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Monitoring Drought in Arizona

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Introduction

Drought is a normal part of climate variability. It is a slow-moving phenomenon moving across space and time which is often difficult to define or identify. The definition of drought is often related to how drought affects someone or something. Climatologists or weather professionals may define drought by the amount of accumulated precipitation. Agriculturists may define it by how it affects their crops or pastures. Hydrologists may define drought by how much snowpack or reservoir levels. Fundamentally, drought can be summed up as when water availability does not meet water demand.

There are different types of drought (i.e. meteorological, agricultural, hydrological, and ecological) and they occur at different temporal and spatial scales and with varying intensity (NDMC, 2018). Opinions vary regarding the definition of short-term drought and whether it spans a certain number of months or across numerous growing seasons. Similar debates occur in defining long-term drought.

Monitoring drought in Arizona is particularly difficult due to a variety of factors. These include an arid climate, seasonality in precipitation (i.e. winter versus summer precipitation) and high variability in timing, intensity and amount. Another factor making identification of drought difficult is a sparse network of rain gauges for data collection. Official rain gauge networks are typically dense near large population centers but relatively sparse in rural areas. In order to overcome missing data caused by a lack of official gauges, careful interpretations must be made through existing drought tools and indices based on gridded data produced through statistical interpolations (Weiss and Crimmins, 2016).

The U.S. Drought Monitor (USDM) is the official, operational synthetic drought monitoring product in the United States. A unique characteristic of USDM is that it is not a statistical model. It would be difficult to use a statistical model due to the differences in definitions, time scales, intensities, etc. While numeric inputs are many (i.e. Palmer Drought Severity Index, Standardized Precipitation Index, Normalized Difference Vegetation Index, etc.), the USDM relies on local and regional experts to synthesize the best available data from models and other sources including local observers to interpret the information (NDMC, 2018). Experts use observational data from local observers using platforms such as the citizen science project, Community Collaborative Rain, Hail & Snow Network (CoCoRaHS), to inform their interpretation and make recommendations to the USDM. Perhaps more an art than a science, identifying drought before it intensifies can reduce impacts and save money. Drought causes losses to agriculture and often negatively affects domestic water supply, energy production, public health, and contributes to wildfire (NDMC, 2018).

The objective of this bulletin is to help those interested in drought monitoring understand how and the types of data used to inform USDM authors. For more information about what the USDM is, please see The U.S. Drought Monitor, AZ0637. And for more information about financial options during drought, please see Financial Options for Livestock Producers During Natural Disasters, AZ0824.

Drought Tools and Indices

Precipitation

Naturally, a prolonged lack of precipitation is considered a key indicator of drought. However, all forms of precipitation are not equal. Precipitation can fall as rain, snow, sleet, or hail. Precipitation is highly variable with respect to accumulation, timing, frequency, intensity, and spatial heterogeneity, each having inherent agricultural and ecological implications.

In reality, total annual precipitation accumulation does not necessarily correlate to agricultural and ecological conditions. For example, it is not an impossible situation for an area that receives 6″ of precipitation annually to receive half the annual total in a single, intense, event or a couple events over a few days. Most of this precipitation is likely to become runoff. Although this may be beneficial in filling reservoirs or tanks for livestock and wildlife, it may have minimal impact on plant growth. Likewise, the same area may receive that same 6″ in many smaller, light events over a longer period of time may be beneficial to plants but not impactful to reservoirs and tanks. Both situations are required on the land and each have their advantages and disadvantages with respect to providing necessary water to support different systems.

Precipitation is typically measured using rain gauges at fixed observation stations. The longest-term records at these sites can extend back over 50 years. Long-term records are important in the calculation of many drought indices that compare how dry or wet a period is to the historical record. The distribution of these stations across much of the western U.S. is somewhat sparse (Figure 1). The arid southwest is no stranger to localized, isolated precipitation events and it is common for an event to be missed by a gauge. Conversely, a localized event may be centered over an observation station and may not reflect accumulation totals in outlying areas. Because of these issues, it is common for climatologists to use gridded data and indices that interpolates data between observation stations.

