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Whither U.S. Drought: Much Ado About Nothing

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1. Introduction

Borrowing from Shakespeare, the phrase "much ado about nothing" seems appropriate for drought. In many ways, precipitation amounts to almost nothing in the more severe droughts. In reality, of course, most droughts are associated with extended periods of less than usual precipitation, but not necessarily zero, and they often result from seemingly modest deficiencies of "only" 25 or 50 percent. The southern plains (Texas-Oklahoma-New Mexico) drought of 2011 is somewhat unusual in that many locations did actually receive next to nothing in terms of precipitation over an extended period. The paradoxical quality and the resulting play on words stems from the greater and greater attention given as precipitation becomes less and less.

Drought typically is associated with the *redistribution* of water. The recently ended Water Year 2011 (October 2010 through September 2011) shows this dramatically (Figure 1). Very dry conditions in the southern plains and southeast U.S. are "balanced" by very wet conditions in other parts of the country: the southwest (cool season), the Missouri River basin (warm season), and the northeast (tropical storm). Major impacts resulted from both the wet and dry anomalies.

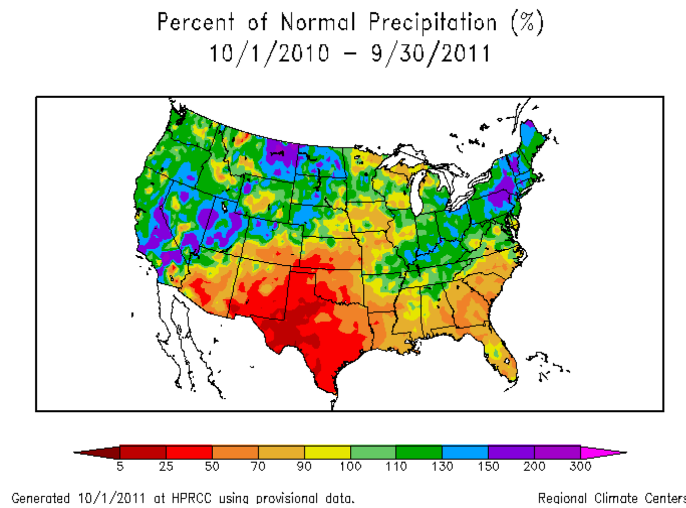

Fig. 1 Precipitation departure (from 1971-2000 mean) during Water Year 2011 (October 2010 through September 2011) based on surface measurements.

As a general rule, the most serious droughts are associated with the loss of the main precipitation season(s), in climates that have pronounced seasonal cycles. In addition, even in regions with a more even distribution of precipitation within the year, some seasons are more effective in supplying groundwater recharge and streamflow; almost always this is the cool season. This is especially the case when snowpack is an important hydrologic factor. A few dry months in a normally dry season do not have the consequences of dry months during (for example) the winter recharge season, or the summer monsoon, or the tropical storm season, depending on the part of the country. Figure 2 shows typical examples of seasonal cycles for Texas and for Arizona. With a double peak during the year, there is some opportunity to recover if the first peak is deficient. The worst droughts involve the loss of both peaks. In the Arizona case, one peak is in winter and the other is in summer. The climate causes and teleconnections that lead to a loss of winter precipitation may be very different from those that lead to a loss of summer precipitation, and thus unless they share a common source, are often relatively uncorrelated with each other.

2. Defining drought

The definition of drought has been the subject of animated discussion for well over a century, and invariably arises during attempts to depict its status and establish relationships to impacts (Redmond 2002). This situation is likely not destined to end any time soon. What appears to be a simple and straightforward

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exercise turns out in reality to be vexingly complicated. A myriad of indicators are available to describe drought (*e.g.* Heim, 2002) and more are steadily proposed and created. For a definition to have much value, it should be applicable in the widest possible range of circumstances, and cover all the types of droughts experienced around the world. It is relatively easy to formulate definitions that fit particular geographic and sectoral circumstances. It is in the attempt to develop a universally applicable definition that we are forced to look at this problem in its generality.

