor, over the same period.

Communities reported several coping mechanisms, including delaying planting to preserve seed moisture, selling or renting farmland, and drilling deeper or new wells and boreholes. Drilling is prohibitively expensive for most farmers. In Qamishli, one key informant reported that some villages were using salty water for irrigation, accelerating the process of soil salinization. In Hasakeh, one key informant reported that land used to grow

31 Humanitarian Data Exchange, Syria NDVI Subnational 2023;Humanitarian Data Exchange, Syria Rainfall Subnational 2023; Google Earth Engine, ESA WorldCover v200 2023

32 Mercy Corps Humanitarian Access Team, Measuring Agricultural Production: Drought and the 2018 to 2022 Growing Seasons in Northeast Syria 2022

vegetables on the bank of the Kahbour River is irrigated with sewage-polluted water, and that harvested produce is sold in the local market.

Adaptation in Syria is complicated by conflict – including conflict-induced damage to critical infrastructure – and differing governing structures. Communities employ several rainwater harvesting methods to supply water for agricultural and residential purposes. For example, on sloped agricultural land, fields may be leveled and surrounded by walls (bunds), which facilitate drainage to downslope fields containing crops that can tolerate water logging.[33] Programs such as the Syria Resilience Initiative are also working with communities to implement climate adaptation programs and mitigate the impacts of drought (see below).

The **Syria Resilience Initiative** – led by Mercy Corps, the Cooperative for Assistance and Relief Everywhere (CARE), and the International Rescue Committee (IRC) in partnership with several national organizations – works with farmers to develop new methods to adapt to drought and climate change, including introducing new irrigation methods. For example, Hiba, a farmer and mother of two, uses a solar-powered system to run irrigation pumps and sprinklers. Previously, Hiba used a diesel engine, which in addition to fuel, required maintenance. The solar-powered system covers a larger area, requires less monitoring, and has contributed to an increase in crop yields and household income.[34]

Drought impact on Hasakeh

Agricultural drought nearly decimated wheat production in Syria's agricultural primary grain producing governorate, Hasakeh, in 2021.[35] The regional agricultural sector employs between 50% and 60% of the local population and produces 36% of the country's wheat.[36] Hasakeh's cultivated lands are divided into two categories: rain-fed and irrigated lands. During the 2021 drought, crops grown on rain-fed land largely failed and farmers who utilized irrigation incurred greater operating costs. Figure 5 shows the change in plant water content[37] in northeastern Syria from 2020 to 2021. Hasakeh governorate experienced the most severe drought effects among all governorates over that period, precipitating a decline in vegetation water content.

Decrease in wheat production and high irrigation expenses

Wheat production on irrigated land decreased in 2021 compared to 2019,[38] with farmers harvesting no more than 50 kilograms (kg) per dunam of wheat cultivated compared to 400 kg to 600 kg in previous years. To increase irrigation, farmers purchased more diesel, most of which was sold on the black market at a higher price, in addition to more frequently paying for pump maintenance. Low precipitation levels reduced borehole replenishment, forcing farmers to pay to drill new ones.

Financial costs pushing farmers away from agriculture

Drought and deteriorating economic conditions, namely accelerating Syrian pound depreciation since 2020, increased agriculture sector-related costs. Autonomous Administration of Northeast Syria (AANES) agricultural subsidies have not proven sufficient for farmers, as they provide 20 liters of diesel to fuel irrigation pumps, which is only a fraction of the total amount of diesel needed to irrigate for the entire season. Farmers also assert that the AANES' wheat purchasing price is not high enough[39] to cover their expenses, let alone ensure a profit. The high

33 Mercy Corps, United Nations Children's Fund (UNICEF) and WASH Cluster, Water Harvesting Interventions Catalogue for Syria 2024
34 CARE International UK, World Environment Day: How farmers in Syria are adapting their methods to keep growing in the face of ongoing drought 2024
35 Al-Akhbar, الحسكة خارج موسم القمح: الدعم الحكومي... أو الكارثة August 6, 2021
36 CGTN, مزارعو الحسكة: القوات الأمريكية و"قسد" تعرقلان وصول القمح إلى مراكز تسليم الحبوب التابعة للحكومة السورية June 14, 2022
37 Normalized Difference Moisture Index (NDMI)
38 Enab Baladi, إنتاج دونم القمح في الحسكة لا يتجاوز 50 كيلوغرامًا مناشدات للتعويض May 31, 2021
39 Syrian Observatory for Human Rights, لا تكفي لتعويض تكاليف زراعة الموسم.. استياء شعبي واسع في شمال وشرق سوريا بعد إصدار "الإدارة

costs and low-to-no profits have led many farmers to gradually abandon agriculture altogether and not cultivate their land, which is exemplified by the decrease in cultivated land in Tal Odeh (Hasakeh).[40]

