Technical Fact Sheet
MENAdrought Project

Developing an operational enhanced Composite Drought Index (eCDI) to support drought early warning in the Middle East and North Africa region

Managing drought under a changing climate

Droughts manifest in a variety of ways. Some are 'creeping' events that emerge slowly and last continuously from autumn to spring. Others are 'late onset', occurring only in late winter or the beginning of spring, following a wet or normal autumn and winter. Also, there are 'flash' droughts that begin and end in a matter of weeks, and 'interspersed' events, where wet and dry spells alternate. While some droughts can be relatively benign, others can extend across vast areas and affect millions of people.

Although droughts are cyclical, natural hazards that have occurred for millennia, their severity and ability to cause extensive loss and damage are increasing due to climate change. According to the United Nations Office for Disaster Risk Reduction, there were 338 disasters caused by drought between 2000 and 2019 globally, compared to 263 between 1980 and 1999. The drought of 2010, which killed 20,000 people in Somalia, was among the top ten deadliest disasters between 2000 and 2019.

Having an effective drought monitoring system in place could help authorities to manage water better (*photo*: Pierre Restoul / IWMI).

This publication was made possible through the support of the Office of Technical Support, Bureau for the Middle East, U.S. Agency for International Development, under the terms of Award No. 7200-ME-18-IO-00001. The opinions expressed in this publication are those of the authors and do not necessarily reflect the views of the U.S. Agency for International Development or the United States government.

Experts predict that conditions will become drier and hotter across the Middle East and North Africa (MENA) region as climate change progresses.[1] If preemptive action is not taken, crop yields from rain-fed farming systems could decrease by 30%–50% in the future, with devastating impacts on food security. The MENAdrought project aims to provide Jordan, Lebanon and Morocco (countries in the MENA region) with the tools they need to anticipate, prepare for and mitigate the impacts of drought going forward.

A central part of the work to date has involved developing a satellite- and model-based drought early warning system, which is built around an enhanced Composite Drought Index (eCDI). The MENAdrought project is led by the International Water Management Institute (IWMI), with funding from the United States Agency for International Development (USAID). The eCDI was developed by IWMI in collaboration with the National Drought Mitigation Center at the University of Nebraska-Lincoln, USA, and the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center, USA.

Defining and quantifying drought according to its impacts

Drought is generally characterized by a lack of precipitation over a defined period, leading to a shortage of water. However, there is no universally accepted definition, as different geographical and socioeconomic contexts influence how drought events develop and the resulting effects. Experts, therefore, categorize droughts based on their impacts. A progression of four types of droughts is recognized:

- **Meteorological drought** – when rainfall is lower than expected in a specific area, particularly during the wet season.

- **Agricultural drought** – when a meteorological drought persists to the extent that residual moisture locked in the soil, which is essential for crop growth, is depleted and starts affecting plants.

- **Hydrological drought** – when drought is prolonged beyond a season, and water levels in reservoirs decrease, along with freshwater and groundwater supplies. This could lead to disastrous consequences, including insufficient municipal water provision, negative health impacts, and fires that devastate forests, rangelands and livestock.

- **Socioeconomic drought** – a combination of meteorological, agricultural and hydrological drought that is identified when the lack of access to water affects the supply and demand of goods, such as food grains, forage, fish and hydropower, and starts having a detrimental impact on people's lives.

Understanding when drought is occurring

Satellite-based remote sensing of environmental parameters has been widely adopted globally. Its extensive spatial coverage and regular return periods allow large swathes of land to be monitored frequently. It is, therefore, a highly appropriate method for assessing the onset and magnitude of different types of drought.

Spectral indices, based on signals detected by satellite sensors, are used to quantify the existence and severity of meteorological, agricultural and hydrological drought, primarily by considering how values deviate from the norm. Meteorological drought is assessed through indices on rainfall anomalies and the duration of dry spells; agricultural drought is revealed by data on the progression of vegetation health/stress anomalies and soil moisture content; and hydrological drought is assessed through indices on water levels of lakes and reservoirs, and snow cover. Meanwhile, socioeconomic drought is calculated using changes in economic levels (unemployment, livelihoods, debt, water and food security) and social factors (out-migration, adverse coping strategies).