The fundamental concept of drought involves a water balance. Through climatological and meteorological processes a supply of water is produced. Through climatological, meteorological, ecological, and social processes, a demand for that water has come about. Note the addition of added factors on the demand side. When supply (broadly defined) is unable to meet demand (also broadly defined), over extended periods, needs for water by human and natural systems are increasingly unable to be fully met. At some point, the accumulated imbalance begins to result in impacts. This "some point" varies, sometimes very greatly, depending on the specific circumstances of each of the many sectors affected by shortages in their own particular water budget. The consequences of these shortages are described as "impacts" and can be expressed in socioeconomic terminology. (The situation for "natural systems" is more ambiguous, and is tied to various kinds of value judgments.) The reason we care about drought is that these shortages (negative water budget) produce impacts. Because of this, drought is thus defined by its impacts. For human systems, if there is no impact, there is no drought. For natural systems, every excess or deficiency in the moisture budget results in some kind of adjustment, and in this case the definition is more murky. Because of dependence on the specific path of causation from climate to impact, the same geophysical drivers need not always lead to the same level of impact, and thus of drought.

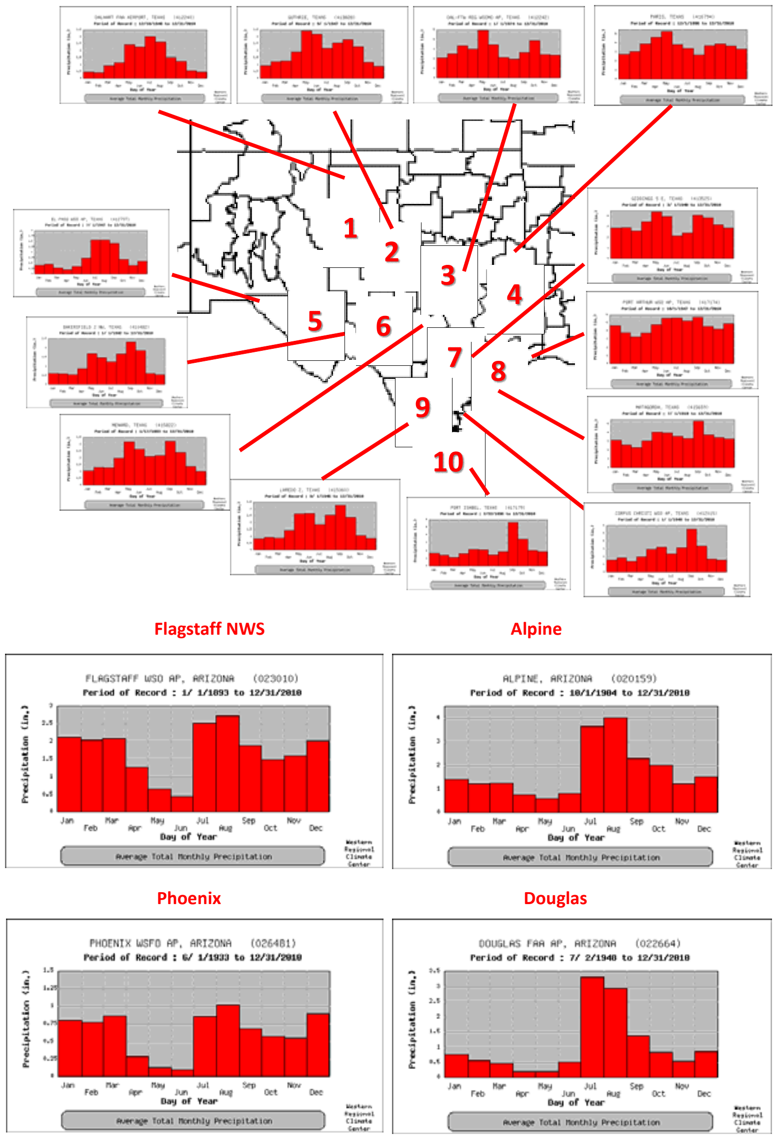

Fig. 2 Qualitative depiction of typical seasonal cycles of precipitation in Texas (top) and in Arizona (bottom). Based on period of record. Graphs cover January to December, and are to different scales.