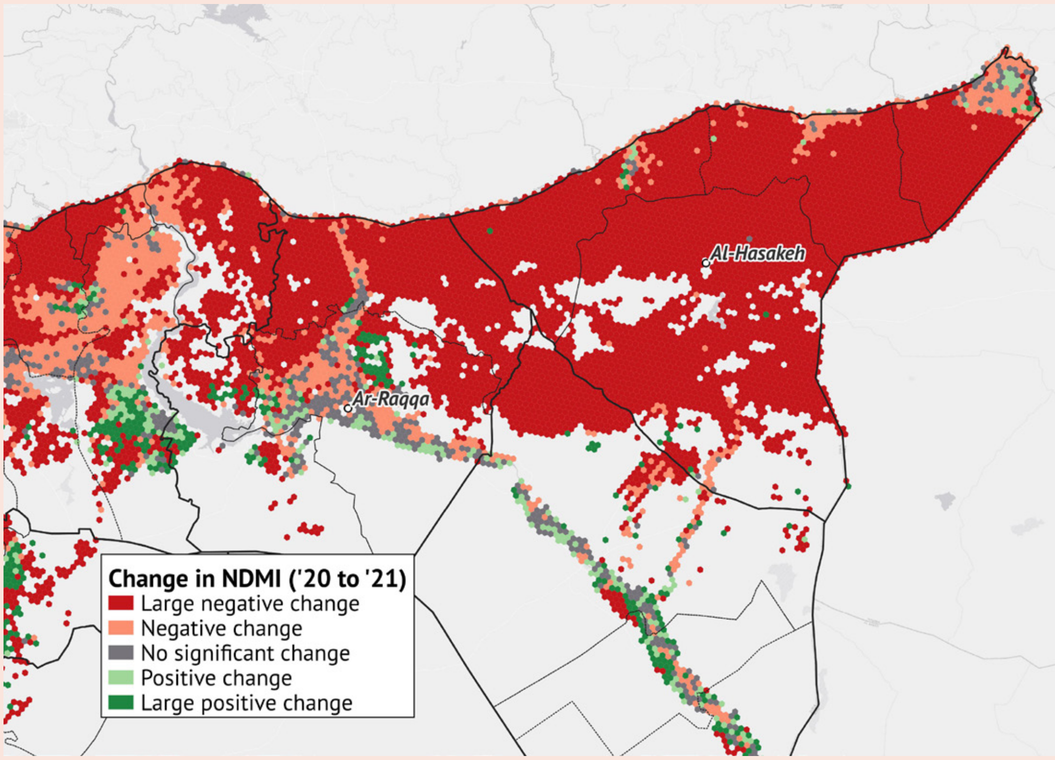


Figure 5. Change in the maximum vegetation water content (NDMI), from 2020 to 2021, in northeastern Syria. Data gathered from the Landsat 8 satellite and only calculated for areas with 100 hectares or more of cropland according to the ESA.[41]

Table 1. Agricultural production in Tal Odeh (Source: Syria Untold).

Year	Cultivated area (ha)	Production per hectare (kg)	Annual production (tonnes)
2019	1100	3000	3300
2020	950	100	1330
2021	980	0	0
2022	900	400	360
2023	500	700	350

Farmers who left agriculture

In June 2024, Mercy Corps interviewed farmers in Hasakeh who no longer work in the agriculture sector about the alternative livelihood sources they have been pursuing, what challenges they have faced, what factors drove them to leave the agricultural sector, and whether they plan to return to the agriculture sector. Interviewed farmers said they were either working as construction workers, Autonomous Administration employees, or opened their own business; one farmer sold six dunams of his land and an old car to buy a truck to sell water in his area.