Developing the enhanced Composite Drought Index (eCDI) for the MENAdrought project

The first step towards developing the eCDI involved collecting climate data from satellites, ground observations and computer models. The data sources for the drought indicators were selected based on data availability and quality, with a timeline going back two decades. This relatively long time series was needed to capture the range of conditions and, in particular, the drought intensity in an area.

The indices chosen are explained below:

- **Standardized Precipitation Index (SPI) – across a three-month accumulation period.** *Data source:* NASA's Integrated Multi-SatellitE Retrievals for Global Precipitation Measurement (IMERG) mission (10 km resolution; half-hourly). SPI is the most commonly used indicator worldwide for detecting and characterizing meteorological droughts. Measuring the SPI across a relatively short time period of three months can help indicate immediate effects, such as reduced soil moisture and diminished flow in smaller waterways.

- **Normalized Difference Vegetation Index (NDVI).** *Data source:* NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) mission (250 m resolution; every five days). NDVI is used to estimate the coverage of live, green vegetation across an area of land to indicate crop health. It works by calculating light reflected by plants. Healthy biomass reflects more near-infrared light, while stressed (important for drought detection) or sparse vegetation reflects more visible light.

- **Root zone Soil Moisture Anomaly (SMA).** *Data source:* NASA's Land Information System modelling framework, with the 7.2 Noah land surface model with multiple parameterization options (Noah-MP), including dynamic vegetation and irrigation scheme options (5 km and finer resolution; hourly). SMA is useful for monitoring the start of the rainy season, drought intensity, planting dates and early warnings of yield losses.

[1] Waha, K.; Krummenauer, L.; Adams, S.; Aich, V.; Baarsch, F.; Coumou, D.; Fader, M.; Hoff, H.; Jobbins, G.; Marcus, R.; Mengel, M.; Otto, I.M.; Perrette, M.; Rocha, M.; Robinson, A.; Schleussner, C-F. 2017. Climate change impacts in the Middle East and Northern Africa (MENA) region and their implications for vulnerable population groups. *Regional Environmental Change* 17(6): 1623–1638. https://doi.org/10.1007/s10113-017-1144-2

