Defining Drought on New Mexico Rangelands

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INTRODUCTION

Drought is a frequent concern and challenge for people living in the Southwest, particularly for agricultural producers who rely on natural resources for their livelihoods. In relation to our food supply, it remains the one "unconquered ill" (H.E. Landsberg forward in Palmer, 1965). It may be argued that drought has a greater economic impact on humans compared to all other natural phenomena, including wildfires, tornadoes, and hurricanes. Drought and its influence on the availability of rangeland forage and water have shaped the livestock industry in the Southwest since the late 1500s (Schickedanz, 1980). It has shaped how New Mexicans rely on the land and what they produce from it.

It is important to define drought to understand and develop a drought management plan. It begins with recognition, which leads to more informed decisions about natural resources use and management. Defining drought also helps us become proactive and plan for—rather than just react to—drought conditions.

Definitions and categories of drought are influenced principally by duration and the amount of departure from long-term average precipitation (normal precipitation). This should not to be confused with **aridity**, which is a continuous condition of low rainfall for a given area. **Drought** is generally defined as a prolonged and chronic shortage of precipitation relative to an average amount measured over a certain period of time. In parts of the world, drought can be considered an abnormal phenomenon. However, droughts in the Southwest are a certainty, although their timing, duration, and severity are unknown until the drought

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occurs. From a rangelands and natural resources perspective, drought may be defined as a period without precipitation during which the soil water content is reduced to such an extent that plants suffer from lack of water (Society for Range Management, 1998). No single definition or method of determining the onset, severity, and end of drought works under all circumstances or in all regions. Drought must be defined in relation to the region and purpose for which it is being applied.

Drought can be characterized into three interdependent categories. **Meteorological drought** is based on a deficit in short-term rainfall amounts relative to a long-term precipitation average for a defined area (National Weather Service, 2008). **Hydrological drought** is a period of limited precipitation that negatively affects water supplies. **Agricultural drought** is linked to meteorological and hydrological drought in that deficits in reservoir levels, rainfall, and soil moisture influence plant growth, productivity, and reproduction.

Turning these conceptual definitions of drought into useful tools for people that rely on natural resources can be accomplished using drought indices. Four common drought indices are described in this guide: percent of normal, Palmer Drought Severity Index (PDSI), Standardized Precipitation Index (SPI), and satellite-based Vegetation Health Indices (VHI). Drought indices are prescriptive, not predictive, and are incapable of determining the beginning or duration of a drought. Timing, type and amount of precipitation, soil types, temperature, and wind are all important influences when considering impacts to rangeland vegetation. Time scales used for the indices can be daily, weekly, monthly, seasonal, or annual. Indices are useful, but are not spatially or temporally precise and cannot quantify impacts.

PERCENT OF NORMAL

As one of the simplest indices, percent of normal characterizes departure from average precipitation as a percentage, calculated by dividing the measured precipitation by the long-term normal precipitation. Using this index's method, drought is defined as when precipitation falls below 75% of normal precipitation for a period of time (Society for Range Management, 1989).

Time scale and location greatly influence interpretation of the indices. Seventy-five percent of normal for eastern Missouri represents different impacts to natural resources than 75% of normal for southern New Mexico. Likewise, less than 75% of normal precipitation during the growing season affects areas differently than the same amount of precipitation during the dormant season.

The percent of normal index assumes a specific statistical distribution of recorded precipitation values for the selected long-term record period. While this distribution may be met when using the long-term precipitation data set, it is usually not met when time periods are short—daily, weekly, monthly, or seasonally. That is, normal precipitation (long-term average or mean) may not be the same as median precipitation—the midpoint value of precipitation occurrences in the long-term climate record. Variability in the precipitation records over time and location make it impossible to compare different regions (Hayes, 1996). Violation of assumptions and variability in precipitation records make this method less reliable in identifying drought.

PALMER DROUGHT SEVERITY INDEX

Palmer (1965) developed the landmark Palmer Drought Severity Index (PDSI) to characterize deficiencies in water spatially and temporally to support planning and decision-making in the context of water availability. The index uses previous precipitation and moisture supply and demand in a hydrological accounting system (Heim, 2002). Palmer (1965) described it as a meteorological drought index, but makes references to agricultural and hydrological drought (Alley, 1984). This is because the PDSI uses precipitation, evapotranspiration, and soil moisture conditions to calculate the index. It represents one of the most widely used regional drought indices, particularly among agricultural producers. PDSI is useful for range managers because it uses parameters that are associated with on-the-ground vegetation conditions. It is one of the few indices that allows for direct comparisons between different regions (Alley, 1984), although the index's accuracy is suspect under some circumstances (Guttman, 1998).

While the PDSI has a long-standing record of use, there are shortcomings with the method that have plagued it since its debut. In particular, PDSI makes assumptions that do not apply well to the Southwest. It uses a water-balance approach in its computation where all precipitation in a month is consumed to meet evapotranspiration, soil moisture demand, or runoff. Human impacts to the water balance, such as irrigation, are not included in the calculation (Hayes, 1996). Further, there is a lag associated with data inputs and drought calculation such that previous months' precipitation, up to 108 months, may influence the current calculation (Guttman, 1998).

