Drought monitoring for a stable society

Equipping governments to identify and prepare for extreme weather before it strikes has wide-reaching implications, both economically and socially

Droughts can have dire economic, social and political consequences. Throughout history, issues surrounding water security have been clearly linked to national security challenges, including civil unrest, conflict and war. As such, the timely and accurate monitoring of drought is imperative to mitigating these challenges on both regional and global scales.

Drought-induced crop failure creates water insecurity which can develop into national security crises. Drought reduces crop yields, which can decrease market supply and increase the price of food, eroding household food security. Notably, the Arab Spring, a period of violent anti-government protests during 2011 in the Middle East and North Africa, coincided with surges in the UN Food and Agriculture Organization's global food price index.

While the causes of the Arab Spring and other periods of public uprising are complicated, there is growing evidence to suggest that high food prices play a contributing role. Early drought detection and monitoring efforts can play a decisive role in effective crop supply management in order to stabilise foods prices and abate social unrest.

Considering that droughts vary greatly in duration, severity, and complexity, management efforts must be tailored to the affected region and are contingent upon timely access to information. However, in the absence of sophisticated monitoring efforts, identifying and managing extreme weather events, such as drought, can pose substantial challenges for policymakers.

Research suggests elevated food prices may have contributed to civil unrest during the Arab Spring of 2011

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In the 1980 coup d'etat in the Republic of Upper Volta, now Burkina Faso, drought-induced famine triggered widespread social unrest, and ultimately, regime change. The decade running up to the coup was the driest on record for the Sahelian region of northern Africa, and Burkina Faso is highly sensitive to drought given that a third of GDP and 80% of its population depend on rain-fed agriculture for their livelihoods (according to USAID).

Notably, Burkina Faso is particularly dependent on cotton, a water-intensive cash crop that exacerbated the impact of this drought. At the time, traditional drought monitoring methods produced an inaccurate understanding of the weather patterns in the region, hindering drought management efforts.

Moreover, the agrarian nation did not have the information necessary to anticipate the length and severity of drought and as a result, many human and livestock lives were lost to famine.

Monitoring methods

Traditionally, drought monitoring methods have relied on ground-based weather stations, which directly record precipitation, humidity, temperature and other meteorological data. Using such methods, information about a drought's spatial extent and severity is limited by the distribution and density of the weather station network. Furthermore, these networks often suffer from inconsistencies between stations such as differing instruments, record lengths, and accuracy issues.

Advances in satellite remote sensing (RS) have improved our ability to monitor drought onset, severity, and duration with improved spatial and temporal resolutions, including for regions that are inaccessible or otherwise poorly covered by on-ground stations. Furthermore, RS data is usually made available online and in near real time, offering significant time, cost and labour savings compared to traditional drought assessments.

Hundreds of earth observation satellites now exist, which carry a diverse range of RS sensors including multispectral/hyperspectral electromagnetic spectrum sensors, laser altimeter, and active microwave sensors. Earth scientists can use satellite-derived data to monitor vegetation health, as well as vegetation stress conditions such as precipitation, surface temperature, soil moisture, groundwater and evapotranspiration (the transfer of water and energy from a plant to the atmosphere).

Understanding drought precursor conditions is fundamental to effective and timely emergency response, such as a regional call to harvest early.

Different plants emit unique spectral signals based on how they absorb and re-emit the sun's energy across different electromagnetic wavelengths. By detecting these spectral signals, RS enables scientists to distinguish between plant species and make inferences about health and growth cycle stage.

Spectral satellites — including MODIS and Landsat — orbit the earth, repeatedly measuring the reflectance of thousands of land-surface pixels. The Normalised Difference Vegetation Index (NDVI) is the most common vegetation index used to analyse plant health. The NDVI considers the relationship between a plant's red and near-infrared (NIR) signal and can thus infers the plant's condition. The degree to which the value diverges from the historical average for that month indicates the level of drought severity.

Despite the popularity of the NDVI and other vegetation indexes, several studies have highlighted the lagged response of vegetation to drought conditions. So, while vegetation indexes provide useful information about the severity and duration of a drought, they are not as helpful for predicting the onset of droughts themselves. For this reason, the observation of drought precursor information can be insightful, most notably precipitation and surface temperature data.

Using RS technologies, policymakers are poised to mitigate the impacts of drought through the development of timely and well-informed drought management strategies.

USAID's Famine Early Warning System Network (FEWS NET) uses RS to support early drought detection for sub-Saharan Africa, Afghanistan, Central America and Haiti. Using a combination of vegetation stress indicators, vegetation health indexes, and weather modelling, FEWS NET detects the early signs of drought and forecasts the corresponding implications on a regional scale. The monitoring network uses this data to forecast food supply issues and regional food insecurity. With this information, policymakers can

For regions dependent on agriculture, droughts can have serious social and economic consequences

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plan for drought by managing the related agricultural consequences.

Similarly, the United States Department of Agriculture also uses RS to inform its Drought Early Warning Systems (DEWS). DEWS equips policymakers with early warning signs, and aims to support informed local decision-making regarding the management of water resources during droughts . By developing an early drought management strategy, policymakers can increase regional drought resilience by mitigating the economic and social losses associated with drought.

Climate change is expected to shift global weather patterns in a way that is spatially and temporally dynamic, and this is likely to profoundly disrupt traditional agricultural systems. As a result, it is critical that policymakers understand how regional drought susceptibility will evolve as a result.

As temperatures rise and rainfall declines, many regions will be increasingly susceptible to periods of drought. For many regions with growing populations and a dependence on agriculture, a drier climate could confer serious social and economic consequences. In order to understand the shifts associated with a changing climate, sophisticated drought modelling will be essential for the predicting, understanding and management of drought. ✛

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