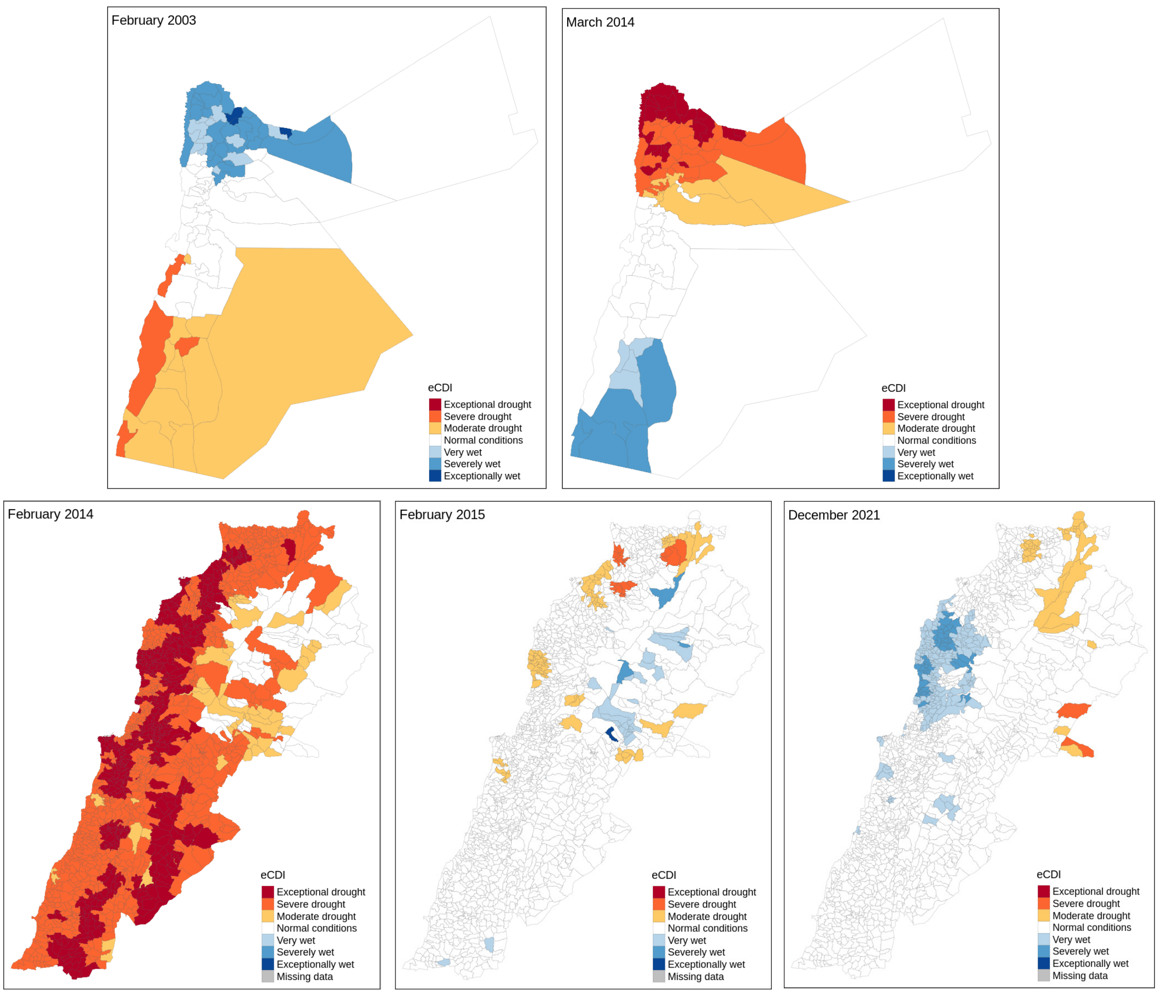
• **Day/night Land Surface Temperature (LST) amplitude anomaly.** *Data source:* NASA's Land Information System modelling framework, with the 7.2 Noah land surface model with multiple parameterization options (Noah-MP), including dynamic vegetation and irrigation scheme options (5 km and finer resolution; hourly). LST can be used as a proxy for evapotranspiration and soil moisture.

To produce the eCDI, these indicators were normalized and weighted as follows: SPI - 3 months (40%); NDVI (20%); SMA (20%); and LST (20%). The historical data made it possible to assess current conditions against events that had occurred during the past two decades. The eCDI was ranked into percentiles related to the frequency with which droughts of different severities had occurred in the past. A contemporary drought falling below the 2% percentile was ranked in the eCDI as an exceptional drought; conditions in the 2%–10% range were ranked as a severe drought; and a drought event falling between 10% and 20% was deemed a moderate drought. These equate to the probability of an exceptional, severe and moderate drought event occurring every 50, 20 and 10 years, respectively.

The eCDI in operational use

When the system is in operation, eCDI values for each 5 km pixel are categorized as 'no drought', 'moderate drought', 'severe drought' or 'exceptional drought', in relation to their percentile value. Monthly drought maps are produced within eight days of the new month, with most of this process requiring a single piece of software – rather than needing numerous steps across programs and modelling frameworks. By providing a means to detect current conditions that can be a precursor to severe drought later in the growing season, these maps are a crucial early warning system.

