Monitoring and Predicting Drought on our Grasslands

By Dr. Imtiaz Rangwala Introduced by Dr. Jacqueline Ott

Summer is coming and so is the potential for drought. Our newsletter thought it would be a good idea to review some current and useful Drought Tools available for the whole United States and sought the input of Dr. Imtiaz Rangwala specializing in climate research at the North Central Climate Adaptation Science Center at the University of Colorado-Boulder. Thanks for the write-up Imtiaz! ~ Jacqueline Ott

How do we know if we are in a drought? One simple way to define drought is the lack of sufficient water to meet the "normal" needs of nature and people. There are several ways to assess if we are in a drought and how severe it is. These include different tools and indices that are accessible in near-real time. If one is interested to get a sense of the large breadth of available drought tools, please have a look at https://www.drought.gov/drought/data-maps-tools. A select few drought tools that are arguably more relevant for grasslands and also more easily accessible to users on the web are discussed below. Many of these tools can also help us with providing early warning of potentially deteriorating conditions that could lead to or intensify a drought. When assessing a situation, it is advisable that one considers a suite of drought tools instead of only focusing on a single tool. As is usually the case, no tool is perfect and there are uncertainties associated with each of them.

United States Drought Monitor (USDM)
https://droughtmonitor.unl.edu/

This is probably the most well recognized and used drought resource. This tool is particularly good to easily find out whether drought conditions exist in your region and how severe they are. The USDM maps are updated every week (every Thursday), so one is able to assess how conditions have changed from previous week or weeks. This tool also provides "Change Maps" so one can see whether drought conditions have degraded or improved over past weeks or months and by how much.

The most important thing to keep in mind when using this resource is that USDM is not regarded as a drought early warning tool. In other words, it does not give much (if any) information on whether there is a risk for drought to develop, worsen or improve in your region. It is largely trying to provide the best assessment of current conditions for a region based on several objective and subjective sets of information on climate, water availability and drought-related impacts available at hand.

UDSM only shows whether there is drought or not. It does not show the other side of the story, i.e. excess wetness, which most other drought indicators do, including the ones that are discussed next. The wet side of the story that most drought indices show can point to a low risk for a drought to develop in the near future and can also point to a potential risk for flooding and saturated soil conditions if precipitation is in the forecast.

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"Like twilight, drought creeps stealthily into existence (with a few exceptions), unannounced and often not obvious. A set of early warning indicators is needed to alert us that societal adjustments may be needed and that other biological systems of concern face similar circumstances." --- Kelly T. Redmond

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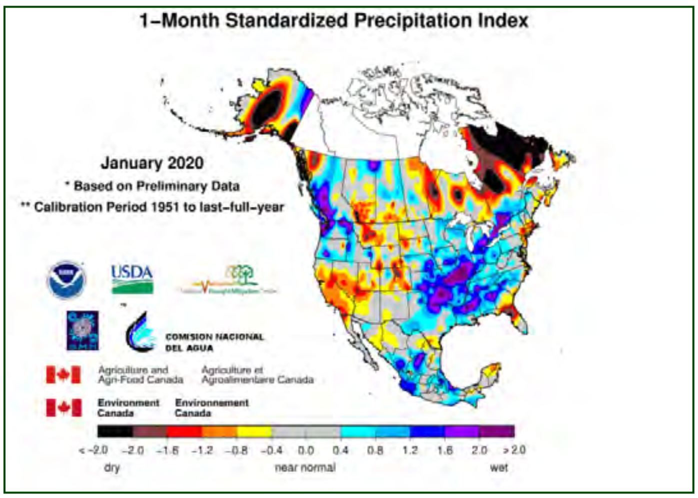
Standardized Precipitation Index (SPI)
https://www.ncdc.noaa.gov/temp-and-precip/drought/nadm/indices

This index has been in use for a long time and it primarily shows how much precipitation a region has received over a period relative to what that region "normally" receives during that period. SPI is available for multiple different timescales, i.e., one can assess SPI for the last 1, 2, 3, 6, 9, 12 or 24 months. Depending on the system and time of the year, certain timescales could be more important than others. On shorter timescales, SPI can inform soil moisture conditions. While on longer timescales, SPI can inform groundwater and reservoir storage. Furthermore, this resource provides maps that show either just the station data or interpolated maps with complete spatial coverage.