الذاتية" لتسعيرة شراء محصول القمح May 26, 2024

40 Tal Odeh is located in Qamishli sub-district in Hasakeh governorate.

41 Google Earth Engine, LANDSAT LC08 C02 T1 L2 2023; Google Earth Engine, ESA WorldCover v200 2023

All interviewed farmers said that they left the agriculture sector after production and input (i.e: fertilizer, pesticides) costs began to rise. Fayez, a farmer in Tal Elshayer, told Mercy Corps that his crops are rain fed and that he has no viable option to irrigate them from a borehole; his land has minimal groundwater with a high sodium content, making it neither potable nor suitable for irrigation. The absence of a viable alternative to rainfall to irrigate his crops during the agricultural drought made him lose most of his crops and left him in debt.

Farmers who were able to adapt

Despite contending with myriad drought-related challenges, not all farmers left the agriculture sector. Some farmers interviewed by CA-SYR who continued to cultivate land adopted the following adaptation methods: employing less water intensive cultivation schemes and drawing on unique sources to fund these adaptation methods such as renting land, securing a second livelihood source, and borrowing money from agricultural cooperatives.

Hamza, a farmer from Al-Shadadi, reduced the amount of land that he was cultivating by 25% and switched to non-conventional farming techniques, including drip irrigation. Hamza stopped purchasing diesel after he bought a solar-powered water pump, built large earthen basins to store extracted water, and opted to grow vegetables and cumin instead of other crops because they are more profitable and have a shorter production cycle. Mahmoud, a farmer from Tal Brak, also purchased a solar-powered water pump and greenhouses to cultivate vegetables, which he says are more profitable than wheat in the long-term. Amer, a farmer from Tal Elshayer, installed a drip irrigation system to conserve water, hired an agricultural engineer to supervise insecticide spraying, dug more boreholes, and dug his pre-existing boreholes deeper (from a depth of 45 meters to 70 meters) to increase water availability.

The farmers procured funding necessary to make these improvements through various means. Mahmoud sold some of his livestock, rented a portion of his land, and constructed mud houses with his family to raise additional funds and purchase a solar-powered pump. Hamza reduced his cost of living by cutting unnecessary expenses and took out a USD 1,000 loan from an agricultural cooperative. Amer rented part of his land.