Jordan, Morocco and Lebanon each experience a rainy season, at the start of which rain-fed crops are planted. This season generally starts between September and December – depending on the country – and ends between March and May. However, rainfall is becoming less predictable due to climate change. Examining data from the satellite drought maps enables users to identify the onset and progression of drought relative to the crop growth stage in the growing season. First, if early rainy season precipitation falls below the norm, this will be evident through a lower-than-usual precipitation signal in the eCDI. Second, if this meteorological drought progresses, the soil moisture signal will also fall below the average. Having an adequate level of soil moisture at key crop growth stages of the season is critical for crop health and development. If the deficit of soil moisture drops to the extent that it begins to affect vegetation and crops, causing an agricultural drought, this will be apparent through the NDVI and the actual evapotranspiration approximated by the day/night LST anomaly in the eCDI as the season progresses. If the drought continues beyond the usual agricultural/hydrological season, it becomes a hydrological drought, with impacts on the overall water budget of river basins and the country. These various stages of drought will have an impact on water resource availability, crop yields, irrigation water requirements, and water and food security.



Maps produced by the enhanced Composite Drought Index (eCDI) showing drought and wet conditions in Jordan (top) and Lebanon (bottom).
Source: Maps created by Karim Bergaoui, IWMI.

Presently, users can download the satellite map data files and undertake their own analyses to verify the presence and progression of drought. However, the MENAdrought project team is also developing thresholds that can automatically trigger responses. This will enable water and agricultural managers and policymakers to be better prepared for drought. Specifically, they will be able to define and implement well-considered drought action plans, including mitigation measures, based on scientific evidence. The drought early warning system is being put into operation within relevant ministries to create long-term sustainability beyond the project life cycle.

Validating the eCDI

It is important that the eCDI is as accurate as possible; droughts are notoriously difficult to identify and characterize in countries that are already experiencing dry weather. To test the eCDI's ability to detect the impacts of drought on rain-fed and irrigated agricultural and water systems, the MENAdrought project team and national partners evaluated the eCDI as a whole, and individual indices, in multiple ways. These included the following:

- Comparing eCDI outputs with available ground observation data (quantitative validation of eCDI components, mainly rainfall).
- Examining the relationship of the eCDI outputs and those of individual indices with anomalies in primary and secondary rain-fed cereal production (retrospective analyses of past droughts).
- Qualitatively assessing the eCDI's performance with key stakeholders (evaluating current conditions using the perceptions and expertise of regional validators, including the network of 37 Regional Departments of Agriculture Validators of the Directorate of Strategy and Statistics at the Ministry of Agriculture, Fisheries, Rural Development, Water and Forests, focusing on 79 rangeland zones across Morocco).

Government agencies in the project countries were particularly interested in how the eCDI's outputs correlated with rain-fed cereal production and yields, and also how the eCDI results compared to the SPI alone when assessing these correlations. The analyses (where possible) showed that the eCDI was more highly correlated with cereal production and yields than the SPI alone, and that the satellite-derived precipitation information compared favorably with observation data.

Project	MENAdrought
Participating countries	Jordan, Lebanon and Morocco
Timeframe	August 2018 - September 2022
Donor	United States Agency for International Development (USAID)
Partners	**International:** International Water Management Institute (IWMI); National Drought Mitigation Center, University of Nebraska-Lincoln; National Aeronautics and Space Administration (NASA) Goddard Space Flight Center; and John Hopkins University. **National points of contact:** *Jordan:* Ministry of Water and Irrigation *Lebanon:* Ministry of Energy and Water *Morocco:* Directorate of Strategy and Statistics at the Ministry of Agriculture, Fisheries, Rural Development, Water and Forests in collaboration with the river basin agency (ABH) of Souss Massa
For more information	Project website: https://menadrought.iwmi.org
	Contact: Rachael McDonnell, Deputy Director General - Research for Development, IWMI (R.Mcdonnell@cgiar.org)

USAID FROM THE AMERICAN PEOPLE
IWMI International Water Management Institute
University of Nebraska Lincoln
NASA
Published: March 2022