Among natural hazards, droughts have hit agriculture the worst in the past decades. These streaks of unusually dry weather driven by insufficient rainfall and high temperatures are getting more frequent and intense globally: for example, drought impacts on European crop production nearly tripled in the past 50 years. Drought-affected croplands lack soil moisture, which is crucial to crop development. The grave consequences aren't long in coming: reduced crop vitality and decreased leaf water content and chlorophyll content are observed.

This ultimately affects photosynthetic activity and changes the spectral signature of plants, i.e. water-stressed crops reflect, absorb, and scatter the solar radiation energy differently than healthy crops would. Therefore, remote sensing vegetation indices derived from satellite images (e.g. NDVI) are increasingly used as a tool for drought analysis and as an input variable in the development of comprehensive drought indices.

The Role of Vegetation Indices in Agricultural Drought Monitoring and Management

Remote sensing indices have found their way into core industries, enabling multiple practical applications beyond scientific research. The widespread utilization of NDVI in precision agriculture is one example of how Earth observation data and vegetation indices assist in crop monitoring, management, and sustaining adequate crop production.

As said above, agricultural drought is a situation when soil moisture levels drop to a point when they can no longer meet the water requirements of growing plants. The effects it has on plants, such as leaf wilting, stunted growth, etc. can therefore serve as valid indicators of the drought onset (alongside subnormal precipitation, surface water deficits, soil moisture lack, and increased evapotranspiration) and be identified using a wide array of vegetation indices.

By utilizing satellite measurements in several regions of the spectrum (visible, near-infrared, shortwave-infrared) to assess vegetation health, photosynthesis activity, soil moisture, and other plant growth-related parameters, we can remotely detect, monitor, and estimate the severity of droughts over large areas. Satellite-derived insights into the state of droughts empower smarter decision-making in terms of water resource planning and irrigation management, and, on a national level, can help prevent extreme food shortages induced by massive crop failure.

Best Indices for Drought Management

Remote sensing indices derived from different Earth observation datasets offer a cost-effective, spatially and temporally scalable solution for drought management based on vegetation and soil assessment. The available index set is characterized by great variability in terms of spectral bands utilized, calculation complexity, and, predictably, some ratios perform better in certain use cases. Let's explore the most widely applied indices that have proven their efficiency in drought-related scenarios.

NDVI-Based Drought Monitoring

The Normalized Difference Vegetation Index (NDVI) has been key to assessing plant health and vigor – a signature ability that's been commonly used in identifying and measuring vegetation response to drought disturbances.

The ratio works by comparing the amount of reflected visible red and near-infrared light to deliver a value between -1 and +1. Based on NDVI values interpretation, we can differentiate between healthy, actively photosynthesizing foliage (absorbing most of the visible red light and reflecting near-infrared light) and unhealthy plants (having higher reflectance in the red band). Lower NDVI values may signal the presence of drought-stressed plants and allow for detecting agricultural drought occurrences at their onset.

VCI as Extreme Drought Indicator

The Vegetation Condition Index (VCI) utilizes NDVI minimum and maximum values observed in a given ecosystem over many years to minimize the influence of spatial index variability across different landscapes and climates. The values range from 0 to 100, decreasing in proportion to vegetation cover vigor.

VCI tends to outperform the Normalized Difference Vegetation Index in identifying water-stressed vegetation that could be a sign of ongoing drought events. It has proven most efficient for detecting severe droughts and less failproof with hydrometeorological hazards of low to moderate intensity.

TCI for Temperature-Related Drought Detection

The Temperature Condition Index (TCI) was developed in recognition of the vital link between in-situ temperatures and vegetation conditions that can be of use in drought monitoring. TCI functions similarly to VCI, utilizing the minimum and maximum land surface temperatures (LST) derived from thermal infrared bands over long observation periods.

Such temperature data can serve as a proxy for estimating evapotranspiration rates, plant water stress, and soil moisture, thus enabling the detection of vegetation suffering from temperature-related stresses. The index values fall between 0 and 100; the higher the TCI values, the greater the possibility of soil moisture deficiencies caused by extremely high temperatures.

VHI Enabling an Array of Drought Applications

So far the Vegetation Health Index (VHI) has shown the greatest potential for drought studies, compared to the results of NDVI drought monitoring and other ratios. This composite index joins a pair of above-mentioned indices – VCI and TCI – to account for both vegetation conditions and thermal vegetation conditions throughout the period of interest.

VHI has been successfully applied to detect droughts, estimate drought severity and duration, as well as develop early warning systems. Currently, it is a standard drought monitoring product provided by NOAA every week.

Case Study: Monitoring Droughts in Iowa from Satellites

Long gone are the days when manual NDVI calculation was the only available option. Thanks to the rapid advancement of computing and data-storing powers, we have acquired the ability to run such analyses within seconds through various digital tools. EOSDA Crop Monitoring developed by EOS Data Analytics is one example of a comprehensive satellite-powered platform that integrates data from multiple sources and offers tools for its analysis and visualization. Thousands of users have leveraged its vast capabilities in a range of vegetation-related applications, including drought scenarios.

In the past few years, droughts in the U.S. corn production powerhouse, Iowa, have gradually increased in duration and intensity as a precursor of the coming crop growth challenges. To maintain high productivity during the longest dry streaks, growers need to factor several key factors into their management strategies – such as precipitations, daytime and nighttime temperatures, soil's water-holding capacity, and groundwater table – all of which determine the availability of soil moisture, the main prerequisite to adequate plant growth.

For these purposes, several key features of EOSDA Crop Monitoring proved to be of most use. The generated NDMI (Normalized Difference Moisture Index) – an index better suited for vegetation water content assessment than the NDVI map – revealed the dynamics of changes in crop moisture content, enabling the assessment of soil's water-holding capacity. The NDRE (Normalized Difference Red Edge) index analysis confirmed the absence of stressed vegetation, that would otherwise indicate a possible water stress or nutrient deficiency.

Additionally, detailed historical weather data graphs provided an overview of daily and accumulated precipitation in the region, attesting to the presence of sufficient soil moisture despite the lack of recent rainfall, and overnight temperatures that were cool enough to keep soils humid.

Given the growing intensity and frequency of heat waves, dry spells, and other weather phenomena contributing to prolonged droughts taking a toll on the agricultural sector, various vegetation and drought indices extracted from satellite imagery prove indispensable in the early detection and monitoring of droughts globally. The retrieved insights enable a better understanding of this natural hazard and a proactive approach to mitigating its effects.