The PDSI uses a two-layer soil model and assumes that moisture is not transferred from the top layer to the lower layer until the top layer is saturated, and that runoff does not occur until both soil layers are saturated (Heim, 2002). It also assumes that the two soil layer capacities are independent of seasonal or annual changes (Alley, 1984).

PDSI drought severity classes are arbitrary (Alley, 1984) and were based on the original study areas in central Iowa and western Kansas (Hayes, 1996). The index is sensitive to the "available water content" of a soil type, and therefore may not be appropriate across an entire National Climate Data Center climate division (Hayes, 1996).

STANDARDIZED PRECIPITATION INDEX

The Standardized Precipitation Index (SPI) was designed to quantify the precipitation deficit for multiple time scales

(McKee et al., 1993). The SPI has less complicated data requirements than PDSI. It is also not affected by the magnitude of mean rainfall, making comparisons among locations possible (Agnew, 2000). The SPI is calculated by transforming the long-term mean precipitation for a given area in such a way that the mean equals zero. Therefore, calculated SPI values for a given time period greater than zero represent above-average precipitation, and SPI values less than zero represent a deficit in precipitation. A drought event occurs when SPI is continuously negative, being less than or equal to -1.0, and ends when it becomes positive (McKee et al., 1993). Drought magnitude is the positive sum of the SPI for each month during the drought event. (Hayes, 2007). The SPI is widely used by state and federal agencies in assessing periods and severity of drought. The strengths of the SPI are that it is simple to compute, spatially consistent, and probabilistic, making it useful for assessing risk and making decisions (Guttman, 1998).

The SPI defines drought as any period in which the SPI is continuously below zero, meaning that drought will occur 50% of the time. Agnew (2000) argues that drought is an abnormal event, and that significant climatic changes must occur for "persistent drought" to be recognized. Common drought leads to exaggerated claims regarding climate change (Agnew 2000) and are a function of assumptions made in calculating SPI. Moreover, this confuses drought with desiccation, a period of aridization occurring over decades. In dry climates, appropriate use and interpretation of the SPI is complicated, especially for short time periods (Wu et al., 2007). This is because of long periods in which no precipitation is recorded, and the seasonality of precipitation events. The SPI and PDSI perform similarly at the 12-month interval (Guttman, 1998). Users of SPI are cautioned to focus on duration of drought events rather than severity (Wu et al., 2007). SPI is a statistical product, and as data sets change through space and time the values will change, making it difficult to understand the meaning of the beginning and end of the drought based on varying SPI values (Wu et al., 2007). Wu et al. (2007) further suggested that SPI is best used as a research tool rather than as an operational index for drought that attempts to link input data to ecosystem functioning.

SATELLITE-BASED VEGETATION HEALTH INDICES

Weather station availability and locations are the primary limitation for use of the aforementioned indices. Advances in technology and satellite-based imagery have provided opportunities to fill weather station observation gaps, particularly in rural areas of the arid Southwest. Satellite-based Vegetation Health Indices (VHI) take multispectral photos (the separation of individual light spectrums that are reflected) across large landscapes to assess plant health.

Vegetation condition and how well the plant is growing depend in large part on the amount of water that is available. In years of average precipitation, green and growing vegetation reflects near-infrared (NIR) solar radiation while absorbing light at the visible spectrum (VIS). Light radiation and absorption are opposite for drought. The comparison of these light spectrums allows for the calculation of a normalized difference vegetation index (NDVI). NDVI has become the most commonly used and accepted imagery index for assessing vegetation condition (Cracknell, 1997). However, a limitation to NDVI is surface and plant temperatures. These parameters influence solar radiation detection. Thermal imagery has been incorporated into NDVI assessments to offset temperature anomalies and better calculate VHI.

Currently the best satellite-based image resolution for combined NDVI and thermal is a quarter-mile, which limits precise measurements of drought conditions for an area. Nevertheless, the imagery does give some insight into drought where other on-the-ground measurements and weather station indices are lacking.

SUMMARY

Regardless of the drought indices selected, understanding the strengths and weaknesses of each will help you make better-informed decisions within the limitations of the indices. The percent of normal index is simply computed and understood, but is not capable of comparison among locations and may be difficult to relate to on-the-ground conditions. The Palmer Drought Severity Index has been widely used in the United States, but is complex and difficult to interpret and is not as comparable among locations as previously thought. The Standardized Precipitation Index is simple to calculate, comparable among locations, and probabilistic, making it useful for decision-making. However, it is difficult to interpret in arid climates and over short time periods, such as seasonal or shorter. Satellite-based Vegetation Health Indices help fill the gap where on-the-ground measurements are lacking but image resolution prevents precise assessments at smaller scales. Despite these shortcomings, calibrating one of these indices to specific vegetation conditions on an individual ranch is possible and useful for natural resources management. Nevertheless, it may be more important to be engaged in monitoring precipitation and vegetation trends on rangelands than to be overly reliant on any particular index.

ONLINE RESOURCES

New Mexico Climate Center: https://weather.nmsu.edu/

National Drought Mitigation Center (NDMC): https://drought.unl.edu/

NDMC Vegetation Drought Response Index: https://vegdri.unl.edu/

National Weather Service Climate Prediction Center: https://www.cpc.ncep.noaa.gov/products/Drought/

North American Drought Monitor: https://www.ncdc.noaa.gov/temp-and-precip/drought/nadm/maps

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Revised October 2022 **Las Cruces, NM**