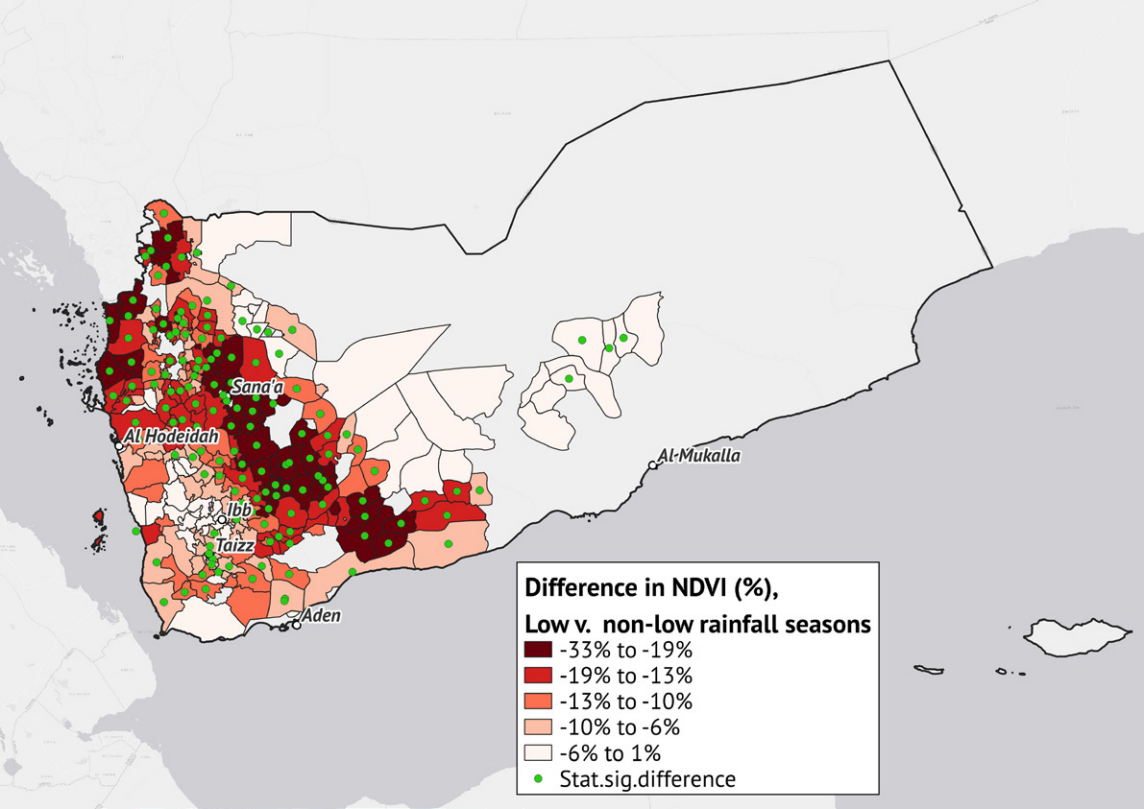
Yemen

Only 3% of Yemen's land is arable, much of which is now affected by desertification and conflict contamination.[42] Drier-than-normal conditions contribute to land abandonment, harvest losses, changed livelihood activities, and increased school dropouts.[43] January 2022 to June 2022 was the third-driest six-month period in Yemen in nearly 40 years, leading to crop losses, rising acute food insecurity, and adverse impacts on livelihoods.[44] Drought impacts were compounded by heavy rainfall during the rainy season, when water could not enter hardened soils, leading to devastating flooding, affecting over 300,000 people by August 2022.[45]

Figure 6 shows the difference in NDVI during seasons with low rainfall and highlights a dense cluster of vulnerable districts in the northern and central highlands. Specifically, over ten and over half of the districts in Amran, Sana'a, and Hajjah were identified as highly vulnerable to rainfall shocks. Small clusters of districts sensitive to lower rainfall levels are also located in the governorates of Al Bayda and Abyan, the northern portion of Yemen's Tihama plain (Hajjah governorate), and central Saadah governorate. Though few districts in

42 Fikra Forum, From Palms to Sands: How Climate Change Is Destroying Green Yemen, 2024.
43 International Committee of the Red Cross, Yemen: Ancestral Honey Production in Yemen at risk due to impact of conflict and climate change 2022
44 Norwegian Institute of International Affairs and Stockholm International Peace Research Institute, Climate, Peace and Security Fact Sheet: Yemen 2023
45 Reliefweb, Yemen: Floods - Jun 2022 2024

Hodeidah – the primary center of production for many crops in Yemen – were highly sensitive to rainfall shocks, the agricultural drought predictions provided by MEACAM are particularly valuable to farmers and aid actors working in the northern and central highlands. In particular, Hajjah and Amran governorates produce 14% and 9% of Yemen's millet and 10% and 4% of the country's sorghum,[46] in addition to the agriculture sector employing a sizable portion of the local workforce.[47]



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Drought and Migration in Wadi Hadramawt

Water demand is increasingly exceeding water availability in Wadi Hadramawt,[49] resulting from a combination of water resource mismanagement, a rapid growth in the number of wells, and a decline in rainfall levels. This depletion has prompted many farmers to sell or simply abandon land that relies on groundwater irrigation.

46 USDA Foreign Agricultural Service, Yemen Country Summary 2023

47 Before the war, the agriculture sector employed 31% of workers in Amran and 39% of workers in Hajjah, according to the ILO's 2013-2014 Yemen Labor Force Survey.
International Labour Organization, Yemen Labour Force Survey 2013-2014 2023

48 Humanitarian Data Exchange, Yemen NDVI Subnational 2023; Humanitarian Data Exchange, Yemen Rainfall Subnational 2023; Google Earth Engine, ESA WorldCover v200 2023

49 van den Berg, H., et al., Water Availability in Yemen: Literature Review of the Current and Future Water Resources and Water Demands in Yemen 2021

A 45-year old farmer from Ghayl Bawazir District, told the the Arab World Press in August 2023[50] that his three and a half acres of land, passed down to him by his father, is no longer productive due to prolonged droughts. The farmer, who has worked on the land for 30 years and has six children, said he is "considering [migrating] from his village due to the threat of the drought" like many before him. Tributaries that he once used to water his land dried up, prompting him to dig a well that sustained his farming for two years before also drying up. Currently his only option is to pay YER 12,000 (approximately USD 45) per hour for irrigation. This is unsustainable, as any potential revenue would not cover the costs of irrigation and seeds.