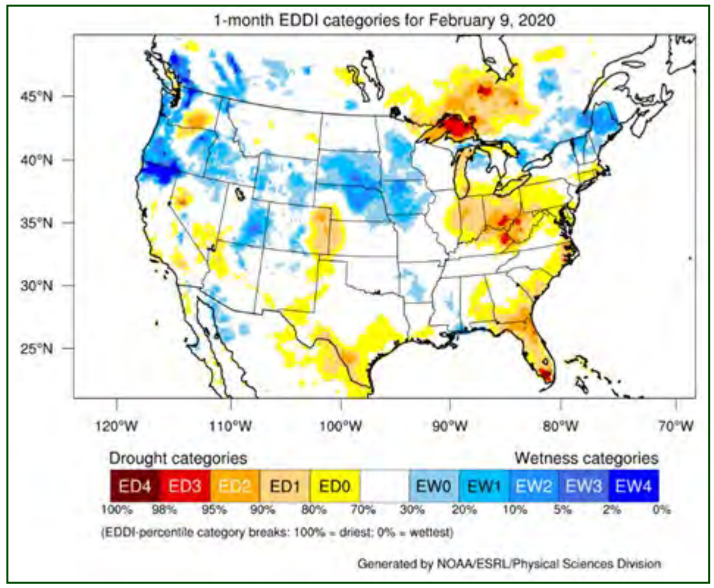


Users should keep in mind that, although extremely important, precipitation is just one factor that influences drought conditions, and other weather-related factors such as temperature, winds, humidity and cloud cover also play an important role.

Evaporative Demand Drought Index (EDDI)
https://www.esrl.noaa.gov/psd/eddi/

This drought tool has been developed primarily to estimate the "atmospheric thirst" over a region at any given time. As the atmosphere gets more thirsty, the more demand it puts on the land for evaporation – hence the term "evaporative demand" in the name. Also, a hotter and drier atmosphere is thirstier than a cooler and drier atmosphere, therefore a high positive EDDI value in the warm season is generally more of a concern than during the cold season. High (positive) EDDI values over weeks to months can drive more evaporation from the ground and deplete soil moisture. Further, as soil moisture depletes significantly, the land and the air above it could heat up if dryness persists, which can further increase EDDI or keep it persistently high. In that way, EDDI reflects soil moisture conditions as well. As drought intensifies, the "atmospheric thirst" keeps increasing and the value of EDDI keeps going up.

EDDI maps are available in near-real time and updated every day. For each day, there are multiple timescales (weeks to months) over which the accumulation



of "atmospheric thirst" is considered and EDDI maps are produced. For example, a 2-week EDDI shows how unusually dry or wet the atmosphere has been over the last 2-week relative to the same 2-week period in the past.

EDDI can be very useful for early warning of droughts. For example, a persistent or increasing positive EDDI value over a period of weeks, particularly in the warm season, is indicative of either an increased demand on the land to evaporate and dry out or the soils drying up and both the soils and the air above it are becoming warmer and drier. EDDI has also shown to be effective at providing **early warning for flash droughts**, particularly when a region is experiencing relatively wet conditions and then one starts to observe sudden increases in EDDI that continues to intensify and persists over the next few weeks. EDDI is also a

suitable indicator for fire risk in the grasslands because EDDI relates strongly with the increased flammability of the vegetation.