The reliance on a water budget approach implies that both supply and demand matter. Demand, as used here, includes such factors as evapotranspiration, as well as human, animal, and vegetative demand. The factors that affect supply certainly include precipitation, but also other climatic elements such as temperature, wind, radiation, and humidity. These factors are even more relevant to demand. The history of drought, over decades or centuries, is affected by the separate histories of both supply and of demand. The presence of numerous buffers, and of different temporal lags (*e.g.*, relating to snowpack formation and melt timing, or of groundwater recharge), and of spatial separation (snow, or its lack, in Colorado affects water supplies in Los

Angeles months or years later), complicates matters further. These issues have themselves been discussed elsewhere, and are beyond the immediate scope of these remarks.

Metrics for drought that are capable of taking all of these real-world effects into account (in order to be practical and useful) are the subject of longstanding discussion. Their formulation is clearly not straightforward.

3. The Drought Monitor

The U.S. Drought Monitor (Svoboda *et al.*, 2002) is both a process and a product. The process is an extended weekly electronic national conversation from a pool of up to nearly 300 participants (typically 30-50 voices in a given week). The product is the map itself and associated descriptive material. The Drought Monitor developed in rather a grass-roots fashion, starting as an experimental product in 1999 arising from a drought around the nation’s capital. An important characteristic is that it is owned by everybody and by nobody, with contributions from a variety of federal and state agencies and individuals. The impact-based definition of drought is adopted to insure that indications from physical measurement are corroborated by indicators of affected sectors. The Drought Monitor is thus a combined social and physical endeavor with real-world grounding. This is especially necessary where the Drought Monitor forms the basis for resource allocation decisions, an increasingly common situation. In many cases the Drought Monitor constitutes a late arrival, especially in western U.S. settings where the complexities of drought are greater, and have been understood and addressed by a variety of interagency approaches over many decades. An outstanding issue is how to represent drought in heavily managed systems.