In Yemen, farmers have employed several methods to address water shortages, including rehabilitating terraces to reduce soil depletion, constructing rainwater harvesting reservoirs, switching to less water-intensive crops such as sorghum, and building bunds to manage water.[51] Traditionally, farmers have relied on spate irrigation, which involves capturing and releasing seasonal floodwaters from riverbeds or wadis to water farm fields. However, conflict-induced damage to spate irrigation systems and increasingly volatile rainfall patterns have reduced the viability of this approach. Farmers have also reverted to using different crops or food sources for their animals, which can have varying impacts on the quality of harvested food products (see case study below).

Honey production and negative coping mechanisms, Wadi Hadramawt

Wadi Hadramawt is world-renowned for its Sidr honey, though climate change is threatening the livelihoods of beekeepers in the region.[52] Lower and irregular rainfall patterns, coupled with high temperatures and conflict have seen honey production decline by 30% to 40% since 2015.[53] Irregular rainfall patterns complicate beekeeper's efforts to find pastoral lands where Sidr trees are flowering during the Spring. Due to conflict, communities have increasingly resorted to felling trees to generate energy, particularly for cooking, which have also contributed to a decline in the number of Sidr trees.

Many beekeepers have been forced to supplement bees' natural diet using bee feed. This approach can negatively impact the quality of honey. Sidr honey can cost up to USD 400 per kilo in international markets.[54] However, if quality is compromised, both demand for and the price of the honey decreases, risking loss of livelihoods for those who rely on the trade.

Using the MEACAM to Predict Agricultural Drought

MEACAM predicts the vegetation health of cropland[55] on a monthly basis using the Normalized Difference Vegetation Index (NDVI).[56] The platform provides predictions for a hexagon grid[57] covering areas of Iraq, Syria, and Yemen with significant cropland coverage.[58] Several explanatory variables[59] were used to predict the NDVI

50 Asharq Al-Awsat, الجفاف يحول أراضي حضرموت الزراعية باليمن إلى صحراء c2023
51 Lackner, H., Yemen's Vulnerability to Climate Change: How to Strengthen Adaptation Sana'a Center For Strategic Studies, 2024
52 Nasher, A. and Al-Muslimi, F., An Ancient Tradition at Risk: Yemen's Beekeeping and Honey Production in Times of War Sana'a Center For Strategic Studies, 2023
53 Albaiti, A., Yemen's Honey at Risk Due to Impact of Climate Change Khuyut, 2023
54 Reuters, Yemen's famed beekeepers feel the sting of climate change 2021
55 The NDVI of cropland as defined by the European Space Agency. Google Earth Engine, ESA WorldCover v200 2023
56 NDVI is a common remote sensing indicator measuring the health and density of vegetation, which is typically used to measure crop health. NDVI was obtained for MEACAM from the MODIS Terra satellite. Google Earth Engine, MODIS 061 MOD13Q1 2023
57 The MEACAM reports predictions at the hexagon level according to H3 global grid system Resolution 6 hexagons, which have an area of approximately 37 km2. H3, H3 Geo 2023
58 Only hexagons with ≥100 hectares of cropland are included.
59 The month prior NDVI, Mean Height Above Nearest Drainage [HAND] (unfiltered); total rainfall over the previous six months; total rainfall over the pre-

using a Cubist regression model covering a period one to four months into the future. Model diagnostics are found in the Annex. The predicted NDVI is compared to the 20-year average NDVI for the predicted month(s) to assess the presence and level of agricultural underperformance. The difference between the predicted and observed 20-year average NDVI are measured using the following two metrics:

1. **NDVI raw difference**: The predicted NDVI subtracted from the 20-year average NDVI of the month.

2. **NDVI proportion difference**: The percent difference[60] between the predicted NDVI and the 20-year average NDVI of the month.