Drought Indices

When it comes to drought indices, there is no shortage within the field of climatology. More than 100 drought indices have been proposed, some of which are operationally used to characterize drought using gridded data at regional and national scales (WMO & GWP, 2016).

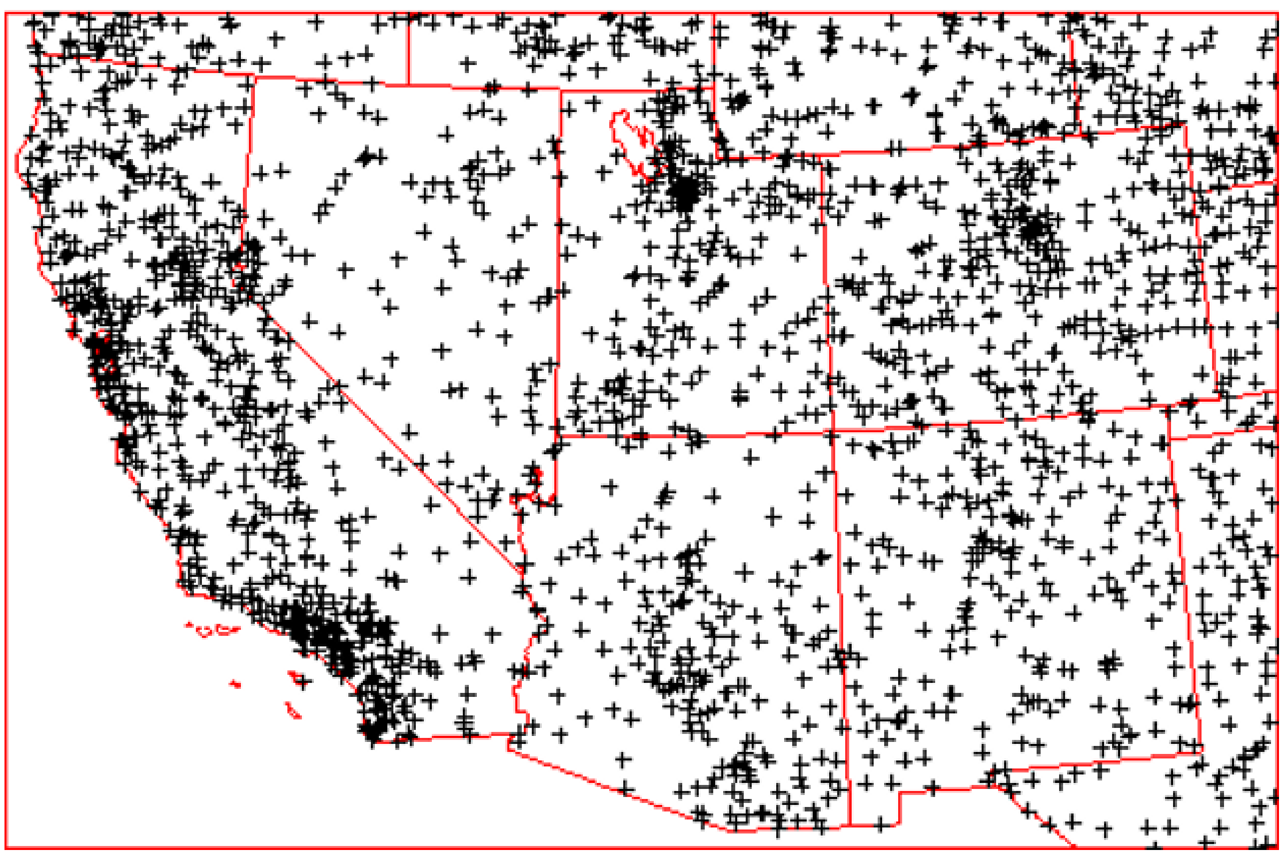

Figure 1. National Oceanic and Atmospheric Administration/National Weather Service (NOAA/NWS) Cooperative Observer Program oversees a network of almost 12,000 observation stations that provide daily maximum and minimum air temperatures, precipitation, snowfall, and snow depth (Arizona Hydrometeorological Networks, 2018).

Table 1. Common Drought Indices.