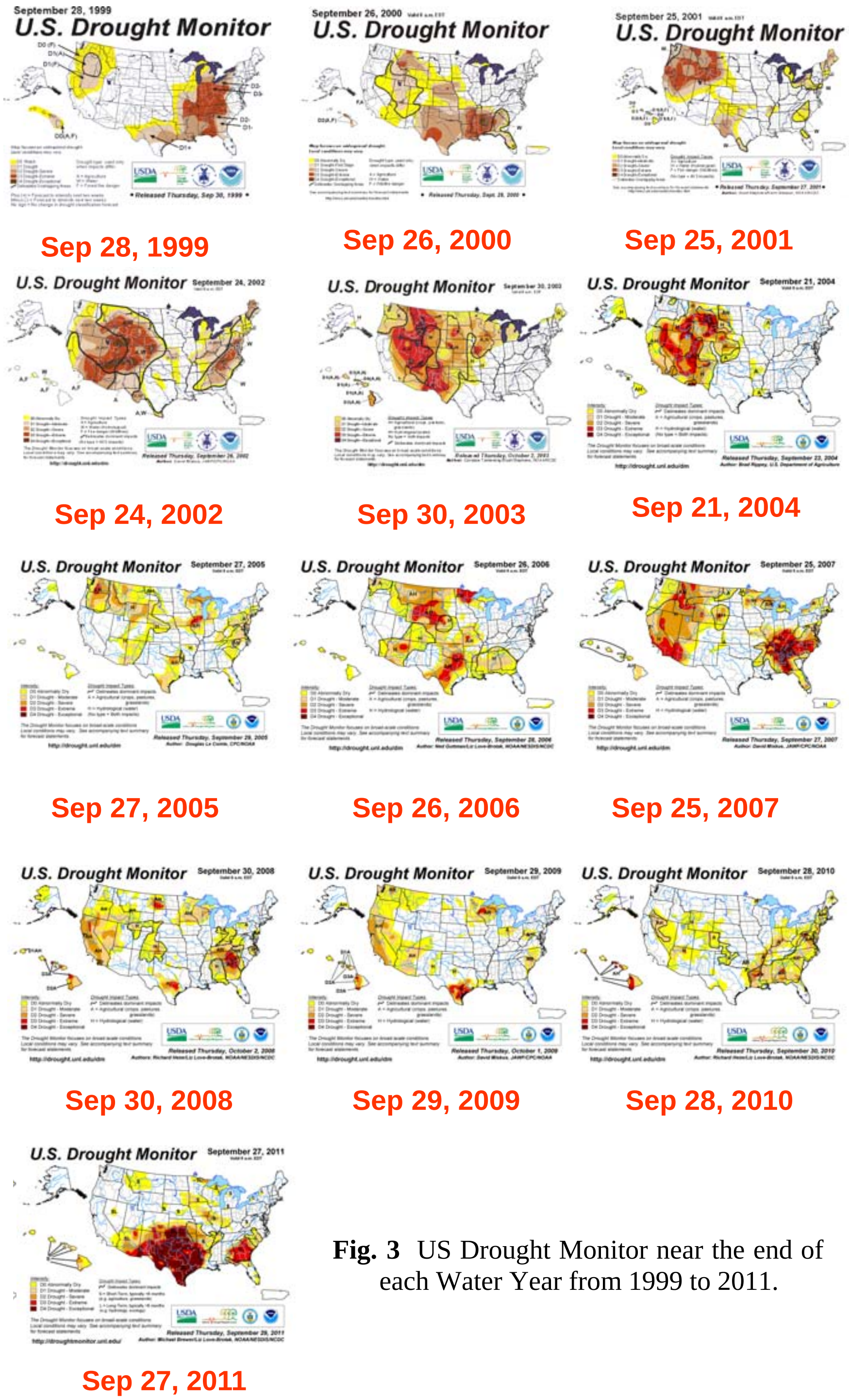

Fig. 3 US Drought Monitor near the end of each Water Year from 1999 to 2011.

The email “conversation” referred to above has proven to be a rich, vibrant, interesting, varied, and generally quite intelligent discussion. This has provoked a variety of real-world, practical, and intellectual challenges to addressing the many dimensions of drought.

Summarized in Figure 3 is an annual snapshot of the Drought Monitor near the end of each Water Year. This shows that over this interval drought has been present somewhere in the United States for the entire time it has been produced (also true of months not shown).

4. The Standardized Precipitation Index

Approximately 30-40 products and tools are first examined by the weekly Drought Author (the person charged each week with assembling the map; there are about 10 such individuals) to provide an initial map. This is then critiqued and modified through community input. Even though drought monitoring requires information beyond merely precipitation, this does remain the most important primary element. One of the tools consulted is the Standardized Precipitation Index (SPI), which uses a long history (in this case about 115 years) to create a suite of five main products, shown in Figure 4. Depending on the basic underlying climate and its typical seasonal cycle, all of these maps have relevance in the assessment of drought status. The SPI itself represents a mapping of the percentile, obtained either from the empirical distribution (usually) or a fitted distribution (sometimes) of accumulated precipitation over a particular duration, typically 1 month to 6 years, onto a normal distribution, and expressed in terms of standard deviations. The percentile map and the SPI map are thus the two most spatially comparable products in the SPI suite. The SPI (see McKee *et al.*, 1993, 1995) was created to explicitly reflect the fact that a region can be simultaneously in excess and in deficit, at different time scales (see Figure 5 for examples). This feature of the SPI is under-appreciated and not utilized to full potential. In part this may a consequence of the lack of a good method for showing the temporal history that has led to the present situation, in the form of a spatial representation of such histories.

5. Concluding comments

In addition to the complexities of representing spatial variations in the recent history of "meaningful" precipitation (not all precipitation is equal in value), other spatial issues are present that are pertinent to drought. Jerome Namias (citation unavailable) once noted that droughts that are long in duration tend to be large in spatial extent. Contrast two significant recent droughts: The southeast drought of 2007 developed rapidly in about February and lasted about 10 months during the worst conditions, and especially affected a relatively small area that just