Using these two metrics, agricultural underperformance is classified as follows:

1. Moderate predicted agriculture underperformance

   a) ≤ -0.05 > 0.10 NDVI raw difference - OR -

   b) ≤ -20% > -30% NDVI proportion difference

2. Significant predicted agriculture underperformance

   a) ≤ -0.10 NDVI raw difference - OR -

   b) ≤ -30% NDVI proportion difference

MEACAM uses these classifications to project the likelihood of agricultural drought.[61] Specifically, if multiple months are predicted to be moderately or severely underperforming, then the location is categorized as at-risk of agricultural drought. There are two categories of drought risk: 1.) **Drought Watch,** when agriculture underperformance is projected for 50% or less of the predicted months, and 2.) **Drought Warning,** when agriculture underperformance is projected for more than 50% of the predicted months. For example, for a four-month prediction window, a Drought Warning would be assigned to a location if the predicted NDVI of three or four months falls within either agriculture underperformance categorization, and a Drought Watch would be assigned if the predicted NDVI of one or two months fit in either agriculture underperformance categorization.

Figure 7 shows the MEACAM agricultural drought threshold applied to observed NDVI in Iraq and Syria during the 2021-2022 growing season, which was heavily negatively impacted by agricultural drought. The categorizations are calculated using observed NDVI values from January to April 2022, essentially mirroring a four-month MEACAM prediction window. More importantly, the threshold applied to observed NDVI data identifies districts most impacted by this drought period.[62]

vious three months; soil type ; climate zone. Google Earth Engine Community Catalog, HAND Project 2023; Google Earth Engine, UCSB-CHG CHIRPS DAILY 2023; Google Earth Engine, UCSB-CHG CHIRPS DAILY 2023; ISRIC - World Soil Information, Soil Geographic Databases 2023; Köppen-Geiger, Köppen-Geiger Climate Classification 2023

60 (Predicted NDVI/Average NDVI)-1

61 The presented agricultural drought definition is subject to change over time upon peer review and future research.

62 The districts categorized as at-risk of agricultural drought match the areas that IOM and Mercy Corps' CA-Syria team identified as the most negatively impacted in Iraq and northeast Syria during the 2022 drought. Center for Agricultural Studies, Measuring Agricultural Production 2023; International Organization for Migration, Migration, Environment and Climate Change in Iraq 2023

MEACAM's agricultural drought predictions are most relevant during the growing season for rainfed crops. In Iraq and Syria, there is a single national predominant growing season for rainfed crops – mainly barley and wheat – running approximately from December to May.[63] Therefore, given the MEACAM's four month prediction window, agricultural drought should be closely monitored from December until April, a month before harvesting begins. Yemen features a regional variation of growing seasons.[64] but the following are the primary regions of agriculture production: 1.) the Northern, Central, and Southern Highlands that feature two rainy seasons[65] and where sorghum begins growing in June and is harvested in October, and 2.) the Red Sea Coast and Tihama Plain that features two rainy seasons[66] and where sorghum begins growing in August and is harvested in mid-December.[67]