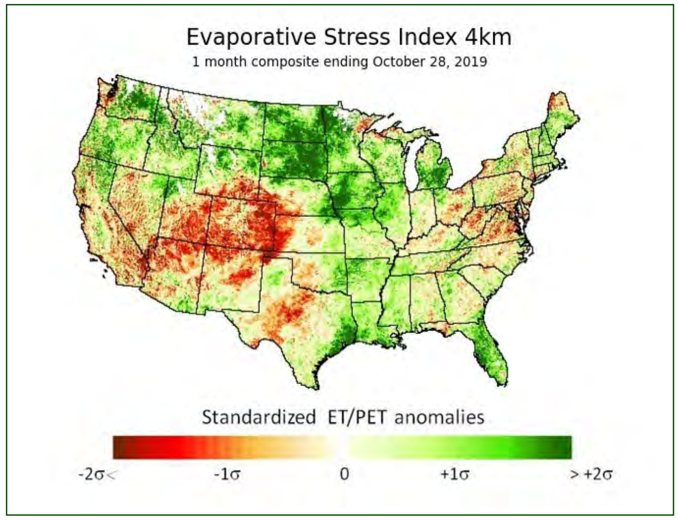
NLDAS Soil Moisture Drought Monitor
https://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Soil moisture conditions are extremely relevant to the grassland ecosystems. However, it has historically been a major challenge to get information about it from direct observations. The number of stations measuring soil moisture out there are not sufficient for the most part. One of the ways to estimate soil moisture is by modeling it and using better known information about precipitation, temperature, soil type, etc. These hydrological models have improved over time.

NLDAS Soil Moisture Drought Monitor is one such resource that provides information on soil moisture by integrating information from more advanced hydrological models. This tool uses the same weather input data to estimate soil moisture that EDDI uses to estimate atmospheric thirst. This resource is also updated every day and it shows soil moisture maps for top 1 m or the whole soil depth. It unfortunately does not show soil moisture conditions for the top 10 or 20 cm of soils which could be particularly relevant for many of the grassland ecosystems with shallow roots. In absence of that, the top 1 m soil moisture conditions are still quite appropriate. To assess how wet or dry the soils are from normal conditions, one important metric to look at is the Current Top 1M Soil Moisture Percentile. The high values above 70 (increasing from green to blue) show wetter than normal conditions, while values below 30 (decreasing from yellow to red) show drier than normal conditions.

Drought Indices Derived Directly From Satellite Observations
Evaporative Stress Index (ESI):
https:hrsl.ba.ars.usda.gov/drought/index.php

Landscape Evaporative Response Index (LERI):
https://www.esrl.noaa.gov/psd/leri/
More recently, newer drought indices have been developed that use direct measurements from the satellite to estimate how dry or wet a region is at relatively higher spatial resolutions (1-4 km) than most other indices. Although derived differently, ESI and LERI work on a similar principle. These indices use direct estimations of the land surface skin (top 5 cm soil) temperature to essentially derive how wet or dry the soil conditions are relative to "normal" in the root zone of the soils that is supporting evapotranspiration (i.e. loss of water to air from the soil and plants). These indices are also available on multiple timescales so one can assess how the situations have evolved over time. Furthermore, ESI and LERI can provide early indications of soils experiencing water deficit. ESI is updated every month during the growing season, while LERI is updated every month during the year, and every 8-days during the growing season.



Near-term Precipitation Outlook
https://www.cpc.ncep.noaa.gov/products/predictions/814day/
If used thoughtfully and in conjunction with each other, many of the drought tools that we have discussed above can provide a good sense of what situation we are in currently, drought-wise, and the risk of it worsening if conditions do not change, which usually is if precipitation does not come soon. That being the case, it is very useful to consider these drought tools in conjunction with the near-term precipitation outlook, i.e., probabilities of above or below average precipitation over next 1 to 2 weeks. Research shows that there is good skill in predicting chances of above or below average precipitation over 1 to 2 weeks. However beyond that timeframe, the skill is pretty low.

Suggested Reading: Redmond, K.T., 2002. The depiction of drought: A commentary. *Bulletin of the American Meteorological Society*, *83*(8), pp.1143-1148. https://www.jstor.org/stable/pdf/26215384.pdf