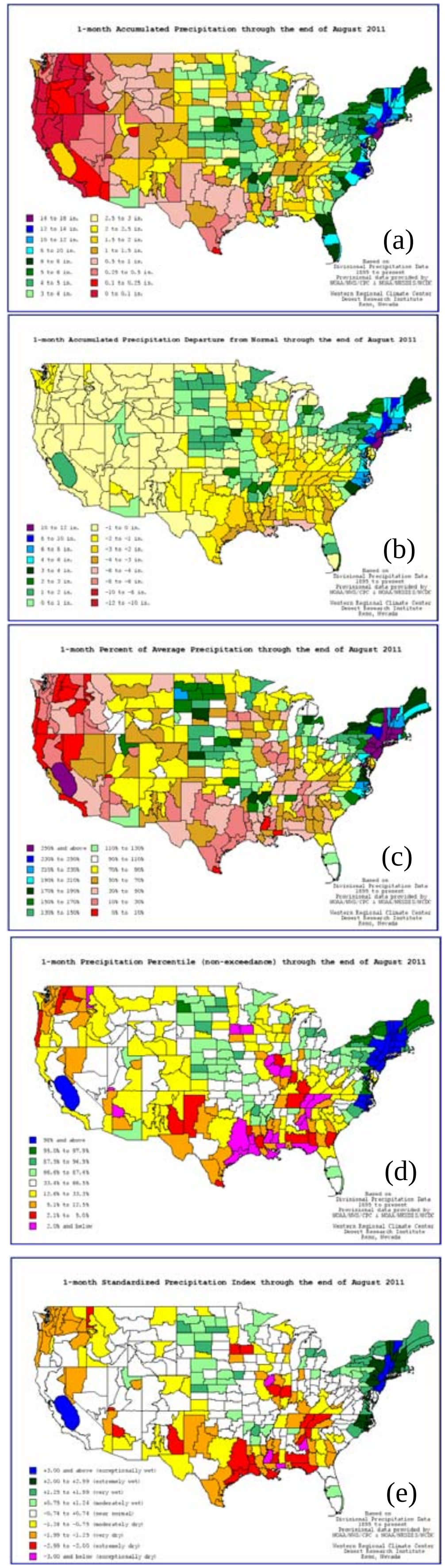

Fig. 4 The five precipitation quantities most requested by water managers and hydrologists in understanding the status of drought (McKee *et al.*, 1993, 1995). These are routinely computed in generating SPI values. One-month quantities for August 2011 are shown, (a) accumulation, (b) accumulation departure, (c) accumulation percentage of average, (d) accumulation percentile, and (e) a standardized measure (the SPI).

happened to be the source of the Atlanta GA water supply. A second drought that also affected water supplies to millions of people in the Southwest developed in the late 1990s, peaked in 2002, but continued to have effects for at least several more years, and has still not entirely abated and may yet re-intensify. This drought affected entire state-sized regions in the headwaters of the Colorado River, which has several years of buffering capacity in its two large reservoirs, Powell and Mead. This drought extended over about a decade and has affected a large area. Multi-year droughts require a multi-year cause, typically suspected to be ocean conditions elsewhere on the globe and the subject of many investigations.