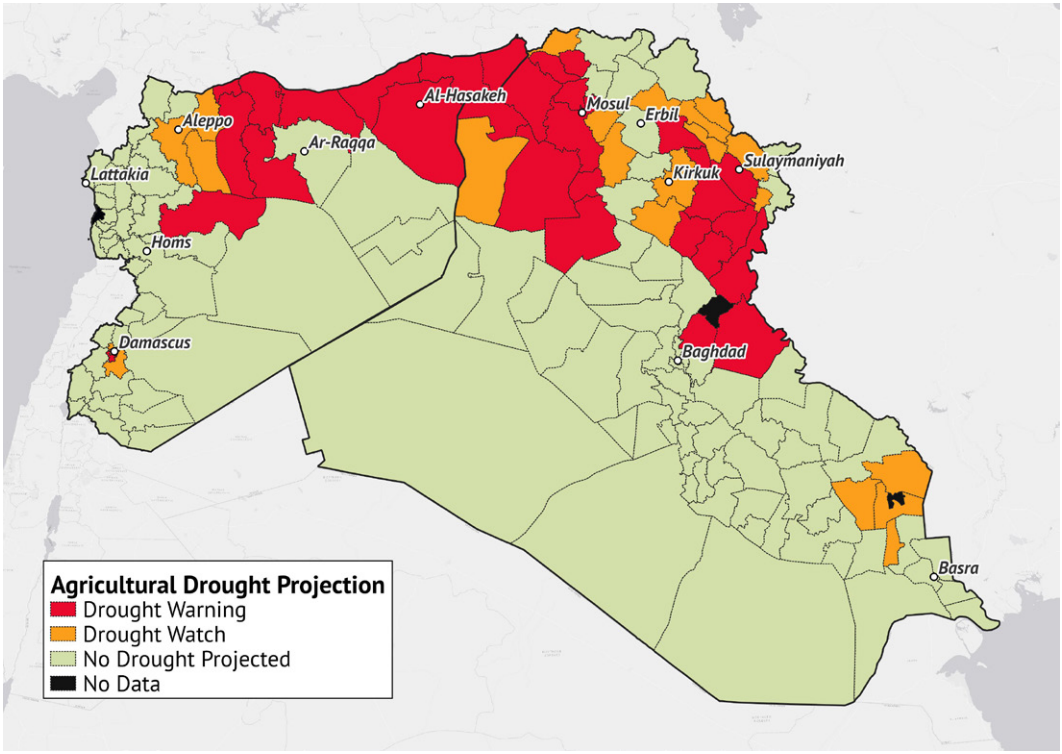

Figure 7. Demonstrative map of the MEACAM agricultural drought thresholds applied to observed NDVI values at the district level in Iraq and Syria from January to April 2022.

Conclusion

Agricultural drought is a major natural hazard in Iraq, Syria, and Yemen and recent trends suggest that the frequency and severity of these events will increase in coming years. This prognosis reaffirms the importance of the MEACAM platform as home for the information necessary to advance early warning and early action

63 The growing season for major rainfed crops in Iraq and Syria vary within this range. According to Syria's crop calendar, barley and wheat begin growing in January but barley is harvested in May while wheat is harvested in June. Similarly, lentils and chickpeas both begin growing in March but lentils are harvested in May and chickpeas are harvested in June. According to Iraq's crop calendar, barley begins growing in December and is harvested in April while wheat, lentils, and broad beans begin growing in January and are harvested in May. Food and Agriculture Organization, Syria Crisis Crop Calendar 2023; Food and Agriculture Organization, About FAO's Data in Emergencies 2023

64 A map of Yemen's agro-ecological zones is available in the Annex (Figure A1).

65 March to May and July to September

66 March to May and July to September, with the latter producing more rainfall (author's calculation)

67 Yemen - Agricultural calendar, FAO Data in Emergencies Hub.

efforts in these three countries. The platform's agricultural drought predictions up to four months into the future are an important contribution towards these efforts, but equally important is MEACAM's flexible architecture that is designed to facilitate collaboration with other actors. Actors that would like to feature static and dynamic geospatial data layers[68] on MEACAM can contact Mercy Corps' MEACAM focal point[69] to begin the process of sharing and loading data.

The MEACAM platform and the drought predictions modules for Iraq, Syria, and Yemen will be publicly launched in March 2025. The four-month drought prediction window offers an ample time horizon on which to base future resource mobilization ahead of an impending agricultural drought, and the current statistical models predict at a satisfactory level of accuracy. The models will be fine-tuned for accuracy before the end of the MEACAM project. Specifically, the planned technical improvements include testing the added-value of using the primary crop water source[70] as an explanatory regression and replacing the NDVI data source from the MODIS satellite with data from Landsat satellites.[71] Lastly, upon MEACAM's release in March 2025, the team will begin to socialize the platform in earnest to ensure that its primary purpose – a home for multi-hazard information – can move toward realization.

68 Static data does not change over time; for example, a vulnerability assessment aggregated by geography. Dynamic data changes over time and may include drought predictions produced by other actors, which can be integrated in the MEACAM platform alongside the existing agricultural drought predictions.

69 Michael Chohaney (mchohaney@mercycorps.org)

70 Irrigated, rainfed, or a combination of both.

71 Google Earth Engine, LANDSAT COMPOSITES C02 T1 L2 8DAY NDVI 2023

ANNEX

Table A1. Cubist regression model diagnostics for two-month NDVI predictions. Diagnostics calculated from mean accuracy of predictions generated for the displayed months in 2022, 2023, and 2024.