Data Type	Based From	Data Included	Scale
Precipitation	Accumulated Precipitation	Precipitation	0 to ∞
Palmer Drought Severity Index (PDSI)	Water Balance	Precipitation and temperature	-10 to 10
Standard Precipitation Index (SPI)	Precipitation and departure from average	Precipitation	Unbounded but typically range from -3 to 3
Standard Precipitation Evapotranspiration Index (SPEI)	Precipitation, Potential Evapotranspiration (PET), and departure from average	Precipitation and PET (or temperature if PET unavailable)	Unbounded but typically range from -3 to 3
Normalized Difference Vegetation Index (NDVI)	Greenness and departure from average	Satellite Data	-1 to 1

Some of the most popular include the Palmer Drought Severity Index (PDSI), Standard Precipitation Index (SPI), Standard Precipitation Evapotranspiration Index (SPEI), and Normalized Difference Vegetation Index (NDVI) (Table 1).

PDSI has the advantage of using both temperature and precipitation data to estimate relative dryness. The standardized index ranges from -10 (dry) to +10 (wet) and is based on a water balance model. PDSI is reasonably successful at quantifying long-term drought. One of the key limitations is that it lacks a multi-timescale feature when compared to SPI or SPEI (Table 1) (Keyantash and NCAR, 2017).

SPI uses precipitation data to estimate drought. The standardized index is unbounded but typically ranges from -3 (dry) to 3 (wet) and is based on departure from the long-term average in standard deviations. Standard deviation is the probability of an event departing from the mean. SPI can be created for differing time-scale windows ranging from 1 – 60 months. It has been recognized as the standard index that should be used globally for reporting drought. However, one of the key limitations is the use of only precipitation data (Table 1). Concerns have been raised about the utility of SPI as a measure of drought associated with climate change, as it does not deal with changes in evapotranspiration (Keyantash and NCAR, 2018).

SPEI is an extension of SPI and uses both precipitation and potential evapotranspiration (PET). As an extension of SPI, SPEI is also unbounded but generally ranges from -3 (dry) to 3 (wet) based on standard deviations. A key advantage to SPEI is that it can account for evapotranspiration, making it more useful for ecological and climate change studies. A disadvantage is the data requirements. If only temperature data is available, it may be sensitive to the method used to calculate PET (Keyantash and NCAR, 2015).

For more information or to view gridded precipitation and drought indices data, see the West Wide Drought Tracker at: https://wrcc.dri.edu.

Satellite imagery and data collection is a tool experts use to evaluate drought effects on surface vegetation. One of the common measurements is NDVI, a measurement of surface greenness (Figure 2). NDVI quantifies vegetation by measuring the difference between near-infrared (NIR) light, which is strongly reflected by vegetation, and red light (RED), which is absorbed by vegetation: NDVI = (NIR – RED) / (NIR + RED). NDVI ranges from -1 (less green) to 1 (more green). Naturally, vegetation is going to be less dense and productive during drought conditions than normal conditions. Today, researchers at the National Aeronautics and Space Administration (NASA) and NOAA have three decades of NDVI data spanning the entire globe. Comparing the current NDVI data to the historical average reveals whether the productivity in a given area is typical, or if current plant growth is significantly more or less productive when compared to historical averages (NASA, 2000).

Observational Data

The distribution of objective precipitation data is not equal throughout the state, and indeed throughout the west (Figure 1). Furthermore, neither precipitation nor drought indices tell a complete story of on-the-ground conditions. In order to describe a more complete, accurate story of local