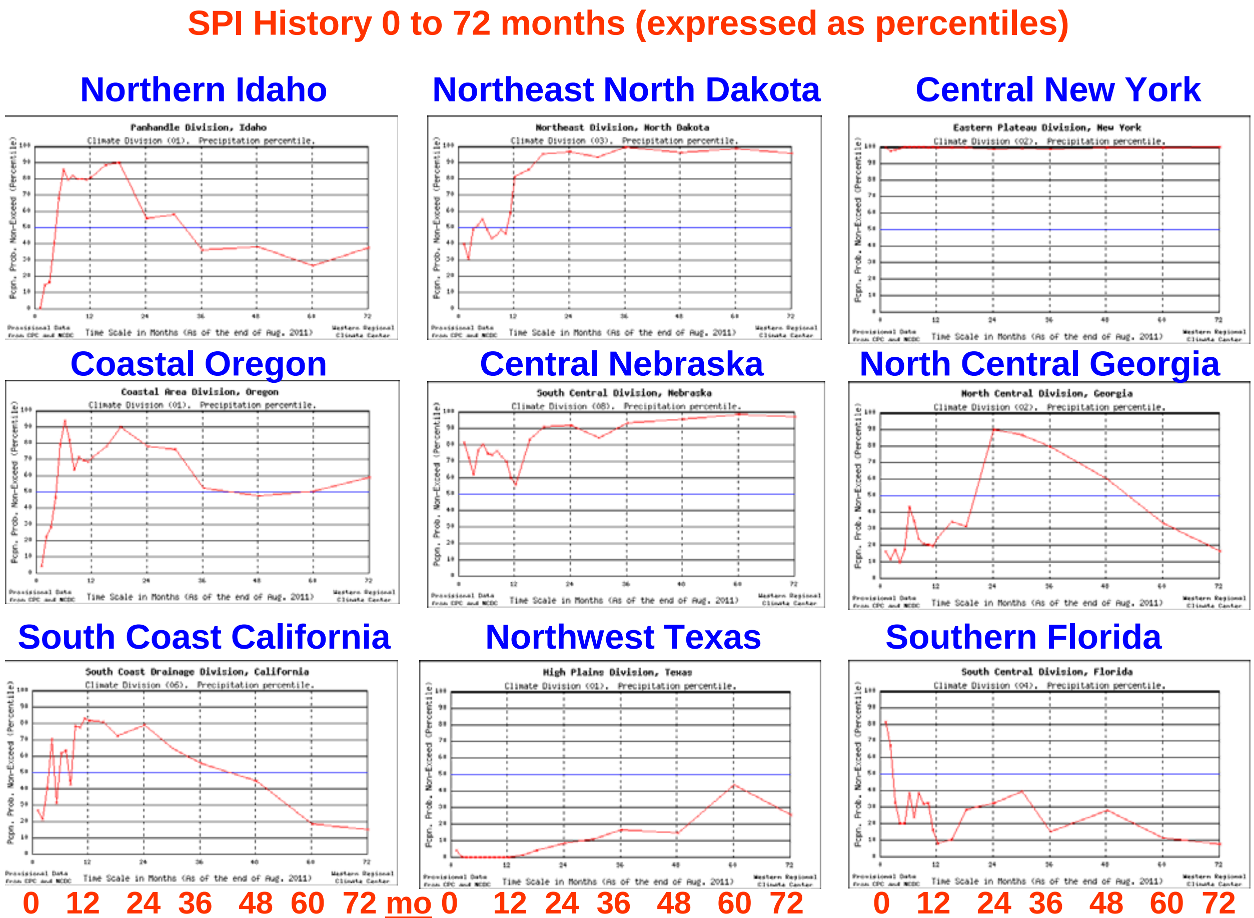

Fig. 5 Examples of the precipitation percentile (scale 0-100) at different time scales for different parts of the U.S. for the period ending at the end of August 2011. Time scales range from past 1 month to past 72 months.

Some of the outstanding issues of drought are as follows:

- We have made a lot of progress in better monitoring, a larger array of tools and products, and improved physical understanding of some drought causes. Social science aspects of drought need more attention and need to be folded into drought activities in the U.S.
- There is still a strong need for granularity and resolution in both the monitoring and prediction of drought. This is especially true in mountain environments, where much runoff is generated in relatively small source regions, and climatic heterogeneity is extreme (sharp spatial gradients in temporal histories).
- We need to give continued and increased attention to understanding, measuring, and depicting the state of the entire water budget, to cover both the supply and demand sides of drought.

- In some places, major fractions of the annual water supply are delivered in a few big events, such as large winter storms or tropical storms. Their occurrence or non-occurrence may greatly affect seasonal precipitation totals and status. The role of significant weather events (an example is atmospheric rivers) in affecting seasonal and multi-year drought status, and elucidation of the climate-weather connection, are greatly in need of further sustained attention.
- We must continue to press for better understanding of multi-year and decadal scale variability. A diversity of methods is needed, including paleoclimate inferences.
- There are many different styles ("flavors," Bumbaco and Mote, 2010) of drought. Most of these tie to the role of differential seasonal contributions to longer-term droughts. There are many nuances that lead to different impacts, and this needs to be better and more widely understood.
- There is really no one-size-fits-all approach to drought.

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