Country	Prediction Months		MAE
Iraq	Mar./Apr./May	0.74	0.03
Syria	Mar./Apr./May	0.92	0.02
Yemen	Aug./Sep./Oct.	0.80	0.04

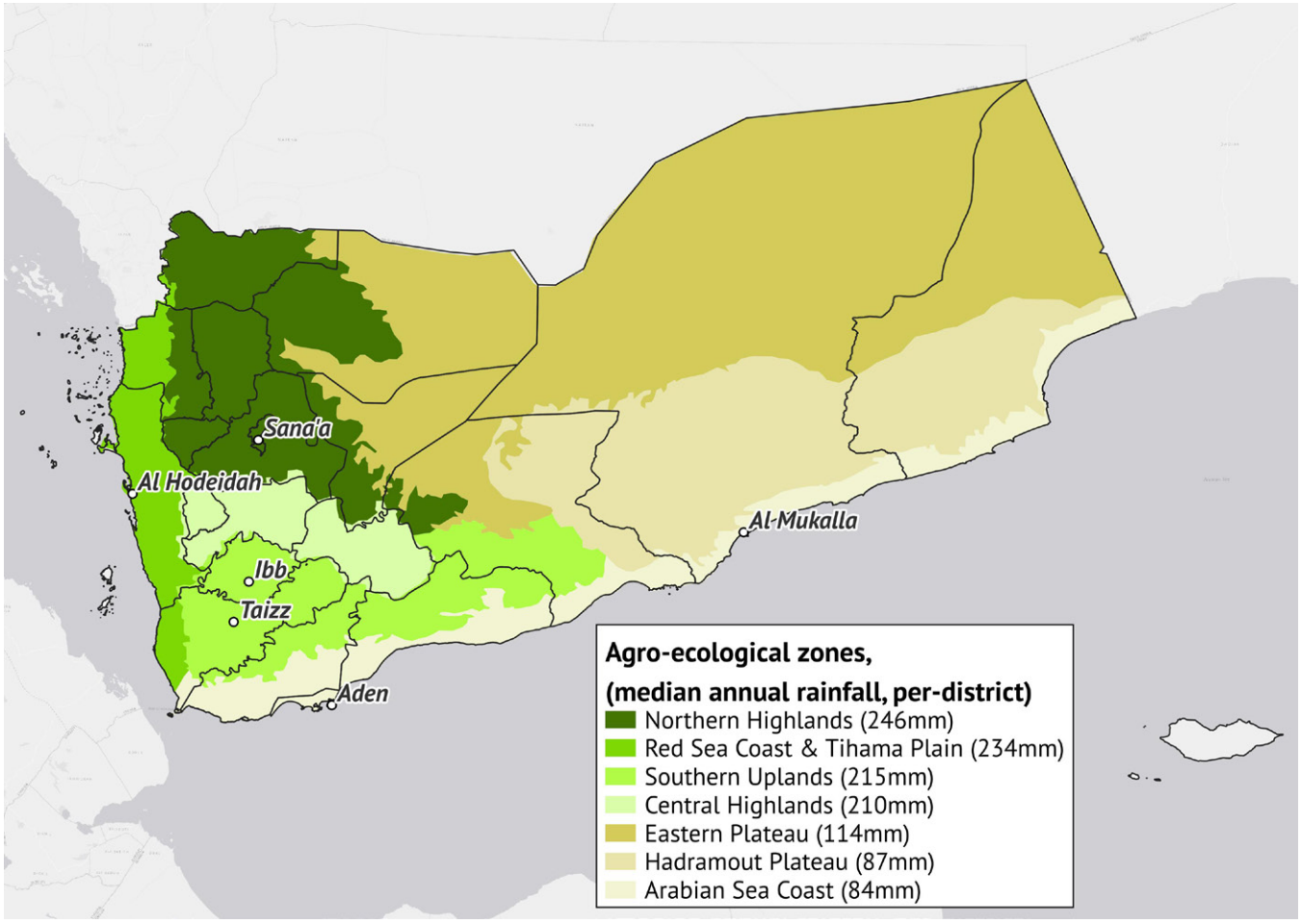

Figure A1. Yemen agro-ecological zones and median annual rainfall per-district. Annual rainfall calculated from January 2004 to December 2024. Agro-ecological zones obtained from FAO and rainfall data obtained from WFP.[72]

72 Humanitarian Data Exchange, Yemen Rainfall Subnational 2023

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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.

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