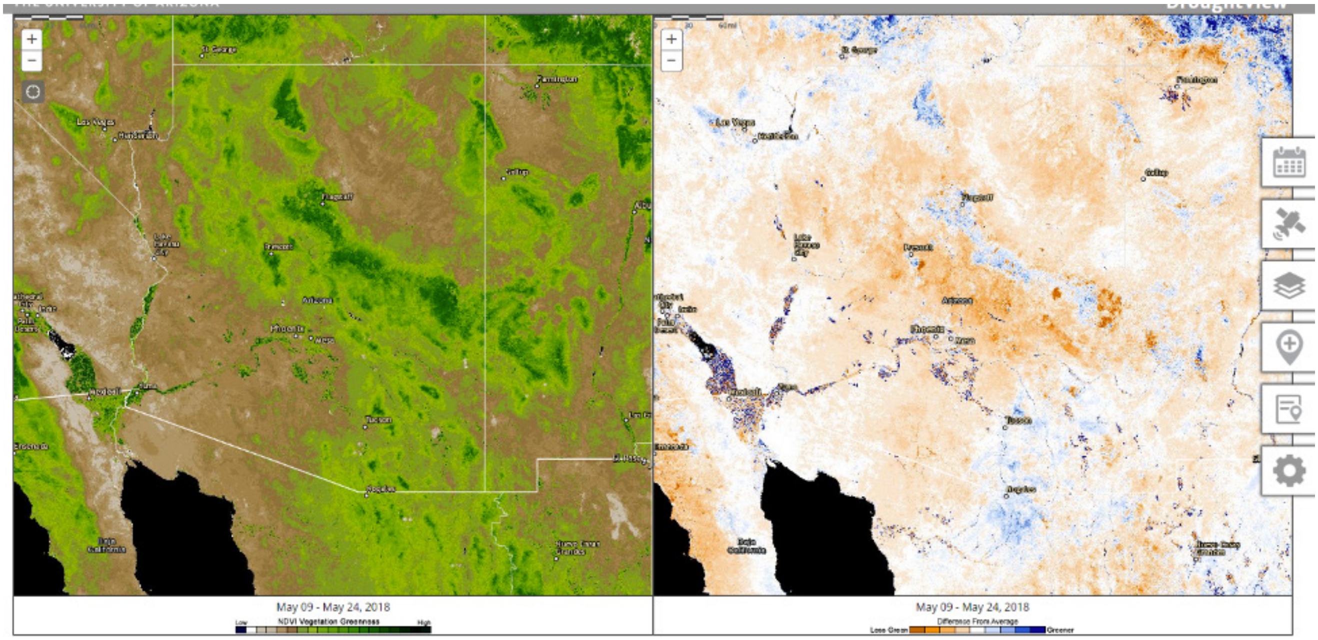

Figure 2. The image on the left is a color-corrected view of NDVI. The image on the right is the difference between current conditions and historical average for a particular time frame. Orange areas represent less green (less productive) locations and blue areas indicate locations more green (productive) than the historical average. The interactive map and updated conditions can be found at https://droughtview.arizona.edu/.

conditions, experts may rely on local observers through citizen science. Citizen science leverages volunteers that are interested in research and science to collect and/or process data as part of a scientific query (Silvertown, 2009). Citizen science projects allow scientists to observe more land, water, species, etc. than their resources or logistics allow.

One citizen science project directly related to drought is the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) which is an international community based network of volunteers who measure and report rain, hail, and snow in their backyards. Anyone can become a reporter and the only requirements are an enthusiasm for watching and accurately reporting weather conditions (CoCoRaHS, 2019). To learn more about becoming a CoCoRaHS observer, please visit www.cocorahs.org. Drought impact reports can be submitted directly to USDM authors through https://droughtimpacts.unl.edu/ConditionMonitoringObservations.aspx. Other avenues to participate in reporting on-the-ground local conditions include contacting your local Extension agent, state climatologist, or the drought monitor:

Local Extension Agent: https://extension.arizona.edu

State Climatologist: www.stateclimate.org.

Drought Monitor: droughtmonitor@unl.edu.

Summary

While drought is infrequent, it will occur and is normal. Drought can often be difficult to identify accurately and in a timely manner. Arizona in particular is notoriously difficult to accurately describe drought due to a variety of factors. Complex interactions between precipitation at different timescales (short vs. long-term drought), summer vs. winter precipitation, and inherent and natural background aridity all play a role when trying to assess conditions and produce an accurate depiction of drought for the USDM. While drought tools and indices are indeed helpful, they often do not tell the complete story of what is occurring across varying temporal and spatial scales. Each index has its inherent advantages and disadvantages. Observational data through citizen science can complement drought indices data and provide a clearer picture of current local conditions.

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